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<td>Author(s)</td>
<td>van Osch, Suzanne</td>
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<tr>
<td>Publication Date</td>
<td>2020-05-05</td>
</tr>
<tr>
<td>Publisher</td>
<td>NUI Galway</td>
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<td>Item record</td>
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Assessing public preferences for Integrated Multi-Trophic Aquaculture

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A dissertation submitted for the degree of Doctor of Philosophy

Submission: September 2019

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<tr>
<td>AIC</td>
<td>Aikike Information Criteria</td>
</tr>
<tr>
<td>ASC</td>
<td>Aquaculture Stewardship Council</td>
</tr>
<tr>
<td>BIC</td>
<td>Bayesian Information Criterion</td>
</tr>
<tr>
<td>CC</td>
<td>Closed Containment</td>
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<tr>
<td>CE</td>
<td>Choice Experiment</td>
</tr>
<tr>
<td>CLAMS</td>
<td>Coordinated Local Aquaculture Management System</td>
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<td>CIS</td>
<td>Common Implementation Strategy</td>
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<tr>
<td>CL</td>
<td>Conditional Logit</td>
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<tr>
<td>CS</td>
<td>Compensating Surplus</td>
</tr>
<tr>
<td>DCMNR</td>
<td>Department for Communication, Marine and Natural Resources</td>
</tr>
<tr>
<td>ETS</td>
<td>Emissions Trading System</td>
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<tr>
<td>EAPI</td>
<td>European Aquaculture Performance Indicators</td>
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<td>EU</td>
<td>European Union</td>
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<tr>
<td>GMXL</td>
<td>Generalised Mixed Logit</td>
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<tr>
<td>GES</td>
<td>Good Environmental Status</td>
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<tr>
<td>HQ</td>
<td>Hannan Quinn Information Criterion</td>
</tr>
<tr>
<td>IC</td>
<td>Information Criteria</td>
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<tr>
<td>IDD</td>
<td>Independent and Identically Distributed</td>
</tr>
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<td>IFCA</td>
<td>Inshore Fisheries and Conservation Authority</td>
</tr>
<tr>
<td>IDREEM</td>
<td>Increasing Industrial Resource Efficiency in European Mariculture</td>
</tr>
<tr>
<td>IMP</td>
<td>Integrated Maritime Policy</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>--------------</td>
<td>--------------------------------------------------</td>
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<tr>
<td>IMTA</td>
<td>Integrated Multi-Trophic Aquaculture</td>
</tr>
<tr>
<td>JRC</td>
<td>Joint Research Centre</td>
</tr>
<tr>
<td>LC</td>
<td>Latent Class</td>
</tr>
<tr>
<td>LAFCILC</td>
<td>Loughs Agency of the Foyle, Carlingford and Irish Light Commission</td>
</tr>
<tr>
<td>MSP</td>
<td>Maritime Spatial Planning</td>
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<td>MSC</td>
<td>Marine Stewardship Council</td>
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<tr>
<td>NPV</td>
<td>Net Present Value</td>
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<tr>
<td>PCB</td>
<td>Poly Chlorinated Biphenyl</td>
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<tr>
<td>PD</td>
<td>Pancreatic Disease</td>
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<td>RPL</td>
<td>Random Parameter Logit</td>
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<td>RUM</td>
<td>Random Utility Model</td>
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<td>SLM</td>
<td>Scaled Logit Model</td>
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<tr>
<td>UK</td>
<td>United Kingdom</td>
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<td>WTP</td>
<td>Willingness-To-Pay</td>
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Introduction

Global seafood security is increasingly challenged by human population growth, an increasing per capita seafood demand and diminishing wild fish stocks (FAO, 2014; Jacquet & Pauly, 2007; Pauly et al., 2002). Farming seafood is considered an alternative to wild fisheries and as a result the aquaculture industry has grown considerably. However, the aquaculture industry is criticised for its environmental impact. Integrated Multi-Trophic Aquaculture (IMTA) is a potentially more sustainable alternative to the monoculture of fin fish species aquaculture that is currently the industry standard. The EU and national governments are interested in exploring the potential of IMTA to stimulate the aquaculture industry while fulfilling environmental protection goals.

Simultaneously, the European public is increasingly aware of the impacts of seafood production and is concerned on issues such as food safety, food quality, health impacts, environmental sustainability and animal welfare (Aarset et al., 2004). Eco-labelling is considered a tool for consumers to differentiate more sustainable seafood from large-scale intensive monoculture fish farms. It can be utilised to inform consumers on the environmental impact of seafood products and thereby increase demand for more environmentally sustainable purchase options.

1.1 Food Production Challenges

Estimates of changes in global food demand vary between an increase of 70% to 100% between the years 2000 and 2050, primarily driven by global population growth and increased prosperity (Charles et al., 2010). Simultaneously, food production (particularly the rearing of livestock) is challenged by greater competition for land, water and energy and is criticised for negatively affecting the environment and ecosystem services (Tilman et al., 2002). Fish could substitute livestock as a source of protein, but the current percentage of fish stocks captured beyond biological sustainability is estimated at 33.1% (FAO, 2018).

In this context, the aquaculture industry is growing rapidly as a protein production
alternative that does not rely directly on the capture of wild fish stocks. The commonly
used definition of aquaculture is that of the FAO (Food and Agriculture Organisation
of the United Nations) which defines aquaculture as “... the farming of aquatic organisms,
including fish, molluscs, crustaceans and aquatic plants. Farming implies some form of
intervention in the rearing process to enhance production, such as regular stocking, feeding,
protection from predators, etc. Farming also implies individual or corporate ownership of the
stock being cultivated.” (Edwards & Demaine, 1998; Lane, Hough, & Bostock, 2014). In
a marine aquaculture system, net pens are lowered into the ocean and young fish are
released into the nets. The nets are then supplied with sufficient feed, drugs and
antibiotics to keep parasites and diseases at bay and the fish are harvested once they
have reached maturity (Asche & Bjorndal 2011). This production process allows for
great quantities of fish to be produced effectively. Aquaculture is increasingly
important to fulfil the global demand for seafood products. The industry has
consistently demonstrated high growth rates fuelled by global population growth and
increasing per capita consumption of seafood (FAO, 2016).

1.2 Aquaculture Industry Development

The global aquaculture sector increased its production by more than 300% in the last
2 decades and reached a value of 107.5 billion Euro in 2012 (STECF, 2014). However,
this growth was heavily skewed towards Asia and production of the EU28 represents
only 1.9% of the global aquaculture volume and 3.5% of its value at 4.3 million Euro
in 2012 (STECF, 2014). This is reflected by the annual growth rate of the European
aquaculture sector which was 0.5% compared to 7% globally in 2014.

The European Union has expressed plans to increase aquaculture production. It will
have to address criticisms towards the aquaculture industry regarding the industries’
environmental impact if it is to gain the public support vital for industry development
(Barrett, Caniggia & Read, 2002; Katranidis, Nitsi & Vakrou, 2003). The effects of fish
farming on the environment and the legislation surrounding aquaculture will be
elaborated on in the next chapters. At this point it is important to note that criticisms
towards the aquaculture industry are based on the linear character of the production
process, where inputs require high consumption rates of scarce natural resources (for
example fishmeal) and outputs including externalised costs (for example runoff). The
EU addresses these critiques by aiming to stimulate industry growth through the
creation of a niche market of sustainably produced seafood, in line with the EU’s Blue
Growth Strategy (European Commission, 2017b). The EU’s proposed strategy is twofold; (1) to shift production methods towards environmentally sustainable technology and (2) to educate the public on the environmental impact of seafood production to stimulate sustainable consuming behaviour, with one of the proposed tools being a seafood eco-label (European Union, 2013).

1.3 IMTA as a Solution

Potential for the European aquaculture industry to grow while minimising the environmental impact may exist in the co-culturing of species in the production process. Scholars have concluded that the production of additional species in polyculture systems is potentially undervalued and underutilised in the European industry when compared to production integration techniques applied in Asia (Newton, Telfer & Little, 2014). Species suited for co-culturing with fin fish species produced in Europe that are currently produced in isolation are oysters (*Crassostrea gigas* and *Ostrea edulis*) and mussels (*Mytilus edulis* and *Mytilus galloprovincialis*). Algae production has started to develop since 2007, consisting mostly of brown seaweed (*Phaeophyceae*). However, legislative barriers restrict the efficient integration of co-species in European aquaculture production processes (Newton et al., 2014). The co-culturing of species is mentioned increasingly in the context of stimulating the aquaculture industry. In particular IMTA has been suggested to stimulate growth of the industry while reaching environmental protection goals by scholars (Chopin & Robinson 2006; Jeffery et al. 2014) and governmental actors (Department of Agriculture, 2015; SEPEA, 2017).

*The Concept of IMTA*

IMTA is a form of aquaculture in which several species are combined with the aim of introducing nutrient cycling to the production process by having one specie feed on the output of another specie. One can grasp the concept of IMTA by visualising a net pen for finfish production, as is common in monoculture, with an added submerged cage under the net pen that holds species feeding on the solid particles floating down from the finfish. Any particles caught in the current are extracted by filter feeders farmed downstream, while dissolved particle can be absorbed by seaweed farmed downstream.

IMTA is a flexible concept as it can be applied in Closed Containment (CC), land based
or open ocean systems and applied with multiple configurations of species and biomass. Under the right configuration it can result in environmental and economic benefits, consisting of higher growth rates for the additional species, reduced environmental impact through nutrient absorption by the added species and reduced economic risk for the fish farmer due to risk diversification. IMTA is believed to be able to contribute to the development of a sustainable aquaculture industry that is environmentally sustainable, profitable and create employment in coastal regions (Barrington, Chopin, and Robinson 2009).

**IMTA Application & Experiments**

The concept of IMTA is not new, as the earliest records date back to 618 AD in China, where empirical trials were conducted that combined agricultural activities with fish ponds to recycle nutrients and increase output (Rabanal, 1988) and reports exist of similar techniques being applied in ancient Egypt, France and Italy (Brzeski & Newkirk, 1997). The concept of polyculture in the context of intensive aquaculture was introduced in the 1970’s during the intensification of the aquaculture industry (Ryther, Dunstan, Tenore & Huguenin, 1972; Ryther et al., 1975) and developed further in the late 70’s when more research was done on the effect of eutrophication on the marine environment with the aim of developing more sustainable food production systems (Hughes-Games, 1977; Huguenin, 1976; Tenore, Chesney, & Browne, 1974).

More recently, experiments have been conducted in Canada (Troell et al., 2009), Chile (Troell et al., 1997), South Africa (Chopin et al. 2010), Israel (Chopin et al. 2010), and China (Troell et al., 2009) that focused on the biological and ecological processes underlying IMTA, but economic and environmental benefits were also identified (Troell et al., 1997). The next step identified by scholars (Chopin et al. 2010) is to further assess the economic and social potential of IMTA as they are vital to assessing the future development path of new production techniques. Assessment of the IMTA market potential is fundamental to the formulation of regulation, to fish farmers’ decision to shift towards IMTA systems and to scaling up IMTA systems to a commercial scale. Further experimental setups to test IMTA in terms of its economic profitability and environmental impact are situated in the UK, Ireland, Spain, Portugal, France, Turkey, Norway, Japan, Korea, Thailand, the United States and Mexico (Chopin et al. 2010; Barrington, Chopin & Robinson 2009).
The objective of IMTA is to combine several species in the production process to create a simplified ecosystem. Fine particles from the finfish’ metabolic and respiratory processes that are normally released in the water column during growth are consumed by deposit feeders (such as mussel, crab, lobster or sea cucumber) and diluted compounds are absorbed by filter feeders downstream (such as oysters or kelp). A more detailed description of the environmental benefits of IMTA and a quantification of the differences in environmental impact when compared with monoculture or CC systems is presented in the next chapter.

Additionally, a number of economic benefits to IMTA systems over monoculture systems have been identified within the academic literature. The benefits of IMTA systems over monoculture systems consist of (1) increased productivity, (2) risk diversification, (3) trading carbon capturing, (4) reducing costs of negative impacts of aquaculture, such as green tides and (5) increasing social acceptability of aquaculture.

**Consumer benefits of IMTA**

Consumers can contribute to stimulating the industry to adopt production techniques with a reduced environmental impact. Research suggests that consumers attribute value to reducing the environmental impact of their purchasing decisions. However, a lack of information on the production method and environmental impact of the products purchased can lead to misinformed decisions that ultimately does not maximise utility.

More specifically, research suggests that consumers derive utility from the reduced environmental impact of IMTA as opposed to monoculture products. Consumers across Canada and the USA were found to prefer IMTA aquaculture over monoculture (Barrington et al. 2010; Shuve et al. 2009; Yip et al. 2016). Consumers in New York considered IMTA to be better for the environment and more considerate of animal welfare (Shuve et al., 2009). With regards to the perceived quality of IMTA produce, consumers in New York indicated they considered IMTA products to be more wholesome and safer to eat. This is surprising, considering that some concerns existed whether the extractive species would accumulate toxins present in the net pen runoff. However, tests of IMTA produce showed that the levels of heavy metals, arsenic, polychlorinated biphenyls (PCB’s) or pesticides were within the food safety limits and no therapeutants used in salmon aquaculture were detected (Haya et al., 2004). Taste
tests of monoculture mussels versus IMTA mussels also showed no difference (Troell et al., 2009) and consumers found IMTA products safe to eat (Barrington et al. 2010; Shuve et al. 2009). Consumers can therefore be considered to prefer IMTA produce over monoculture produce, mainly due to the reduced environmental impact. Estimates of the value derived from IMTA is called for by academics as a requirement for IMTA adoption, as any added value to IMTA produce can create incentives for both financing institutions and governments to stimulate IMTA development through financing and regulatory measures (Chopin et al. 2010). Research on estimating the preferences of consumers for IMTA products has been conducted across several regions. Estimates of price premiums consumers are willing to pay for IMTA vary from 10% in Canada to 39% on the US West coast (Barrington et al. 2010; Yip et al. 2016). Research in Europe is limited to a study on Scottish consumers, which identified a positive value for environmental sustainability in the production of salmon (Whitmarsh & Wattage, 2006), indicating that a positive WTP for environmental friendly production technologies may be present across Europe. However, no such estimates have been performed for the European industry.

The social adoption and consumer knowledge of aquaculture practices and the concept of IMTA has been found to be low (Barrington et al. 2010; Yip et al. 2016). The adoption of IMTA in the European aquaculture sector is conditional upon social acceptability (Barrington et al. 2010), so the development of IMTA would benefit from public education of seafood production and the ability of IMTA to differentiate itself from monoculture produce. Differentiation of IMTA products is key to IMTA development if consumers are to play a role through their purchasing decision-making processes by including WTP for certain production techniques. One of the potential ways to differentiate products is by providing information on the product packaging that would otherwise remain unknown to the consumer.

Research has shown that consumers in the US are willing to pay a price premium for an eco-certification (Yip et al. 2016), which would assist in the diversification of products. Perceived quality, eco-labels and traceability are all required for consumers to determine their individual ethical premium. A premium can lead a market-driven change in the industry from monoculture to IMTA production techniques, but this is however conditional on consumers being able to differentiate IMTA products from monoculture produce on the market place (Abreu et al., 2011; Ridler et al., 2007; Troell
et al., 2009). One of the proposed strategies is through eco-labelling (Chopin et al. 2010; European Union 2013; SEPEA 2017), which is evaluated as a tool in this thesis.

1.4 Theoretical Background

The choice experiment (CE) is a widely used tool to estimate public preferences and Willingness-to-Pay (WTP) for changes in environmental quality and products that have not yet entered the market or have introduced new product attributes (Hoyos 2010; Louviere & Henscher 1982; Louviere & Woodworth 1983). It has been applied to estimate preferences on the seafood market (Brécard et al., 2012; Jaffry et al., 2004; Johnston et al., 2001; Roheim, Asche & Santos, 2011; Uchida et al., 2014; Yip et al., 2016) and is used to estimate the public’s WTP for IMTA produce in this study.

The WTP for a change in the CE attribute levels can be estimated from the CE data using econometric analysis.

Preference heterogeneity

The marginal value of the attribute levels is commonly estimated using the conditional logit (CL) model. However, this model does not control for variations of preferences across respondents, an issue referred to as unobserved preference heterogeneity (Price, Feick & Higie, 1989).

Several alternative models to CL that address preference heterogeneity exist. First, the Random Parameter Logit (RPL) model tolerates variation of coefficients, thereby allowing preferences to vary across individuals. Second, the Latent Class (LC) model identifies underlying groups in the sample, allowing preferences to vary across these groups. Both these models are applied to minimise the effect of not observing preference heterogeneity (Bujosa, Riera & Hicks, 2010; Hynes, Hanley & Scarpa, 2008). Specifically for seafood preferences, the RPL model has been applied by Uchida et al. (2014) and the LC model by Yip, Knowler, Haider & Trenholm (2016).

Scale heterogeneity

Scale heterogeneity can be described as the standard deviation of utility over different choice situations per individual (Greene & Henscher, 2010). It reflects the degree of respondents’ certainty or consistency in their expressed preferences. The effect of scale heterogeneity is estimated by the Scaled Logit Model (SLM) while the Generalised
Mixed Logit (GMXL) accounts for both scale and preference heterogeneity (Fiebig, Keane, Louviere & Wasi, 2010). Failing to include scale heterogeneity may lead to biased coefficients and eventually biased welfare measurements that can lead to poor policy recommendations (Train, 2003). However, seafood preference studies have focused predominantly on preference heterogeneity. Chapter 5 will present the results of the models including scale heterogeneity to add to the current body of research on seafood preferences.

1.5 Research Objectives

In terms of policies surrounding aquaculture, the EU is aiming for industry growth, yet recognises the environmental concerns associated with the planned expansion of the European aquaculture industry (European Commission, 2015c). Several aspects of the environmental impact of aquaculture are directly mentioned in EU marine or environmental legislation, particularly nutrient and organic matter enrichment (EU, 2008), the introduction of non-indigenous species (European Commission, 2010a) and sea lice infestations (European Commission, 2009). The EU’s proposed strategy to deal with these environmental impacts while stimulating industry growth is twofold; (1) to shift production methods towards environmentally sustainable technology and (2) to educate the public on the environmental impact of seafood production to stimulate sustainable consuming behaviour, with one of the proposed tools being a seafood eco-label (European Union, 2013).

In this context of increasing recognition of the environmental impact of aquaculture a growing body of scholars have suggested to shift aquaculture production systems from monoculture to IMTA systems (Chopin & Robinson 2006; Jeffery et al. 2014). Experiments with IMTA demonstrated that IMTA contains incentives for producers in terms of increased growth rates (Chopin et al. 2004), potential higher market prices (Ridler et al., 2007) and reduced risk (Barrington, Chopin & Robinson 2009; Ridler et al., 2007), as well as incentives for governments in the form of decreased environmental effects of the industry. Based on these research findings and the policy goals formulated at a national and European level, IMTA could fulfil the need for more sustainable production techniques. IMTA uptake by the industry has however been slow, despite it being mentioned as an industry priority by the Irish government and the EU.
Academics have called for market research to facilitate IMTA development (Chopin et al. 2010). Particularly, they defined a need for estimations of the economic value of environmental and societal services of IMTA is emphasized. Information is particularly called for on the issue of the additional value of IMTA products resulting from consumers’ WTP for seafood produced by more sustainable production methods, such as IMTA.

The principal research objective of this thesis is to assess consumers’ WTP for IMTA products across Europe. The primary approach taken within this research is to assess the market potential through estimating consumers WTP for IMTA produce in comparison with monoculture produce. Following this approach, four research questions have been defined that focus on estimating the public WTP for IMTA across Europe and with an emphasis on the Irish public. These aims are addressed in three papers contained in this thesis and are formulated as follows:

Research goal 1
Estimate the Irish consumers’ WTP for IMTA salmon

The first research aim focuses on identifying WTP for IMTA for the Irish public and is presented in chapter three. As discussed, the need for WTP estimations is driven by EU development plans and directly from scholars such as Chopin et al. (2010). The justification of this research goal lies particularly in the extent to which the plans of the EU -to develop a sustainable aquaculture industry- link up with the successful development of the Irish aquaculture industry -into an organic aquaculture niche market-.

The Irish market is of particular interest due to the development path of her aquaculture industry. Irish aquaculture has been challenged by a combination of the infectious disease, Pancreatic Disease (PD) (McLoughlin et al., 2003) and falling market prices due to competition. Ireland’s national salmon production decreased as a result (from 23 thousand tonnes in 2001 to 12 thousand tonnes in 2005) (Browne & Deegan, 2006). The Irish aquaculture industry has managed to increase production by developing into an organic niche that diversified Irish products from alternative (unorganic) salmon products (DAFM, 2015). Irish salmon production has recovered since, as production has increased (to 44 thousand tonnes in 2016) (Vega & Hynes, 2014) and is planned to continue to increase by 123% between 2015 and 2023 (Dept. of...
The Irish public is therefore selected as a case study of particular interest, as its aquaculture industry hinges on organic production as a niche market, identical to the EU’s plans to create a niche market for sustainably produced salmon (EU, 2013). The research aims at modelling the WTP of the Irish public for the sustainability attribute of salmon.

Research goal 2
Estimate the European consumers’ WTP for IMTA finfish

The second research aim is presented in chapter four and is based on the same need for information on consumer value for sustainability in seafood production. It however has a wider scope and estimates the WTP of the European public for IMTA across several species. The selection of Atlantic salmon and seabream is justified by the current growth of the European aquaculture industry being predominantly driven by Atlantic salmon in the Atlantic region and seabream in the Mediterranean area. The selection of data across the entire data set, spreading across the European territory and across the Atlantic and the Mediterranean areas, aims to support the generalisation of the estimates over the European area.

Research goal 3
Assess the effect of the selection of econometric models that take into account preference and/or scale heterogeneity

The third research aim is presented in chapter five and assesses public WTP for all salmon producing sample countries (Ireland, UK, Norway), to correct for any effect that the specie may have on WTP estimates, as different aquaculture species can be considered to make up a separate market. In this analysis several econometric models (RPL, SLM and GMXL) were used on the CE data for the salmon producing sample countries to estimate their WTP.

The final research goal is to assess the effect of model choice on final WTP estimations and the resulting policy recommendations, particularly models aimed at capturing the effect of preference and scale heterogeneity across CE data. The WTP estimations throughout the results chapters are based on several models (CL, RPL, LC, SLM and GMXL). Analysis started with the CL and each additional model takes into account preference heterogeneity, scale heterogeneity or both by different methods. Particularly the RPL, SML and GMXL models will be compared to each other by
model fit indicators.

This research addresses these goals by utilising CE data collected as part of the research consortium project IDREEM (Increasing Industrial Resource Efficiency in European Mariculture). This project ran from 2012 to 2016 and aimed at demonstrating IMTA in European waters (IDREEM, 2015). A survey containing a choice experiment (CE) was conducted as part of this research project, which provided the data for the research contained in this thesis. In addition to the CE data, the survey provided data on consumers’ knowledge of and attitudes towards aquaculture and IMTA, consumers’ shopping behaviour and familiarity with eco-labels as well as sociodemographic information. Additionally, an eco-label has been designed to assist respondents in their CE decision making, as it allows consumers to differentiate IMTA produce from monoculture products on the choice cards. An English copy of the survey including the CE is included as appendix A.

1.6 Research Output

Published work

This research resulted in several outputs, consisting of publications and presentations. With regard to the publications of academic papers, three papers were produced. The first paper (chapter 3) was published in 2017 in the journal ‘Marine Policy’ with the title “Estimating the Irish public’s willingness to pay for more sustainable salmon produced by integrated multi-trophic aquaculture”. In this paper estimations of the public’s WTP are presented specifically for the Irish public. This research applied CL and RPL to a selection of CE data from respondents residing in the Republic of Ireland. It contributes to current knowledge as estimations for IMTA produced salmon were limited. Additionally, the inclusion of the eco-label in the choice experiment provided an opportunity to assess its effectiveness as a tool to convey any differences in environmental impact resulting from a change in production process to respondents.

The second paper (chapter 4) was published in a special issue of the journal ‘Sustainability’ in 2019 with the title “Estimating the public’s preferences for sustainable aquaculture”. This paper advances the first paper by including data from all European countries to facilitate generalisations of WTP estimations for sustainable aquaculture production techniques for the European public. The paper contributes to current knowledge as the publics WTP for IMTA has not been estimated, despite its
importance for further IMTA adoption (Chopin et al. 2010). This research applies RPL and LC models to CE data to account for preference heterogeneity in the data. Additionally, differences in eco-label use and response to the CE label across countries are assessed.

The third paper (chapter 5) is entitled “Scale heterogeneity and preference heterogeneity in discrete choice models: Demonstrating the effect of model choice on WTP estimates for sustainable salmon production in Europe”. This paper assesses the effect of including scale heterogeneity in econometric models on WTP estimations. This research applies RPL, SML and GMXL models to CE data and compares the WTP estimations and goodness-of-fit indicators to determine the preferred model. The paper contributes to current knowledge as scale heterogeneity has not been taken into account in publics WTP for IMTA.

Presentations

- “Public perceptions & preferences towards aquaculture across Europe and the United States”
  Atlantic Ocean Research Alliance WG Meeting.
  Halifax (Canada), June 2017.
- “Estimating the publics’ value for sustainable aquaculture in Europe – a country comparison”
  XXII Conference of the European Association of Fisheries Economists.
  Dublin (Ireland), April 2017.
- “Consumers’ WTP for sustainable seafood across Europe”
  Beaufort Day.
  Galway (Ireland), November 2016.
- “The European consumers’ WTP for sustainable seafood”
  Whitaker Day. Won prize for best presentation.
  Galway (Ireland), April 2016.
- “Irish consumers’ WTP for sustainable seafood”
  Beaufort Day.
  Galway (Ireland), November 2015.
- “Consumer WTP for IMTA produce”
  IDREEM Annual Meeting
  Cyprus, October 2015.
Chapter 1

- “Estimating the Irish Public’s Willingness-to-Pay for Sustainably produced salmon”
  ENVIRON2015.
  Sligo (Ireland), April 215.

1.7 Structure of the Thesis

This chapter has outlined the research context and aims. This thesis assesses the added value of Integrated Multi-Trophic Aquaculture (IMTA) products on the European seafood market. IMTA is an aquaculture production process that has a reduced environmental impact and several perceived economic benefits. Given the right conditions and composition, IMTA may be able to facilitate economic growth without negatively impacting the environmental sustainability of the sector and thereby increasing long term growth of the industry. Yet industry uptake of IMTA has been slow and research on its economic implications limited. This thesis aims to assess the market potential of IMTA produce through assessing the Willingness-To-Pay (WTP) of consumers across Europe for IMTA products.

The rest of the thesis is structured as follows. Chapter two provides a description of the development of the aquaculture industry in Europe and in the sample countries (2.1), highlighting the main differences between the industries. It also provides information on the environmental impact of aquaculture (2.2), assessing both the positive impact it has on the environment through efficient protein production, as well as the negative impact. The chapter then moves on to describe the responses of different actors to the environmental impact. Section 2.3 describes the legislative structure affecting aquaculture regulation by European bodies and governments, while section 2.4 specifies the use of eco-labelling in the seafood market as a market or public effort to steer the industry.

The results of the CE analysis are presented in chapters three to five. Chapter three addresses research aim 1, to estimate consumers’ WTP for IMTA salmon in Ireland. This chapter starts with an introduction describing the research context and aims, after which the methods are set out. The survey and CE design are elaborated on and demonstrated to the reader, after which the survey statistics and the CL and RPL model results are presented, as well as the WTP estimations for the individual attributes as for types of salmon holding bundles of attributes. The chapter ends with
a discussion on IMTA adoption and the role an eco-label can play in the development of the sector.

Chapter four addresses the second research aim, to estimate consumers’ WTP for IMTA finfish across Europe. This chapter overlaps with the previous chapter, but encompasses a more diverse data set, including respondents from Ireland, Italy, Israel, Norway and the UK. The chapter introduces the research topic and sets out the context by describing IMTA and its perceived benefits, and the need for more information on public value for IMTA produce. The materials and methods are elaborated on in the next section, explaining the CE method and the definition of the CE attributes and attribute levels, as well as the approach of the LC model. The results section presents the summary statistics of the CE respondents, the methods by which the number of classes were specified and the model results for the individual country data as well as for the pooled data set. Additionally, consumer profiles were defined based on the model results after which the results were discussed in the final section.

Chapter 5 presents consumers’ WTP for the salmon producing countries in Europe and assesses the effect of the selection of econometric models that take into account preference heterogeneity and/or scale heterogeneity. It introduces the topic of heterogeneity and scale heterogeneity in the introduction, along with a description of the most common methods of accounting for heterogeneity across data. The second section addresses the theory behind discrete choice analysis as well as the econometric methods used in this paper, being the RPL, the SL and the GMXL. The third section turns to describing the sample, the CE design, which is identical to the design applied in the previous chapter. The results section presents the model output as well as an overview of goodness-of-fit indicators for each model. The WTP estimations are presented for both the individual product attributes and for products containing sets of product attribute combinations. The final section addresses the implication of model choice and taking into account sources of heterogeneity on the model estimations, WTP estimation and final policy recommendations.

The final chapter summarises the conclusion from the chapters and answer the research questions according to the findings from these studies. The study will be assessed in terms of research weaknesses and potential avenues for future research. Finally, policy recommendations are made based on the results.
Chapter 2

Aquaculture Development Context

This chapter provides information on the aquaculture industry in Europe; supporting an understanding of the multidisciplinary research context. It will provide high level overviews of the development of the aquaculture industry across Europe and of the characteristics of industry in the sample countries (2.1). Attention will then turn to the main environmental effects of the aquaculture industry, both in terms of the positive and negative impacts (2.2). A potentially more sustainable form of aquaculture, IMTA, will be elaborated on (2.3) as an alternative to the monoculture production process that is associated with the aforementioned environmental impact. The remainder of the chapter describes how these impacts are addressed, particularly in Ireland; firstly, through the top-down response from governmental and international actors through regulations and legislation (2.4) and secondly through the bottom-up response through public preferences for seafood (2.5), awareness and market instruments such as the eco-label (2.6). Finally, the development of the methods used to model preferences is described and the debate surrounding the development of methods is described (2.7).

2.1 Aquaculture Industry Development

Marine aquaculture production in Europe takes place mainly in the Atlantic Ocean and the Mediterranean Sea, with Atlantic salmon and sea bream as dominant farmed species in the regions, respectively (EEA, 2018). Atlantic salmon is a key species to the European seafood market, e.g. out of all species farmed in Europe salmon was consumed the most and had the highest production value in Europe in 2014 (EUMOFA, 2016). The industry has experienced intensification, indicated by an increase in production volume and concentration of salmon producing firms (Asche et al., 2013). The main producers of Atlantic salmon within the borders of the EU are Ireland and the UK, whereas outside the EU territory Norway is one of the largest producers of farmed salmon globally. With regard to seabream production in Europe, the Mediterranean EU member states are the largest producers globally, but their industries are increasingly under pressure by competition from Turkey (FAO -

This study will assess sample countries, being Ireland, the UK, Norway, Italy and Israel, whose aquaculture industries followed different development paths due to variations in geographical, political and socioeconomic positions. The characteristics of each sample country will be discussed subsequently.

Ireland

The first empirical chapter of this thesis specifically focusses on the Irish aquaculture industry. Despite the relatively small proportion of the total aquaculture production of EU member states originating from Ireland (7.5% in 2017) (BIM, 2017), the Irish industry is of particular interest to this study due to its development over the last years. Ireland’s aquaculture industry has struggled with an infectious disease, Pancreatic Disease (PD) (McLoughlin et al., 2003) and falling market prices, causing the national industry to shrink from an annual production of 23 thousand tonnes in 2001 to 12 thousand tonnes in 2005 (Browne & Deegan, 2006), which challenged the industry to adapt.

Consequently, a niche market for organic salmon was developed that diversified Irish products from other aquaculture produce (DAFM, 2015). The Irish aquaculture industry has recovered, showing particularly strong growth in the period 2014-2016, producing 44 thousand tonnes across 290 enterprises in 2016 (BIM, 2017; Vega & Hynes, 2014) and aims to continue to increase its production by 123% between 2015 and 2023 (Dept. of Agriculture, 2015). The industry is currently characterised by the production of multiple species, i.e. salmon, oysters and seabed or rope cultured mussels, with most of the growth driven by gigas oysters (18% growth in 2016) and Atlantic salmon (24% growth in 2016). In the same year, the production of gigas oysters and Atlantic salmon had a value of 41.5 million and 108.6 million euro, respectively (BIM, 2017). Ireland has successfully created a niche market on the seafood market in line with the action proposed by the European Union for the development of the EU aquaculture industry (EU, 2013) and will therefore be assessed in more detail than the other sample countries.

The United Kingdom

The UK aquaculture industry spreads across England, Wales, Scotland and Northern
Ireland and made up 16.0% of the total production from EU member states in 2015 (European Commission, 2015a). Production is dominated in both volume and value by Atlantic salmon farming in Scotland (FAO, 2019a). Scottish fish farms are part of larger conglomerates, whereas fish farms in England, Wales and Northern Ireland tend to be small-scale companies operating locally. These small enterprises have integrated their production with other economic activities, such as recreation and fisheries. Therefore, their socioeconomic impact is likely to be higher than estimated (Hambrey & Evans, 2016).

The national growth objective of the UK aquaculture industry is an increase in production volume of 24% between 2015 and 2020 (DEFRA, 2015). However, with the exception of positive growth rates in Scotland, all countries saw a decline in recent years across all species (from 34 thousand tonnes in 2010 to 21 thousand tonnes in 2014) (Hambrey & Evans, 2016). The sector faces competition from imports, particularly Norwegian farmed salmon, leading to lowered prices. The UK aquaculture sector is assessing diversification by farming other species and is evaluating expanding the production of mussels, oysters and clams to reach its aims for sustainable industry growth (FAO, 2019b; Hambrey & Evans, 2016).

**Norway**

Atlantic salmon is the main species for Norwegian aquaculture and with a production of 1.06 million tonnes in 2011 it accounted for over 93% of its national aquaculture production. The Norwegian salmon industry is characterised by intensive aquaculture practices focusing on efficiency and mechanisation. It developed in the 70’s and, in contrast to the EU industry, has paralleled global aquaculture development (Directorate of Fisheries, 2019).

The Norwegian aquaculture industry however has not been without challenges. In the 1980’s the Norwegian aquaculture industry faced bacterial diseases which led to increasing amounts of antibiotics to be used and spread in the marine environment, until it peaked at 50 tonnes of antibiotics used in 1987. Treatment was however unsuccessful until vaccines were introduced in combination with increased attention to environmental practices in management plans. Currently the industry faces issues with sea lice and escapees, but is overall regarded as a well-controlled industry (FAO, 2019d) in which environmental sustainability is considered a significant factor.
in development plans and integrated management is used to combat infectious diseases and parasites (Norwegian Ministry of Fisheries and Coastal Affairs, 2009).

Italy

The Italian aquaculture industry produces a mix of marine, freshwater and shellfish species. The shellfish sector is the largest in terms of volume, while the marine is the smallest in volume but largest in value. Italy increased its production from 75 thousand tonnes in 1980 to 163 thousand tonnes in 2012 and made up 11.38% of the total production of the EU member states in 2015 (EC, 2015a). The industry grew intensively in 1985-1999 but this growth levelled off and recent years have seen a decline in production, although this decline has been partially attributed to environmental factors (FAO, 2015). The national growth strategy defined Italian aquaculture growth aims to be 32% of overall production (from 141 thousand tonnes in 2013 to 207 thousand tonnes in 2025 (European Commission, 2015b)).

Current industry growth is driven by the marine species, particularly molluscs, European seabass and gilthead seabream. The Italian industry is however confronted with lowered prices due to competition from seabass and seabream producers across the Mediterranean region. Addressing this competition through increasing productivity has proven challenging, which has been partially ascribed to a lack of public research supporting the industry to innovate (FAO, 2015). The industry is additionally challenged by administrative fragmentation, which negatively affects farmers ability to acquire farming licenses and to enforce environmental legislation (FAO, 2015). Italy aims to support industry development by simplifying administration, coordinating spatial planning, enhance competitiveness through investments in knowledge and skills and market research (European Commission, 2015b), which is in line with the EU plans for the sustainable development of EU aquaculture (European Commission, 2013d).

Israel

The inception of the Israeli aquaculture in the 1920’s was earlier than its European counterparts. A virus outbreak in 1945 nearly caused the collapse of the industry, but instead resulted in research laboratories being set up. Research has had a supportive role in the industry since and introduced additional species to be farmed and polyculture systems to be set up. The main marine cultured species is Gilthead
seabream, but ornamental fish are farmed increasingly due to their value.

The Israeli aquaculture industry is challenged by a combination of (1) the closing of fish farms around Elat due to environmental concerns, (2) an increasing population, (3) Mediterranean wild fish stocks being overfished and (4) increasing competition. However, water shortages in particular have affected the development of the industry in Israel in the 80’s and 90’s (Mires, 2000). One of the strategies to counter water shortage was to use super-intensive systems, which initially lead to small producers to disappear and production rates to drop in the 1980’s, but since the mid 80’s production has increased steadily (FAO, 2019c).

Aquaculture industries across the sample countries have commonalities such as; being impacted by environmental factors, the availability of species and territory, and market factors such as competition playing a role in how the industry develops. However, the differences across aquaculture industries are striking. Environmental factors influence species selection and issues such as drought and storms which can impact production. Additional differences exist between the countries in terms of political affiliation. EU member states, while free to choose implementation methods under recent marine policies, are bound to EU legislation on environmental protection while also falling directly under the EU’s plan to expand the industry. The non-EU member states are not directly impacted by the EU, but can be influenced indirectly through the Atlantic Action Plan and the Integrated Maritime Policy for the Mediterranean region (European Commission, 2017a). The methods by which the multi-level legislation and implementation functions will be elaborated on later in this chapter, but first the environmental impacts of aquaculture are set out.

2.2 Environmental Impact of Aquaculture

The aquaculture industry is criticised for its environmental impact by scholars (Naylor et al., 2000), environmental NGO’s (Greenpeace, 2008) and the public. Simultaneously it is argued that aquaculture has a positive environmental effect when compared to the impact attributed to the production of alternative protein sources for human consumption. This section will provide more details on the elements contributing to and reducing the environmental impact of aquaculture.
production processes.

Positive Environmental Impact

The majority of high-protein products for human consumption are produced by the livestock sector which has been identified as one of the most significant contributors to anthropogenic emissions (Gerber et al., 2013) and the degradation of land and water (Tolkamp, Wall, Roehe, Newbold, & Zaralis, 2010). Indicators of production effectiveness are the feed conversion, energy retention and protein retention rates. The Feed Conversion Ratio (FCR) expresses how many kilograms of feed is necessary to produce 1 kilogram of animal product (Tolkamp et al., 2010). The score of farmed salmon indicates higher efficiency on protein conversion rate (compared to pork, for sheep and beef) as well as on the energy and protein retention rates of pig and chicken (Gerber et al., 2013; Tolkamp et al., 2010). This suggests that farmed salmon is a protein source that converts feed into animal product more efficiently than other animal products (excluding dairy products). Farmed salmon can therefore be considered a protein source that is environmentally friendly relative to livestock, when judged by resource inputs in the form of feed.

Regarding the impact of aquaculture specifically on wild fish stock rates, a commonly held perception is that aquaculture compensates for falling wild catch rates. Wild fish stocks fulfil significant functions within the marine ecosystem, amongst others as a carbon sink as wild deep sea fish alone removes one million tonnes of CO2 every year from UK and Irish waters (Trueman et al., 2014), indicating the value of one of the ecosystem services fish stocks produce. However, Naylor et al. (2000) found that the decision of which species are farmed and which production systems are applied are key to the sustainability of aquaculture practice. Depending on these two factors, aquaculture can either serve as a solution to the degradation of the marine environment, or contribute to it. Aquafeed is a particularly important element in determining the sustainability of aquaculture production, especially for carnivorous species such as salmon where other wild fish make up a proportion of the fish feed. Naylor et al. (2000) state that the aquaculture industry must alter aqua feed sources to reduce wild fish inputs and adopt management practices that are more ecologically sound if it is to contribute to the world fish supplies and limit the negative environmental impact.
Negative Environmental Impact

The environmental impact of the aquaculture industry consists of several elements. First, aquaculture requires fish feed which often contains fish-products retrieved from the oceanic environment. This leads to an increase in demand for wild fish, causing higher pressure on wild fish stocks.

Second, drugs and chemicals are used in aquaculture in large amounts over long periods of time. This extensive drug use can become problematic in cases where bacteria in fish farms become antibiotic-resistant. Resistance determinants have spread to fish pathogens and can spread to life outside the fish farm, altering the bacterial flora in sediments and in the water column. These changes can have severe health implications for both human and animal health (Cabello et al., 2016).

Third, aquaculture is linked to diseases and parasites (Ariel & Olesen, 2002; Nylund, et al., 2003; Rimstad, 2011). In the case of salmon farming, sea lice have been shown to have an effect on the wild fish populations (A. Nylund et al., 2003; Torrissen et al., 2013). The extent of sea lice impact on fish stocks remains debated, but sea lice infestation can lead to increased mortality depending on infection intensity, development stage of the sea lice and size of the infected fish (Heuch et al., 2005).

Fourth, overfeeding and fish waste pollute the direct environment of the fish farm, which contributes to eutrophication (Talbot & Hole, 1994). Eutrophication is a source of environmental modifications on all trophic levels; for example it can cause algal blooms and decrease the ability of crustaceans to form shells (Pinto-coelho, Bezerra-Neto & Morais, 2005).

Fifth, escaped fish can function as invasive species that compete with native species for territory and food or, through interbreeding, change the genetic makeup of wild species. When invasive species are successful in the new environment they can consume food supplies to such a degree that native species go extinct (Pillay, 2004).

Finally, fish farms intrude the natural marine environment. This occurs both physically with nets and cages and by causing noise pollution which can affect native species behaviour (McCarty, 2004). On a global scale, aquaculture indeed decreases pressure on wild fish stocks, albeit dependent on species produced and decisions on aquafeed (Roderburg, 2011), but this is not the case for the high-value
carnivorous fin fish species the European aquaculture industry focuses on. The environmental impact of the European aquaculture industry is substantial and cannot be ignored if fish production is to be optimized.

*Balancing impacts*

Acknowledging the positive impact of aquaculture production does not diminish the negative effects of salmon farming on the environment, as these can have far stretching consequences on the direct environment of fish farms. However, when perceived from the wider goal of feeding the global human population, aquaculture production can have less negative effects when compared to alternative (lifestock) protein sources. The negative environmental impact of the industry is however recognised and managed in multiple ways. Governments and international organisations aim to reduce the environmental impact through international and national legislation. Additionally, bottom-up incentives exist to change consumers’ awareness and purchasing behaviour through information provision and increasing public awareness through eco-labels.

However, a method of addressing the environmental impact of fish farming closer to the source of the negative impact would be to make alterations to the production process to reduce impact. IMTA has been suggested as a potential way of reducing the negative environmental impact of fish farming while maintaining or increasing production. The methods of decreasing environmental impact will be discussed in the following sections, with the next section expanding on the concept of IMTA (2.3), followed by a description of the methods by which the industry is currently regulated (2.4) and the eco-label as market-instrument that currently exists on the European seafood market (2.5).

### 2.3 Integrated Multi-Trophic Aquaculture

IMTA is an alternative production process that aims for a cyclical production system, in contrast to the linear monoculture production process that is currently standard in the European aquaculture industry (Hughes & Black, 2016). Within the term IMTA, *integrated* signifies the proximity of species to form a system that allows the exchange of nutrients and runoff (Barrington et al., 2009) and *multi-trophic* refers to the use of species from different trophic levels in an ecosystem and it is this point
that differentiates IMTA from polyculture production (Chopin 2006).

On an IMTA farm, several species are combined in the production process as depicted in Figure 1. Species are selected by their function in the ecosystem and their economic value. They are combined with other species in appropriate proportions in such a way that plants and animals absorb each other’s output in the production process. At the basis of the constructed ecosystem is usually a fin fish with a high market value per weight. Its output consisting of excess feed and waste functions as input as it is absorbed by kelp, seaweed and mussels that are cultivated downstream. The output of these species consists of water that is filtered and higher in oxygen, as photosynthesis takes place in the plants and water purification in the mussels. Excess food and waste from the fin fish, seaweed and kelp sinks to the bottom, where it is eaten by deposit feeders, such as lobsters and sea cucumbers. The IMTA system can be seen as a simplified artificial ecosystem with extreme flexibility in application.

The effects of IMTA over monoculture production techniques will be assessed for
the environmental and economic aspects of aquaculture production as described in the previous section. Due to the interrelated character of IMTA as a unified system, the effects overlap and reinforce each other. The environmental effects of IMTA systems consist of (1) increased efficiency of protein production and a reduction in (2) aquafeed impact, (3) the use of drugs and chemicals, (4) diseases and parasites among crops and (5) eutrophication, whereas the effects on (6) sound pollution will be highly context-dependent. The economic impact of IMTA consist of an increase in (1) productivity and (2) risk diversification, and a decrease in (3) carbon released into the environment, (4) costs associated with eutrophication and (5) public resistance, whereas finding financial support to start an IMTA facility is perceived more difficult than for monoculture systems. These effects will be discussed in more details.

**IMTA environmental impact**

IMTA surpasses monoculture in its efficiency of producing protein. The production of aquaculture products (salmon) has been established to be more efficient than the main cattle species when assessed by the protein conversion rate and the energy and protein retention rates. IMTA does not necessarily outperform monoculture on these indicators for the main fin fish species. It is however more efficient overall due to nutrient cycling, which increases the final product output per unit input through the additional species that grow of the finfish feed.

Aquafeed is a particularly strong element in the environmental impact of aquaculture production. Especially in the case of carnivorous fin fish species produced in Europe, developments stimulating aquafeed efficiency can decrease the environmental impact of aquaculture production (Roderburg, 2011). Although aquafeed technologies have improved over the last years (Tacon and Metian, 2008), part of IMTA is the further development of feed alternatives that reduce the amount of wild fish required to create fish meal (Shpigel et al., 2017). One example is through the use of macroalgae as aquafeed ingredient (Wan et al, 2019). This would imply a significant cost reduction as the main cost of the aquaculture production process consists of feed (Shpigel et al., 2017).

IMTA outperforms monoculture systems with regard to the use of drugs and chemicals in aquaculture. This is closely connected to the next point of disease and
parasite mitigation. It is suggested that IMTA systems are more efficient in mitigating diseases and prevent the spread of certain parasites. As a result, IMTA may require lower doses of antibiotics and drugs, thereby potentially reducing the risk of antibiotic resistance in the direct environment of the farm.

The spread of diseases and parasites is found to be lower for IMTA systems, although it is highly dependent on species selection and environmental factors such as water currents. Experiments found that mussels (*Mytilus edulis*) provide potential for the mitigation of sea lice, one of the main impacts of salmon farming (Bartsch et al., 2013), and disease mitigation, particularly the infectious salmon anaemia virus (ISAV) (Skår and Mortensen, 2007). Additional studies have reported IMTA organisms to be healthier when grown together with other organisms than when grown in monoculture (SEPEA, 2017).

Another aspect of IMTA production is the reduction in eutrophication. IMTA experiments with open net-pen systems in Chili demonstrated that excess nutrients released from the fin fish net pens were indeed absorbed by 5% of dissolved inorganic nitrogen and 27% of the dissolved phosphorous (Max Troell et al., 1997). However, the true extraction rate may be higher as identified in this study, as the open nature of the production process complicates nutrient capture measurements. In comparison, experiments with contained (land-based) systems demonstrated seaweed to have removed 35% to 100% of dissolved nitrogen produced by fed species (Troell et al., 2003).

IMTA has the potential to reduce the environmental impact of salmon production for the reasons outlined above. However, it does not address all environmental aspects related to degrading environmental conditions. The likelihood and effect of escapees remains under IMTA systems as well as sound pollution. In fact, when additional structures are required for the supplementary species and for activities such as electricity creation, the sound pollution of IMTA systems may in fact be more severe than for monoculture systems. Additionally, the environmental benefits identified in experiments cannot be linearly scaled up to a commercial site as they are dependent on the characteristics of the species and of the site (Troell et al., 2009). IMTA can therefore not be regarded as a solution to all the issues aquaculture poses. However, the results from experiments look promising in partially mitigating
impacts and improving aquaculture production technologies.

**IMTA economic impacts**

IMTA economically differs from monoculture systems. With regard to productivity levels, IMTA system experiments demonstrated higher growth rates for the extractive species due to higher levels of nutrients surrounding the fish farm. An IMTA experiment in the Bay of New Fundy (Canada) demonstrated higher meat yields in mussels, where the growth rates of kelps and mussels grown next to salmon pens were between 46% and 50% higher than those grown at control sites, which was attributed to the increase in nutrients from the salmon farm runoff (Chopin et al. 2004). Additionally, the revenue from these additional species compensated for additional labour and material costs through a 24% increase in the Net Present Value (NPV) (Ridler et al., 2007).

Additionally, IMTA has been suggested as a strategic choice for producers as it provides fish farmers with diversification of risk across several species (Barrington, Chopin & Robinson 2009). Ridler et al. (2007) confirmed the effect of IMTA on risk by executing a scenario analysis of IMTA experimental farms that assessed the impact of environmental and economic shocks over a 10 year period. They demonstrated that additional species in the IMTA systems had a dampening effect on any external effects affecting the income from the finfish by providing an uncorrelated source of income. Risk diversification is especially interesting for smaller farms as they are more sensitive to price shocks due to a lack of financial resources and economies of scale (Ridler et al., 2007). The Irish salmon industry experienced this when salmon prices dropped as a result of large amounts of Norwegian produced salmon entered the market and caused the national industry, that was characterised by relative small scale production, to shrink considerably (Browne et al., 2008). IMTA could prove a strategy of small farmers to protect themselves against market shocks, as well as a strategy of governments to protect the industry against competition or other external effects.

The production of carbon as a side effect of food production can have a negative economic impact when viewing it in context of the emissions trading system (ETS), especially when taking into consideration the cap on carbon emissions and the value that lies in trapping and sequestering carbon. IMTA extractive organisms may
produce value by capturing nitrogen, phosphorus and carbon in their meat and shells, which can be calculated and used on the carbon trading market (Chopin et al. 2010).

The recycling of runoff and reducing levels of nitrogen, phosphorus and carbon can result in lower probabilities of green tides. Such tides are costly to remove and can damage tourism and other sectors related to marine recreational activities. Although the benefits of the prevention of green tides is hard to calculate, their prevention can be cost reducing (Chopin et al. 2010).

IMTA can increase the social acceptability of fish farms. Increasing public knowledge and awareness has been mentioned by policy actors as a key requirement for further development (European Union, 2013) and academics have linked public hindering of aquaculture activities to low public acceptance (Burridge, Weis, Cabello, Pizarro and Bostick, 2010). Robinson et al. (2018) conducted a study on the knowledge of the general public of aquaculture and of their attitudes towards aquaculture development in Canada. This study showed that the public’s attitude towards aquaculture is positive (60%), mainly attributed to its economic benefits. Yet public support was greater for the development of IMTA (90%), even in cases where familiarity with IMTA was low (Robinson et al., 2018). Sustainability is key to the development of the aquaculture industry and studies outside Europe indicate that the public has a positive attitude towards the development of IMTA (Yip, Knowler, Haider & Trenholm 2016).

Last, financing IMTA systems differs from monoculture systems, as more varied materials are required to facilitate the growth of several species. As a result, the initial costs to develop an IMTA system is higher, which can constraint IMTA adoption. Experiments are conducted that integrate aquaculture systems with other function to overcome this barrier. One example is the addition of energy production to IMTA farms in offshore wind parks that are anchored on aquaculture systems in the North Sea (SEPEA, 2017).

Overall, the development of IMTA incites positive effects on both environmental and economic aspects, leading researchers to refer to IMTA as a win-win (Hughes & Black, 2016). Yet, industry uptake of IMTA technology is slow. One of the potential reasons for this slow adoption of IMTA in the industry is the lack of facilitation of
these technologies by the regulatory and legislative systems.

2.4 Regulation & legislation surrounding aquaculture

The ability of states to regulate their aquaculture industries varies, depending on their position in multiple international communities. Particularly the regulation of EU member states are complicated by their position in multiple governance layers. The rights of a state over their marine resources are exclusive in the sense that no party may exploit these resources without the consent of the state (UN, 1982). EU member states however ceded certain rights to the EC, which makes for a distinct relationship between national, European and international legislation.

The Relationship between European and National Legislation

The marine resources of any EU member state are currently managed both by the national government and EU legislation, while non EU member states manage those resources through their national government and international agreements. Marine resource legislation has been formulated at the international (UNCLOS) (UN, 1982), European and national levels. The legislation at these different levels is discussed in detail in appendix A.

The distinction between primary and secondary sources of law is important when assessing legislation devised at different levels. Primary sources of law are nationally devised legislation and, in some cases, European Community law. Secondary sources are those that have been devised internationally. These secondary sources lack any force of law until they have been integrated into national law. These levels of the law work differently; international law gives a general jurisdictional framework, contemporary European law sets out goals to be achieved by the Member States and national law defines the implementation of national plans and secondary law.

European Legislation on Aquaculture

Aquaculture regulation in European member states is predominantly in the hands of the national government, yet heavily influenced by international and European law. Despite EC law being defined as strong law and therefore overruling national law (including national constitutions), the influence of the EC on the aquaculture
industry is minimal as this area falls under national sovereignty (Long, 2007). Implementation on the national level is influenced by two principles in EU law. Firstly, it is stimulated by the ‘integration principle’, which stipulates that environmental protection requirements must be integrated in national law, particularly when they aim for sustainable development. However, and secondly, the implementation methods remain unspecified, demonstrating the ‘principle of subsidiarity’ which leaves member-states free in their method of implementation to facilitate their country-specific situation or system (Dhondt, 2003). These principles are designed to stimulate the effective and timely implementation of EC policies into national regulations.

Any influence the EU exerts over aquaculture development is through the Marine Strategy Framework Directive (MSFD) (European Union, 2008), the Blue Growth Strategy (European Commission, 2012b, 2017b), the Habitats Directive (European Council, 1992) and the Maritime Spatial Planning (MSP) platform (European Commission, 2013b). These pieces of legislation address different aspects of aquaculture production and differ in the extent to which they impact the industry. The implementation of these pieces of legislation into national policies has been challenging due to the fragmented nature of EU policies and the fact that environmental polices do not necessarily align with plans in other policy areas such as economic development (Dhondt, 2003).

Therefore, the EU has taken a more integrated and holistic approach since 2000 through two methods (Apitz, Elliott, Fountain & Galloway, 2006). Firstly, more recent EU marine legislation consists of Directives rather than regulations (Boyes & Elliott, 2014). Directives are based on the principle of subsidiarity, meaning that action is taken on a regional or national level rather than on the EU level. Concretely, subsidiarity in this context entails that member states are given the objectives to be achieved, but are free to select the methods by which to achieve them (European Union, 2012). This allows member states to create policies that are suitable for their specific territory. Second, the Integrated Maritime Policy (IMP) was created to function as an umbrella strategy; setting out coordination actions to develop an integrated and coherent European policy (European Union, 2011). The IMP stresses integration of existing actions, using the ecosystem approach, marine spatial planning and stakeholder inclusion to create an integrated ocean management plan.
Chapter 2

for marine regions.

Integrated management as proposed by the EC may be able to provide a balanced approach. Integrated management is a form of management that incorporates tools such as the ecosystem approach and marine spatial planning, integrating various planning and management systems into one unified framework. The rationale is that integrated management is better able to deal with the plurality of legal norms and uses, as well as resolving conflict between users of coastal regions (Long, 2007). In order to achieve integrated management, a combination of instruments must be used in a unified method. What this exactly means remains unspecified, but Laffoley et al. (2004) suggest that this can be achieved by creating policy coherence between environmental, economic, social, spatial, temporal, scientific and institutional policy actions. Ireland is an interesting case-study to witness the integration of a fragmented marine policy landscape. The process of marine governance in Ireland did not initially exhibit such policy coherence (Long, 2007), but in recent years developed an integrated approach to advance the sustainable use of Ireland’s marine resources and thus its long-term economic development. A more detailed description of integrated management in the EU can be found in appendix A.

National Implementation in Ireland

The European aquaculture industry is regulated by national governments through national development plans and the implementation of European law. Specifically for the Irish aquaculture industry, European law is the main source of law regulating marine activities under Irish jurisdiction (Long, 2007). Aquaculture is governed by statute law, consisting of Acts that are enacted by the Oireachtas.

The bodies responsible for the aquaculture industry in Ireland are multiple, with the main bodies being; (1) the Department for Communication, Marine and Natural Resources (DCMNR), which supports the sustainable development of the Irish aquaculture sector in order to maximize its contribution to jobs and growth in coastal communities and to the national economy; (2) the Planning Authorities, which are the local authorities that influence aquaculture development indirectly through local development plans; (3) The Loughs Agency of the Foyle, Carlingford and Irish Light Commission (LAFCILC), which deals with issues specifically on the bay surrounded by Irish and Northern Ireland territories and therefore regulated by
two separate sets of law; (4) several bodies concerned with food and safety law that are responsible for the implementation of European and national legislation by producers, transporters and food processing parties; and (5) the Coordinated Local Aquaculture Management System (CLAMS) which manages the overall development of Irish aquaculture at a local level by taking an integrated management approach.

Ireland is an interesting example of integration of European into national law as its regulation of the marine economy has changed to a more integrated approach. Scholars such as Long (2007) emphasized the dispersion of responsibilities in the Irish aquaculture industry into a fragmented system. He stated that this lead to separate sector policies dealing with individual aspects of the use of the marine environment, which caused Irish marine governance to predominantly centre on economic development and lacked consideration on the long-term impact of decisions on the wide marine environment. This effect was enhanced by the absence of scope within the legislative framework for harmonizing existing laws and policies and as a result, the legislative framework in Ireland was fragmented and unlikely to deliver sustainable marine resource use in the long term (Long, 2007).

The need for actors to cooperate in order to successfully implement EU aims lead to the creation of an integrated marine plan that contains a centralised approach for all agencies involved with the Irish marine economy (OOW, 2012, 2017). This approach is updated every few years and aims to balance the topics of the marine economy, ecosystem health and public engagement with the sea. The latest update stated that Ireland is on track to achieve the 2020 and 2030 targets for economic growth and invested in aquaculture development, including IMTA projects. With regards to environmental protection, the report states that implementation of the MSFD and EU Water Framework Directive are ongoing (Government of Ireland, 2018), although the EC reports that, based on the information provided by Ireland, it is uncertain if GES will be achieved in the timeline stipulated in the Directive (European Commission, 2018). In terms of implementation of the MSP, Ireland is on track to reach her objectives (Department of Housing Planning and Local Government, 2017).

National Implementation in the United Kingdom

The governance of aquaculture in the UK is devolved across the administrations of
Wales, England, Northern Ireland and Scotland and across several organisations in each state. To illustrate, the main authorities in England consist of the local authority (for planning permission), the Fish Health Inspectorate (for authorisation and inspection), the Crown Estate (for territory use), local authorities (for safety and hygiene permissions), the Marine Management Organisation (for development licenses), the Environmental Agency (for discharge consent) and Natural England and the local Inshore Fisheries and Conservation Authority (IFCA) (for development consent in protected areas).

The UK system governing the aquaculture industry is criticised for its fragmentation, overlapping responsibilities and inconsistency. Particularly the heavy administrative load of regulatory procedures have been pointed out as industry pain point (Hambrey & Evans, 2016). It is therefore not surprising that the complexity of the system has been identified as a barrier for industry development in England and regulatory streamlining is advised to facilitate growth (DEFRA, 2015).

The strategy for the development of UK aquaculture encourages industry growth and presents the aim of increasing the finfish production of Scotland, UK’s main producer, from 181 thousand to 210 thousand tonnes and shellfish production from just under 8 thousand tonnes to 13 thousand tonnes over the period 2014 – 2020. The UK national strategy stresses the importance of environmental sustainability and suggests IMTA as one of the possible avenues for future development (DEFRA, 2015), but the need for more research is stressed (Hambrey & Evans, 2016).

The effect of EU regulations on the development of the UK aquaculture industry is evident in the national strategy through the main actions supporting industry development. The main actions consist of reducing the administrative burden, integrating coordinated spatial planning, investing in innovation for the aquaculture industry, improving public perceptions of European aquaculture products, promoting stakeholder inclusion and sharing best practices for farm management procedures, containment promotion and invasive species avoidance (DEFRA, 2015). These are action points of the EU plans for sustainable aquaculture development (European Commission, 2013c) and the IMP.
National Implementation in Italy

Italian regulation and governance of the aquaculture industry is dispersed over two main governmental authorities, the Ministry of Agriculture and Forest Policies and the DG for Fisheries and Aquaculture. Additionally, the Ministry of Infrastructure and Transport and the DG for Maritime and Inland Navigation Infrastructures bear some responsibility related to the allocation of national territory to aquaculture facilities. Outside the national government, Italian aquaculture regulation is influenced by the “Blue Table”, consisting of regional councillors, the presidents of national aquaculture associations, national trade unions and the Ministry of Environment and Land Protection. Aquaculture is regarded a matter for regional governance, whereas environmental protection is governed across regional and national government. In addition, Italy is signature country to the Barcelona Convention of 1976 for the Protection of the Marine Environment and the Coastal Region of the Mediterranean, which affects aquaculture development through the requirements of best environmental practices to be created (European Commission, 1976).

The national growth objectives of the Italian aquaculture sector have been set to an increase from 141 thousand tonnes (2013) to 207 thousand tonnes by 2025, signifying a 32% increase in just over 20 years. The majority of the growth is expected to come from marine fish farming at a 58% increase in volume by 2025. The section of aquaculture aimed to have the second largest growth is mollusc farming at a 31% increase in volume by 2025 (European Commission, 2015b).

In line with the Commissions’ plans for the development of the European aquaculture industry, Italy has taken action towards the four main goals stipulated at European level. First, Italy has simplified the administration surrounding aquafarming by adopting one single aquaculture law and creating a centralised platform for stakeholders. Second, Italy has supported coordinated spatial planning through creating aquaculture zones and monitoring plans for the environmental quality of these regions. Third, Italy has worked towards enhancing competitiveness through supporting research, providing training and sharing best-practices. Last, in terms of creating a level European market, Italy has improved coordination of
aquaculture producers, market research and product traceability (FEAMP, 2015).

2.5 Public Preferences for Seafood Production

Preferences for Seafood Attributes

Consumer preference for seafood has received more attention in the academic literature in recent years as consumer acceptance is recognised as a crucial aspect of the successful development of the aquaculture industry (Vanhonacker, Pieniak & Verbeke, 2013). Research in consumer preferences for seafood has identified several seafood attributes for which consumers have a positive utility. The main seafood attributes identified in academic literature are (1) origin of the product, (2) wild caught produce over farmed seafood, (3) species, (4) product form, (5) marketing-related attributes such as brand and packaging, (6) sustainability and (7) product labels. One could argue that labels fall under marketing-related determinants, but as eco-labels are a substantial part of the CE design product labelling will be discussed in a separate section.

Interaction between Attributes

Seafood attributes are presented here separately, yet the literature suggests that interactions exist between certain attributes. For example, Witter & Stoll’s (2017) assessment of seafood marketing linked the rise of alternative marketing to a broad set of seafood characteristics that consumers desire, consisting of a set of local, sustainable, healthy, traceable and ethical seafood attributes (Witter & Stoll, 2017). The definition of the stimulating factor behind alternative seafood marketing as a set implies that interaction may exist between these attributes. Interaction between attributes can impact research outcomes to a large extent. Aarset et al. (2004) explore consumer knowledge and perception of organic salmon farming through focus group discussions across five European countries. They found that the majority of consumers is unknowledgeable on the exact meaning of product attributes and public knowledge was mostly based on a process of osmosis they described as “accidental learning”. This led to incomplete and in some cases incorrect knowledge, causing a majority of consumers to mix up the “organic” and “locally produced” attributes with the “sustainability” attribute. Additionally, consumers respond differently to labels. A majority of European consumers was unaware of labelling
and organic certification processes, which led to scepticism towards product labels (Aarset et al., 2004). Brécard et al. (2009) added to this that consumer response to labels may be influenced by the product form. Consumers have a higher preference for product labelling for fresh seafood, mainly due to a desire for product traceability. Product labels ensure consumers of the nutritional safety of the product, which is valued more for fresh fish as this is considered riskier to consume than frozen fish (Brécard et al., 2009). Unless researchers clearly communicate attribute descriptions to respondents there is a risk of research bias based on confusion surrounding the attributes or distrust towards the instruments used to convey information (product label).

Product Origin

Consumers have a preference for locally produced food over other sourced food (Chambers, Lobb, Butler, Harvey & Bruce-Traill, 2007; Jaffry et al., 2004; Salladarré, Guillotreau, Perraudeau & Monfort, 2010) and in some cases these preferences are found to be stronger than for organic attributes (Yue & Tong, 2009). Production location was also identified as one of the main attributes by Brayden, Noblet, Evans & Rickard (2018). However, a qualitative study that interviewed seafood stakeholders and collected survey data across 8 European countries found that the origin of fish can have limited importance when combined with other attributes, such as a distinction between wild-caught or farmed seabass and seabream (Vanhonacker, Pieniak & Verbeke, 2013; Loureiro & Hine, 2002).

Wild Caught vs. Farmed Seafood

Several studies indicate that consumers prefer wild seafood over farmed seafood. In the US, Roheim et al. (2012), assessed consumer preferences specifically for wild and farmed salmon and shrimp by conducting a conjoint experiment. Data was retrieved from a sample of 250 seafood consumers in Rhode Island (US) through an in-person intercept survey. Preferences were estimated using a conditional logit model. Roheim et al. (2012) found that consumers perceive aquaculture products as a distinctly different from wild seafood. This is in line with Davidson et al. (2012), who assessed the WTP of Hawaii consumers for fish products, particularly for the species tuna, salmon, tilapia and moi acific threadfin. WTP estimations were retrieved from data from a questionnaire including a CE with an attribute for farmed vs. wild-
caught products. Data (n = 610) was collected in-person and online. Estimations were based on conditional logit conjoint analysis and respondents indicated a higher WTP for wild seafood based on perceived taste and environmental concerns.

Research identifying consumer perceptions across Europe indicated comparable results. Schlag & Ystgaard (2013) assessed consumer perception of the production and consumption of wild seafood compared to farmed seafood across Europe. This study was qualitative in nature and data was retrieved by 28 focus groups across European capitals (France, Italy, Germany, Greece, Norway, Spain and the UK). A clear positive preference for wild-caught seafood was identified. Additionally, a study on consumer preferences for seabream in Spain also identified a positive preference for wild caught sea bream opposed to farmed seabream (Fernandez-Polanco, Loose, & Luna, 2013). Finally, Claret et al. (2014) assessed the effect of consumer perception of wild and farmed fish on the development of the aquaculture sector through focus groups and questionnaires across Spanish seafood consumers. They analysed survey data (n = 919) through triangulation, a commonly used qualitative method to establish validity by assessing an element from multiple perspectives. This study found a clear difference in consumer perception of farmed and wild fish, with a preference for wild products (Claret et al., 2014).

These studies indicate that European consumers have a positive preference for wild-caught seafood over farmed seafood and point at several potential causes for this difference. A qualitative study conducted by Schlag & Ystgaard (2013) indicated that European consumers have less trust in the production and consumption of farmed fish, mainly due a feeling of “unnaturalness” and unfamiliarity with the production process. Additionally, Claret et al. (2014) found that consumer perceptions were more positive for highly educated consumers as these individuals were more willing to accept scientific evidences and alter their views and ultimately their decisions (Claret et al., 2014). These results emphasize the importance of information strategies as part of efficient marketing strategies to increase the image of the aquaculture industry.

Specie

Research assessing seafood preferences clearly specifies the selection process of the species included, as studies indicate that consumption patterns, preferences and
WTP can vary across specie. Wessells et al. (1999) assessed the influence of several product attributes on consumer preferences using a choice experiment. The products included in the choice experiment varied on the species salmon, cod and cocktail shrimp. Data was collected over phone interviews and led to 4,633 observations from 1,640 randomly selected households across the Southern US states. Using the logit model and performing likelihood ratio tests, Wessells et al. (1999) found that interactions between dummy variable for species demonstrated that respondents did not treat all species equally when selecting their most preferred options in the choice tasks. It is questionable whether the findings can be directly extrapolated to the European market, as the selection of species was made based on consumption levels in South US, which may be different across Europe. However, variation in preference or consumption across species has also been identified in Rhode Island (Roheim et al. 2012) and Hawaii (Davidson et al. 2012), further indicating that variation may exist in the preference for species.

**Product form**

The 2018 Eurobarometer indicates that a majority of EU consumers buys aquaculture products that are frozen (68%) or fresh (67%) (European Commission, 2018). This distinction between frozen and fresh products is taken into consideration in the design of seafood preferences studies, including Brécard et al. (2009). They consider frozen and fresh fish as distinctly different products with different characteristics, mostly due the health attribute, which is more strongly attributed to fresh fish.

Similarly, using their CE data for preferences for salmon, cod and cocktail shrimp, Wessells et al. (1999) confirmed that consumers treat frozen and fresh fish differently. One of the differences Wessells et al. identified was that respondents who frequently purchase seafood in frozen form were less likely to choose seafood with eco-labels.

**Brand & Packaging**

Marketing-related elements have been demonstrated to affect consumers’ preferences for seafood products, particularly seafood brands and packaging form. Research conducted in the UK demonstrated price premiums for preferred brands. Roheim, Gardiner & Asche (2007) used scanner data of the frozen processed seafood market in the UK. The results indicated that brand is an attribute that influences
consumer purchasing decisions, with the most preferred brands having a premium of approximately 10% over the average product process.

Product packaging is another marketing-related aspect that has been identified to influence consumers’ value for seafood products. Consumer preferences for certain types of packaging has been identified across studies that are not limited to the seafood industry. Steenis, van der Lans, van Herpen & van Trijp (2018) identified a preference for more sustainable packaging types. Preferences for product packaging specifically for the seafood industry have been assessed by Loose, Peschel & Grebitus (2013). They conducted a study assessing the impact of packaging and the related ease of preparation of oysters through an online choice experiment. In addition to various product packaging and processing options, the CE included traditional attributes known to influence preferences (price, origin, species, health, environmental impact and product quality). Data was collected from 1718 respondents in Australia and analysed using a scale adjusted latent class model which was specified to include six classes. The results indicated that packaging indeed influences consumer choice, albeit a minor effect compared to the other attributes. The effect of the preparation format attribute was comparable to the effect of price and species (Loose, Peschel & Grebitus, 2013). However, this study focuses on Australian oyster consumers only so one must be cautious in extrapolating these results to the European market for other (fin)fish species.

**Sustainability & Product Labelling**

Marketing tools have become increasingly important in a context of growing consumer awareness of environmental issues. Studies have identified public awareness of and concerns about sustainability issues (Galbreth & Ghosh, 2013). This is demonstrated by the increase of the proportion of consumers that has been labelled as “green consumer”. The green consumer is defined as any consumer with strong pro-environment views, high WTP for environmental attributes and a belief that individuals can make a difference. The green consumer therefore consumes products they see as the greenest option available on the market place. The proportion of green consumers has increased from 27% in 1999 to 33% in 2000 (OECD, 2002), indicating a clear increase of the importance of sustainability for consumers. The increase in public awareness of sustainability issues is affecting the seafood market. Witter & Stoll (2017) explored the drivers and challenges of seafood
marketing in the US through a qualitative interview-based study. They found that a set of non-market values lie at the base of the recent surge in alternative seafood marketing (Witter & Stoll, 2017).

Closely related to consumer preferences for sustainability is the labelling of seafood, as eco-labels are often the only indication of the environmental impact of a product available to consumers. Several studies indicated that seafood products with eco-labels are preferred by consumers (Brécard et al., 2012; Bronnmann & Asche, 2016a; Jaffry et al., 2004; Uchida et al., 2014). The sustainability and eco-label attributes are central elements of this study and therefore the next sections will provide an in-depth discussion of the literature on consumer preferences for sustainability and eco-labelling of seafood products.

Preferences for Sustainable Seafood

Research in consumer preferences for sustainability attributes is built on two assumptions defined by Mussa & Rosen (1978); (1) consumers prefer less polluting products over more polluting products, and (2) consumer vary in their WTP for the decrease in pollution (Mussa & Rosen, 1978). The role of altruism in decision making has been researched to assess this variation in WTP and has been found to influence individual decision-making (Andreoni, 1989).

However, in making these seemingly altruistic choices individuals can be motivated by unaltruistic motivations such as gaining respect and friendship (Olson, 1971), or by social objectives such as social prestige that can be reached through publicly visible displays of “charitable” behaviour (Becker, 1974). Andreoni (1989) found that models including such seemingly more selfish motivations had a higher predicting power than those including pure altruism (Andreoni, 1989). The term “impure altruism” was introduced (Andreoni 1989; 1990), referring to the “warm glow” effect of altruistic purchasing choices. Viewing consumers’ decision making processes as being influenced by impure altruism implies that consumers derive some form of utility from choosing products whose production led to less pollution, suggesting that the utility for the public good attribute competes with other product attributes. Indeed, studies have identified that consumers also consider moral and social attributes and attributes that directly affect their health (Ek & Söderholm, 2008; Kotchen & Moore, 2007) and they can be willing to pay for the wellbeing of other
species (van der Naald & Cameron, 2011). This includes green alternatives that contribute to a better environment through partially internalizing externalities (Boyer, Mahenc & Moreaux, 2006) such as IMTA.

A study conducted in Maine (USA) by McClenachan, Dissanayake & Chen, (2016) consisted of interviews of seafood consumers. The research had a dual aim. First it assessed consumers’ understanding of the role of sustainability in seafood. A majority of the respondents understood the term ‘ecologically sustainable’ well (57%) or fair (24%). Socioeconomic benefits of seafood were associated with benefit to the local community (53%) or related terms (27%). Secondly, the study aimed to model consumers’ responses to seafood labelling and certification through discrete choice analysis. The CE asked respondents to either select a seafood restaurant presented on the choice cards or select the opt-out option. The CE presented each respondent with 6 choice cards that contained 4 attributes: ecological suitability, product origin, social sustainability and cost. Each attribute was reflected by either a specific, a vague or no product label. Data was collected by approaching pedestrians randomly to conduct interviews, which provided 235 completed surveys. Data was analysed using CL and RPL models, which indicated that respondent had a WTP for vague sustainability labels ($14), followed by local seafood ($13) and social sustainability ($7). These estimations were consistent across the models. However, WTP was higher for specific labels, which indicates that vague labels may appeal to consumers with a good understanding of seafood sustainability terminology, but more specific labels have a wider appeal. This study demonstrates that consumers across the Maine (US) region prefer more environmentally and socially sustainable seafood production techniques (McClenachan, Dissanayake & Chen, 2016).

Similarly, Whitmarsh and Wattage (2006) assessed the preferences of the Scottish public for more sustainably produced aquaculture products. They distributed a postal questionnaire among 296 households. The questionnaire elicited respondents’ preferences by two methods. The first part asked respondents to rate industry objectives covering environmental, economic and social criteria according to their preference or perceived importance. The ratings were analysed using the Analytical Hierarchy Process (AHP). This part of the research found that minimization of environmental pollution ranked the highest amongst the objectives with a priority
weight of 39.1%. The second part of the survey utilised contingent valuation to assess the monetary value the Scottish public assigned to reducing the pollution resulting from salmon farm production. The preference elicitation format was open-ended and asked the percentage a respondent was WTP for a salmon produced in a less polluting method than a normal salmon. The majority of the respondents (76%) was willing to pay a price premium for salmon that was produced in a production method that produced half the pollution as a normal salmon product. The average WTP estimates was 22% of the market price, although variation across respondents was identified. A positive correlation was identified between the priority weight for environmental performance and the WTP indicated in the CV. This study concluded that there is indeed financial benefit to be derived from green product differentiation and that eco-labelling will be an important element in reaching a high value sustainable niche market for European aquaculture (Whitmarsh & Wattage, 2006).

Preferences for IMTA Products

Consumers have been found to prefer IMTA over other production techniques outside of Europe across the US West Coast, New York and Canada. In the US Pacific North-West Yip et al. (2016) assessed preferences for IMTA and Closed Containment (CC) aquaculture of consumers. The study applied a choice experiment, where the choice scenarios included five product attributes; species, production method, eco-certification, country of origin and price. The species included in the choice experiment design were Atlantic, Sockeye and King salmon as these were the dominant species on the market. The production method was specified as being either conventional farming, IMTA, CC or wild production. The choice cards also included an eco-label attribute, which was described as a generic eco-label. The country of origin was included to account for any differences in perception of salmon from certain countries. The price attribute functioned as the financial denominator in the welfare estimates calculation, with the average market price as a reference price. A market research company collected data from the target population through online questionnaires including the CE. The data (n = 2067) was analysed using Latent Class Analysis. Respondents indicated in the survey that they preferred IMTA and CC over conventional farming 44.3% and 3.9% respectively. The CE showed similar positive preferences for IMTA and CC over monoculture salmon.
and price premiums of 9.8% and 3.9% for IMTA and CC, respectively.

A qualitative study in New York (n=649) also identified positive preferences for IMTA (Shuve et al., 2009). It assessed preferences of consumers through an online consumer survey through questions exploring three elements; (1) exploring consumer attitudes towards IMTA systems and IMTA products, (2) identifying the benefits attributed to IMTA mussels and (3) identifying changes in purchasing behaviour. Due to the high level of unfamiliarity with IMTA, the survey introduced the term IMTA and provided basic information on the production system prior to the survey questions. It assessed consumer preferences on seafood attributes, consisting of sustainability, animal welfare, food safety, health, product wholesomeness, product quality, freshness, taste, accessibility, availability and price. IMTA products scored considerably higher on most attributes but outperformed monoculture salmon the strongest on the main seafood purchase determinants of product quality, freshness and taste. Approximately 56% of respondents indicated they would be willing to pay a price premium upwards of 10% (38%) or 20% (18%) of the market price (Shuve et al., 2009).

Positive public attitudes were identified in Canada by Barrington et al. (2009). This study was qualitative in nature and data was retrieved from focus group sessions with three sectors of the general public affected by IMTA, such as restaurateurs, residents near IMTA experimental production facilities in the Bay of Fundy, Canada and the general public. The focus group approach was chosen as it facilitates discussion and supports gaining an understanding of underlying issues due to the flexible nature of the approach. Five focus groups with twenty-three participants were held. Respondents indicated a positive attitude towards IMTA in comparison with monoculture production in terms of improvement in (1) the environmental impact (65%), (2) waste management (100%), (3) employment opportunities (91 %), (4) community economies (96%), (5) industry competitiveness (96%), (6) food production (100%) and the overall sustainability of aquaculture (73%). Smaller proportions of respondents were positive towards IMTA’s potential to reducing the risk of disease outbreaks (22%), natural stock recovery (23%) and improving food quality (32%). The study has a small sample size, but indicates the mixed feelings of the public towards IMTA. The concept of IMTA is believed to have potential, but the public lacked faith in the required management practices due to a general lack of
trust. This study indicated that there is potential for the development of IMTA in a niche market, but informative labelling and consumer education will be key to its success (Barrington et al., 2009).

Martínez-Espiñeira et al. (2015) further explored the market potential of the biomitigative effects of IMTA by assessing consumer choices and estimating consumer WTP for IMTA salmon in Canada. They applied the contingent valuation method by providing respondents with choice tasks where they could select an alternative where IMTA products become available either against a price premium, at the same price or at a discount. The IMTA attribute was identifiable through product labelling. Coupled with this choice was the question how respondents would alter their future shopping behaviour. A random-effects negative binomial model was applied to estimate separate demand curves for IMTA farmed salmon and conventionally farmed salmon. Based on these demand curves, consumer surplus for the availability of IMTA produced salmon was estimated. However, large variations existed, with estimations ranging from 280 million (lower bound) to 1.5 billion (higher bound) Canadian dollars a year. Despite this large variation, the experiment demonstrated that there is a positive consumer WTP. Respondents indicated that IMTA salmon and conventionally farmed salmon are not considered as substitutes, conditional upon adequate product labelling so diversification can take place at the consumer level (Martínez-Espiñeira et al., 2015).

Studies conducted on European samples have come to similar conclusions. Alexander, Freeman & Potts (2016) assessed stakeholder perceptions of IMTA in comparison to perceptions of conventional aquaculture. They conducted 44 in-depth interviews across twelve stakeholder groups in Cyprus, Ireland, Israel, Italy, Norway and Scotland. They found variation in the levels of awareness and understanding of IMTA across stakeholders and countries. One of the main benefits identified by industry stakeholders was the higher value of IMTA produce as it was believed consumers are willing to pay an environmental premium. Production stakeholders also indicated risks in switching to IMTA systems, particularly risks to the environment, government-related issues and risk for the industry development. However, respondents indicated that they believe these risks can be managed when academic research, education and legislation are adequately applied (Alexander,
Freeman & Potts, 2016).

A recurring theme of research on consumer preferences for sustainable food production is the role information provision on the environmental effects of seafood production to the public. On the one hand, educating consumers on food production techniques and the environmental impacts of seafood increases environmental awareness and thereby affects the value the public attributes to sustainability in seafood production. On the other hand, informing consumers on the environmental impact on the product level is conditional for making informed purchasing decisions. A widely used tool to communicate production information to respondents is the eco-label.

2.6 Eco-labelling in the Seafood Market

Eco-labels provide information on products and services through labelling products that fulfil certain criteria set out by labelling organisations (OECD, 2002). Eco-labelling ultimately aims to influence purchasing behaviour by indicating the environmental impact of purchasing decisions to the public. In doing so, eco-labels assist consumers and professionals in making environmentally aware purchasing decisions. Governments can use eco-labelling to educate consumers on the environmental impact of the products’ production, consumption and discard to change purchasing behaviour and thereby reducing overall impact of the industry. Simultaneously, companies are stimulated by eco-labels to use environmentally friendly production methods and proliferate themselves on the market as being sustainable. In a marketplace where sustainability is increasingly valued by consumers, eco-labels can assist in gaining a greater market share and potential higher profits resulting from consumers’ preference for sustainable production (Jacquet & Pauly, 2007).

Seafood related eco-labels were first introduced in the 1970’s, when the collapse of certain fish stocks increased concerns for the sustainable use of the oceans resources. Several successful eco-labels exist on the seafood market, the most well-known being the Dolphin Safe and the MSC (Marine Stewardship Council) labels (Jacquet & Pauly, 2007). Aquaculture products are perceived as distinctly different from wild caught produce (Roheim et al., 2011) and therefore a separate and less familiar eco-label specifically for aquaculture products, the ASC (Aquaculture Stewardship
Council) label was launched, although it enjoys less familiarity than its MSC counterpart.

Preferences for Seafood Eco-labels

The effects of seafood eco-labels on consumer purchasing behaviour have been studied across the US and the European seafood market. In the US, Fonner & Sylvia (2015) assess how multi-labelling products influences consumer preferences for seafood information labels of consumers in Portland (Oregon, US). In the CE, respondents were asked to make pairwise choices in a hypothetical CE that included salmon and crab products with several labels. They included four types of labels in their CE design, being (1) safety (2) quality, (3) locally produced, and (4) an eco-label. The CE data was analysed using a Conditional Logit model. A positive WTP was identified for each label included in the CE design and this preference was strongest for the local and eco-labels. Based on these results, labels have the potential to add value to seafood products, even when competing with other labels. These results should be interpreted with care, as data collection was limited to a niche supermarket chain. However, the results do suggest that there may be market potential for an environmental niche market for seafood (Fonner & Sylvia, 2015).

Hallstein & Villas-Boas (2013) assessed eco-labels as a market based mechanisms to shift consumption patterns. Particularly, they assessed consumer responses to an eco-label with a traffic light design and used sales statistics to assess the effect of the eco-label on purchasing decisions. Data was collected from a supermarket chain in San Francisco (US) and analysed using a differences in difference identification strategy. The results indicated an overall decline in seafood sales when using an eco-label, but no change in sales volume occurred for green or red labelled seafood. As other studies indicate a higher value for eco-labelled seafood (Fonner & Sylvia, 2015), there may indeed be a high-value niche sustainable seafood market.

These results are in line with research aiming to identify consumer acceptance for seafood eco-labels. Wessells et al. (1999) conducted a telephone survey on randomly selected US households. This survey covered demographics, seafood preferences, seafood consumption, environmental preferences, knowledge of environmental impacts and a CE. The choice cards contained pairs of salmon, cod and shrimp products, with each product containing the attributes price, an eco-label and
information on the certifying organisation behind the eco-label. The choice data was analysed using Conditional Logistic regression, which indicated positive WTP estimations for seafood eco-labels. Likelihood ratio tests of species interaction variables indicated that respondents treat species differently in choice sets, which results in a different premium being estimated per specie. The analysis also showed that consumers that are more educated on environmental impact have a higher WTP for eco-labels. In terms of demographics, women use eco-labels more than men and interestingly, no differences were identified across trust in certifying agencies (Wessells et al., 1999).

A qualitative approach was taken in Australia by Lawley et al (2019), who assessed the relationship between the knowledge on sustainability in seafood production and seafood purchasing behaviour of consumers. Data was retrieved through an online survey that contained open-ended questions. The analysis was divided into identifying consumers’ knowledge of sustainable seafood and drivers of purchasing decision making. Lawley et al. (2019) identified a link between higher knowledge of environmental impacts and higher value for sustainable purchases. This positive relationship could support the claim that information-based strategies are vital in stimulating sustainable production practices and Lawley et al. (2019) conclude that information provision will increase the knowledge and the importance of sustainability in purchasing decision.

A study on random households across the US and Norway assessing consumer preferences for eco-labelled seafood also identified positive consumer preferences for eco-labelled seafood (Johnston et al. 2001b). In this study, randomly selected respondents were approached over the phone and a CE was conducted. Johnston et al. (2001b) concluded that the factors influencing eco-labelled seafood purchasing decisions particularly consist of species, consumer group and certifying agency. Interestingly, Johnston et al. (2001b) demonstrated variation in the effect these factors had on consumer decision making across US and Norway, suggesting heterogeneity in responses to seafood eco-labels across borders. Therefor research conducted on European consumers will also be assessed.

**Preferences for Seafood Eco-labels across Europe**

Research assessing seafood preference is conducted across Europe and has found an
overall positive attitude towards seafood eco-labelling. In Italy, Del Guidice et al. (2018) conducted a small-scale study that was based on real purchasing decisions in supermarkets for canned tuna. Respondents were interviewed after they selected canned tuna in the supermarket, thereby bypassing the hypothetical bias that is mentioned as a weakness of the CE method (Roheim et al. 2011). Del Guidice et al. (2018) assessed consumer preferences for existing seafood eco-labels and identified the effect of eco-labels on choice and price using hedonic pricing and CL models. The study found that consumers actively look for eco-labels when purchasing seafood and have a positive WTP for indicators of “responsible” production. Del Guidice et al. (2018) concludes that corporate social responsibility can therefore be used as a marketing strategy, particularly by environmental and social certification.

In France, the effect of seafood eco-labels was assessed by Brécard et al. (2012) and Salladarré et al. (2010). Brécard et al. (2012) aimed to identify any potential differences in consumer attitudes towards eco-labelled seafood compared to non-labelled seafood. They included a CE in a national seafood survey with choice cards that contained French seafood products with a health-, eco- and fair trade label. The preference for these labels was estimated through a rank-ordered multinomial logit model with random intercepts. Based on the model estimates Brécard et al. (2012) identified two types of respondents; (1) pro-eco-label and pro-fair trade label consumers and (2) pro-health label consumers. This variation is attributed to differences in the degree of altruism, environmental consciousness and socioeconomic factors.

Salladarré et al. (2010) focused on changes in purchasing behaviour when eco-labels are introduced to the French seafood market. They assessed the demand for eco-labels on French seafood products in the context of growing consumer and retailer awareness of environmental issues. Data was collected through a French survey that was carried out on more than 1,000 seafood consumers in France. Data analysis aims to identify the factors influencing consumer demand for seafood eco-labelling with an ordered Probit model. The analysis results indicate a significant relationship between eco-label acceptance and the purchase criteria. Production process characteristics (specified in the research design as origin, wild vs. farmed, level of natural stocks) affect demand for eco-labelling stronger than product attributes (specified as form, visual appeal and freshness). With regards to variation in
preferences, consumer demand for eco-labelled seafood is higher for young and highly educated consumers in non-coastal regions.

Taking a Europe-wide perspective, Zander & Feucht (2018) assessed consumer preferences and estimated WTP for sustainability in seafood production across Europe. They conducted an online survey containing a CE across seafood consumers in 8 European countries (Finland, France, Germany, Ireland, Italy, Poland, Spain and the United Kingdom). Respondents were selected based on quota for gender and age, which led to a sample higher educated than the national averages (n=4,103). The CE choice cards contained a payment scenario where respondents were asked how much they spend on fish and how much they are willing to spend more (ranging from 100-200% in 8 increments) for fish products that are produced (1) more sustainable, (2) according to organic standards, (3) locally, (4) by coastal fisheries, (5) with higher animal welfare standards, (6) in Europe and (7) discard free. Data was analysed using bivariate analyses including cross tabulation with chi-square statistics and one-way ANOVA comparison of means. Additionally, Zander & Feucht (2018) segmented consumers into clusters according to WTP for the sustainability attributes through using a two-step cluster analysis. MNL analysis identified correlation between values, attitudinal variables and socio-demographic indicators in the clusters.

With regards to consumer attitudes, the results indicate variation in the interpretation of the term sustainability. Respondents ranked the issues they considered the most important environmental factors in aquaculture as (1) hormone and drug use (38%), specie endangerment (37%), pollution (33%) and animal welfare (31%). In fisheries, the main environmental issues are ranked as specie endangerment (50%), overfishing (44%), stock recovery (41%) and protection of juvenile fish (34%). Consumer WTP of the pooled data set was highest for seafood that is produced organic (14.8%), sustainable (14%), with higher animal welfare standards (14%) and locally (12.6%). However, large differences exist across the countries and across the clusters. A proportion of the population (9%) has a high WTP for sustainability in seafood production (40-50%). Zander & Feucht (2018) stress that this is a particularly interesting segment that indicates potential for sustainable seafood development in the European seafood market.

In the UK the potential of eco-labels to promote sustainable fisheries was assessed
by Jaffry et al. (2004). Eco-labels are used as a means to differentiate between commonly caught and sustainable seafood. Data was collected through a seafood survey (containing a CE) that was collected for seafood consumers and non-seafood consumers (n=600). The choice cards included 4 purchasing options, each containing seven attributes; product form, certification, certifier, product origin, production method, price and brand. Data was analysed with a CL model. Results showed that British consumers have a positive preference for quality and sustainability labels. The marginal WTP for salmon products was estimated at £5.17 for sustainability, £2.38 for governmental eco-labelling, £4.94 for nationally produced and £1.72 for wild salmon. Jaffry et al. (2004) conclude these results indicate the existence of opportunities for a niche marketing for sustainability in fisheries.

Focusing on the London metropolitan area, Roheim et al. (2011) assessed whether or not a price premium is being paid in the retail market for eco-labelled seafood. They use a hedonic price model on scanner data on frozen processed Pollock products. The willingness of consumers to pay a price premium for eco-labelled seafood is estimated at a 14.3% premium. However, to what extent these findings can be extrapolated to other product forms, species and territories is unclear as this study is limited in specie selection, the territorial scope and product form. Roheim et al. (2011) state that the hypothetical nature of the CE should not be ignored and this study adds to the literature by proving an actual payment for eco-labels on the seafood market, which indicates a potential return of investment of sustainable production processes to producers.

Preferences for Aquaculture Eco-labels

A smaller body of research exists specifically for eco-labels for the European aquaculture market. Bronnmann & Asche (2017) conducted a seafood survey across Germany with the aim of estimating revealed preferences for labels on seafood and comparing preferences for sustainability labels for wild and farmed salmon products. The study additionally assessed if consumers’ preference for wild products can be attributed to a perceived lack of sustainability or quality for farmed products. A CE was conducted on fish consumers in supermarkets across Germany. The choice cards consisted of two seafood products and an opt-out. Each of the seafood products contained the attributes price, production process (wild or farmed), sustainability certification (MSC or ASC) and processing (frozen or fresh).
The data was analysed using a mixed logit model to compare preferences for farmed salmon with ASC labels and wild salmon with MSC labels. The results indicated that differences in preferences between wild and farmed seafood exist in the German seafood market, most notably a preference for wild seafood. This could be caused by the environmental concern coupled with the belief that aquaculture is more environmentally damaging than wild-caught produce. The ASC label negates the effect of negative associations with farmed salmon to such an extent that consumers’ WTP is equal to that of wild seafood with a MSC label. The WTP for an aquaculture product with the ASC label in comparison to a wild product with a MSC label is €3.71 and €2.74 per 250 grams of salmon, respectively. This indicates potential benefits on the German market for producers that wish to acquire the ASC label (Bronnmann & Asche, 2017).

The preferences of Norwegian seafood consumers were examined by Olsen (2003) with the aim of assessing the relationship between seafood consumption and certain factors identified in literature to impact seafood consumption (age, attitudes toward healthy eating and convenience). A survey amongst seafood consumers (n=2,500) was collected from a cross-sectional selection of households. Using structural equation modelling, Olsen (2003) identified a positive relationship between age and seafood consumption, which was attributed to attitudes towards seafood, health and perceived convenience. The frequency of seafood consumption among Norwegian consumers is mediated by attitudinal and motivational variables. Elder people expressed positive attitudes towards seafood as they valued health-benefits more than young people. However, the structural equation modelling methodology is purely correlational and Olsen (2003) states that additional research is required to fully understand this relationship.

Preferences for IMTA Eco-labels

Research on consumers preferences for eco-labels on IMTA products is limited to Shuve et al. (2009), who assessed preferences New York city consumers for eco-labels on IMTA produced mussels. A detailed description of this study is given in the literature review on consumer preferences for IMTA. However, this study also focused on the purchasing behaviour of consumers. Respondents indicated that they would buy eco-labelled seafood if it was available at their regular shop (41%) and a small proportion of respondents would travel further for eco-labelled seafood (31%).
Out of the respondents that would buy eco-labelled IMTA mussels, 38% indicated to be willing to pay a 10% premium. Out of this group 18% indicated to be WTP 20% more for an IMTA product with an eco-label. These results are limited by the geographical scope of the study and the inclusion of mussels the sole specie, but are in line with preferences identified in research on seafood eco-label preferences.

The research on consumer preferences for eco-labelled seafood demonstrates several trends. Seafood consumers (1) prefer higher sustainability in seafood production, (2) have a WTP that is positively related to the level of sustainability in aquaculture production; (3) positive preference for eco-labelling on seafood and (4) stressing of potential of a sustainable niche market.

**Eco-label Effectiveness**

In more general terms, the WTP and the ideal label are both determined by altruism, social norms and intrinsic motivation (Frey and Stutzer, 2006), ethical values and beliefs, customs, culture and social, political and moral values (Berglund and Matti, 2006; Torgler and Garcia-Vilañas, 2007). Note that health, environmental and social concerns are generally strongly related, as shown in studies dealing with eco-labelling (Grankvist and Biel, 2001, 2007; Torgler and Garcia-Valiñas, 2007), and that it is not easy to disentangle the factors explaining preference. In order to put a value on the characteristics promoted by the label, consumers need to be informed about any issues involved in the production and consumption of the good. Accordingly, consumer knowledge level is another crucial determinant of the WTP and the ideal label. The WTP and the ideal label are also explained by the socio-economic characteristics of consumers.

The analysis in this chapter has established that large differences exist between the sample countries in terms of their aquaculture industries, the systems regulating aquaculture and the development of the industries. Concurrently, it is widely recognised that current aquaculture practices have deleterious environmental impacts that could be minimised if aquaculture techniques were to be improved and appropriate regulatory, control and monitoring procedures were in place (P. Read & Fernandes, 2003). Acknowledging the strong influence of international and EU policies on marine governance, regulation of aquaculture industries can no longer be considered to take place dominantly on the nation state level. Instead, it requires
interaction between state and significant market actors, supranational organisation and public society to form a multilevel and multi-layered institutional system of management (Soma, van Tatenhove and van Leeuwen, 2015). Haya, Sephton, Martin, & Chopin (2004) state that the strategy and regulatory framework of the EU is one to be drawing lessons from for the future of marine governance as it facilitates for the regulation at a higher level while maintaining respect of national sovereignty. One of the ways of doing this is through the use of market instruments such as eco-labels for aquaculture products. The effectiveness of such market instruments is often assessed using discrete choice analysis. The following section will describe the literature surrounding several models’ approaches.

2.7 The Role of Heterogeneity in Discrete Choice Analysis

Heterogeneity issues, specifically preference and scale heterogeneity, have gained increasing attention in discrete choice literature. Preference heterogeneity can be defined as the variation of consumers’ tastes and preferences across consumers (Price, Feick & Higie 1989). In the context of discrete choice analysis, preference heterogeneity reflects the variation in consumers’ utility across individual respondents for the attributes included in the CE design.

Scale heterogeneity expresses the standard deviation of utility that is identified over the choices an individual makes. It is therefore also defined as the variance of the variance term ($\varepsilon$) across respondents (Fiebig, Keane, Louviere, & Wasi, 2010; Greene & Hensher, 2010). Scale heterogeneity in discrete choice analysis reflects the degree of consistency in respondents’ choices. This variation can be a result of respondents’ certainty, their focus on the choice task at hand, their ability to choose or other aspects that fall outside of the CE design. Therefore, accounting for scale heterogeneity in choice experiment analysis integrates any variation of the degree of randomness in the completion of CE choice tasks in the model. Within discrete choice methods, multiple models have been developed that account for preference and/or scale heterogeneity.

Preference Heterogeneity

Multinomial logit (MNL) choice models are well established in assessing consumer preferences of non-market goods. However, MNL is restricted by its underlying
independence of irrelevant alternatives (IIA) assumption (Luce, 1959) which specifies that preference homogeneity across respondents is assumed based on unobservable characteristics. Yet research indicates that preferences often exhibit preference heterogeneity. This is demonstrated by several studies, including research comparing multiple model specifications of travel preference data. For example, Amador, González & De Dios Ortúzar (2005) retrieved revealed preference data from randomly selected students for transport modes to university and assessed if preference heterogeneity could be detected. Using Bayesian methods, they found that the superior specification allowed for both systematic and random taste variation, suggesting that preference heterogeneity is indeed present (Amador, González & De Dios Ortúzar, 2005). Similarly, Espino, Martín & Román (2008) conducted a stated preference (SP) experiment to estimate preferences for airline services. A comparison of individual WTP estimations demonstrated that individual respondent estimations are sensitive to preference heterogeneity. They concluded that failing to account for preference heterogeneity can lead to a vast overestimation of WTP (Espino, Martín & Román 2008).

Failing to include preference heterogeneity may lead to the loss of information, biased coefficients that lead to biased welfare measurements and ultimately to poor policy recommendations (Hynes, Hanley & Scarpa, 2008; Provencher & Bishop, 2002; Train, 2003). Two dominant approaches to assess preference heterogeneity by extending the MNL model have been developed. These models incorporate heterogeneous tastes over observed and unobserved attributes and consist of the random parameter logit (RPL) model and the Latent Class (LC) model (Hynes, Hanley & Scarpa, 2008; Provencher & Bishop, 2002).

The Random Parameter Logit (RPL) model (Train, 1998) relaxes the assumption that preferences are homogeneous across individuals based on unobserved characteristics. The relaxation of the IIA assumption allows preferences to vary across respondents and accommodates preference heterogeneity by estimating the utility of every individual. The RPL model is commonly applied in sustainable seafood valuation studies (e.g. Bronnmann & Asche 2016; McClanahan, Dissanayake & Chen 2016; van Osch et al. 2017), estimations of consumers’ WTP for eco-labels on the seafood market (Uchida, Onozaka, Morita, & Managi, 2014) and for IMTA products across Canada (Troell et al. 2009), Scotland (Whitmarsh & Wattage, 2006) and the US Pacific
Chapter 2

Northwest (Yip et al., 2016).

However, the RPL does not take scale heterogeneity in account, while research indicates that a proportion of the preference heterogeneity captured in the RPL random parameters may be better expressed as scale heterogeneity in the scale term (Louviere et al. 2008; Louviere and Meyer 2007). The RPL is therefore considered a poor approximation if scale heterogeneity is present within the CE data (Fiebig et al., 2010). Additionally the RPL has been criticised due to its inability to handle within-group heterogeneity and its’ inadequacy of dealing with samples that are composed of several groups with group-specific preferences (Bujosa, Riera & Hicks, 2010; Lenk & DeSarbo, 2000). In such cases the LC model may provide a better approximation for the data.

The LC integrates sources of preference heterogeneity by identifying underlying groups in the data set. In LC models the mixing of preference intensities takes place over a finite group of preference classes (Hynes, Tinch, & Hanley, 2013). Members of each class are assumed to have identical preferences that are not directly observable from the CE data. The LC model is applied commonly in environmental economics (Shen & Saijo, 2007; van der Naald & Cameron, 2011) and more specifically to estimate consumer preferences for seafood (Mauracher, Tempesta & Vecchiato, 2013; Nguyen, Haider, Solgaard, Ravn-Jonsen & Roth, 2015) and for sustainable seafood production (Brécard et al., 2012; Yip et al., 2012).

However, the LC model is criticised for its assumption that each member within a class has identical preferences as this may be an over-simplified representation of the preference distribution across the population. This may be especially true in cases where LC models were specified to have few classes and where continuous preference distributions exist within classes (Allenby & Rossi, 1999; Bujosa et al., 2010). Additionally, Allenby & Rossi (1999) state that LC models may not fully capture preference heterogeneity as it underestimates the degree of heterogeneity within the data.

Scale Heterogeneity

The issue of scale heterogeneity in resource economics is addressed to facilitate the understanding of respondent’s choices for sustainable goods (Louviere & Eagle, 2006; Louviere et al., 1999, 2008; Louviere et al., 2002). Two extensions on the MNL have
been developed specifically for scale heterogeneity, being the Scaled Multinomial Logit (SMNL) model and the Generalised Multinomial Logit Model (GMNL).

The Scaled Multinomial Logit (SMNL) model was developed to take into account scale heterogeneity across CE data. The inclusion of scale heterogeneity is especially relevant in stated preference studies, as CE respondents can differ in their interpretation of choice tasks and information presented in the survey, and vary in the amount of attention paid to choice tasks and the level of choice certainty (Train & Weeks, 2005). Thus it would be expected that the scale of the error term could be greater for some consumers than for others.

Fiebig et al. (2010) developed an extension on the MNL in the Generalised Mixed Logit Model (GMNL) based on the suggestion of Keane (2006) to combine RPL and SMNL into one model. The GMNL can be regarded as a RPL including both preference and scale and heterogeneity (Hole & Yoo, 2014), expressed by a distribution parameter ($\gamma$) and a scaling parameter ($\tau$), respectively. This model has been demonstrated to improve model fit based on Goodness-of-Fit criterion as it accounts for respondents that exhibit extreme or near-random preferences in CE (Fiebig et al., 2010).

Early applications of models taking into account scale heterogeneity primarily compared the performance of the SMNL and GMNL to established modelling approaches. Christie & Gibbons (2011) compared the performance of MIXL (to account for taste heterogeneity), SMNL (to account for scale heterogeneity) and GMNL (to account for both taste and scale heterogeneity) on discrete choice data from two separate CE’s. They found that accounting for preference heterogeneity improved model fit, accounting for respondents’ ability to choose (scale heterogeneity) improved preference revelation and the model accounting for both sources of heterogeneity (GMXL) outperformed the other models in terms of model fit (Christie & Gibbons, 2011).

Taking a similarly comparative approach but executing it on a larger scale, Keane & Wasi (2012) examined six models to assess the best approach to account for heterogeneity using data from ten stated preference CE’S. The performance of the MIXL, LC, GMNL, SMNL, Mixed-Mixed Logit (MIXL with a discrete mixture-of-normal heterogeneity distribution) and T-MIXL (MIXL with theoretical constraints) models was assessed based on the BIC of each model. In line with literature, no
singular model was dominant, but the GMNL, Mixed-Mixed Logit and T-MIXL outperformed the more established MIXL and LC models. This difference could be explained by these outperforming models capturing both choice behaviour based on respondents focusing on limited attributes and those that exhibit random choice behaviour (Keane & Wasi, 2012).

After the creation of the scale heterogeneity extensions, the role of respondents’ certainty in the selection of CE alternatives and the attention paid in completing the choice task were studied to determine if they affected scale heterogeneity. With regard to choice certainty, higher complexity of choice tasks could potentially lead to lower determination in respondents’ selection of preferred alternatives, which could affect the degree of scale heterogeneity. Beck, Rose & Henscher (2013) included a certainty indicator in their CE where respondents express how certain they are of their selection after every choice card. Respondents’ certainty was found to affect choice; it was negatively related to scale heterogeneity, meaning that higher levels of certainty in the completion of the choice tasks could lead to more consistent preference expression by respondents (Beck, Rose, & Henscher, 2013).

With regard to respondents’ attention to the choice tasks, the degree of attention to the selection of CE alternatives was expected to be negatively related to scale heterogeneity. Hildebrand, Chung, & Boyer (2019) used eye tracking technology in the CE to gain data on respondents’ focus while completing the choice task. They compared the utility parameters and Goodness-of-Fit indicators of MIXL and GMNL and found that not including a respondent’s attention change in model estimation can produce biased WTP measures as it is not included in the scale parameter (Hildebrand et al., 2019). Therefore, behavioural considerations such as certainty and focus during the CE selection process should play a role in CE design (Beck, Rose & Henscher, 2013), for example through avoiding complex choice sets by reducing the amount of alternatives and attributes included in any choice cards.

The models accounting for scale heterogeneity are now established in the field of discrete choice analysis and have been applied to numerous studies. The application of the models ranges from estimating consumer preferences in the selection of air travel (Hossain, Saqib, & Haq, 2018) to consumers’ WTP for rice quality attributes (Nguyen, Van Loo, Rutsaert, Tuan & Verbeke, 2017). These studies identified that both scale and preference heterogeneity have an impact and it is therefore important to
account for both scale and preference heterogeneity to avoid bias (Hossain et al., 2018).

**Criticism on Models Accounting for Scale Heterogeneity**

The hybrid model received criticism, as it proved difficult for the GMXL model to correctly distinguish scale heterogeneity from other sources of heterogeneity. Rose, Beck & Hensher (2015) identified this when they expanded their research on the relationship between choice certainty and scale heterogeneity by conducting a joint analysis. They added two indexes to their CE design after each choice task; a certainty index, where respondents indicated how certain they were of their selection; and an acceptability index, where respondents indicated whether they considered every attribute level on the choice card an acceptable option. The analysis separately estimated choice and certainty jointly; and choice and acceptability jointly. They found that a proportion of the heterogeneity identified by the GMXL as preference heterogeneity is a result of respondents’ uncertainty in completing the choice task and should, therefore, be identified as scale heterogeneity. Similarly, the inclusion of unacceptable choice alternatives in the choice cards while forcing the respondent to select one of the alternatives, leads to including this variation in preference heterogeneity while it should be captured by the scale heterogeneity parameter. This stresses the importance of including a status-quo (or opt-out) option in the CE design to diminish this effect.

However, literature around this topic is inconsistent, as Greene & Henscher (2010) have interpreted the model as identifying scale and taste heterogeneity separately. However, Fiebig et al. (2010) stated that the GMXL merely facilitates a more flexible distribution. Hess & Rose (2012) used CE data of binary route choices as an empirical example to demonstrate that efforts to disentangle scale and preference heterogeneity are misguided, as they ignore the confounding of scale and taste sensitivity (Scarpa, Thiene & Train, 2008). Hess & Rose (2012) concluded that both scale and preference can be captured by the model, but they cannot be estimated separately, leaving the analyst uncertain in what true proportion of scale heterogeneity is expressed in the scale parameter.

Further research into the sources of correlation among utility coefficients in models taking into account heterogeneity issues confirmed this model limitation. Particularly Hess & Train (2017) critique the interpretation of models including scale
heterogeneity. The mixed logit allows for correlation, so the GMNL, being a form of the mixed logit, can account for scale heterogeneity through allowing for correlation. However, GMNL does not separate scale heterogeneity from other sources of correlation. The scale heterogeneity parameter can therefore also include other sources of correlation. Analysts should be aware that not all sources of correlation or heterogeneity should necessarily be represented in the model. Hess & Train (2017) advocate for the use of a mixed logit with full correlation instead, modelled in WTP-space, with a restricted covariance term with special consideration to the fact that the interpretation of the scale parameter may not reflect pure scale heterogeneity (Hess & Train, 2017).

A common approach in the application of models accounting for scale heterogeneity is to assess the model based on Goodness-of-Fit indicators (Christie & Gibbons, 2011; Keane & Wasi, 2012). However, improvements in model fit may be attributed to econometric differences rather than an increase in the models’ representation of the variation in the data, particularly when scale and preference estimates can be confounded (Beck, Rose & Henscher, 2013).

**Justification of CE Design and Modelling Approach**

This research uses CE data on consumer preferences for sustainable aquaculture production to model WTP estimates and address how WTP estimates are dependent on the inclusion of preference and scale heterogeneity in discrete choice analysis. Academic literature has influenced the CE design and modelling approach taken in this study.

First, the most significant element to be taken into account in the research design is the potential confounding of the scale and preference heterogeneity parameters (Beck et al., 2013; Hess & Train, 2017). Literature suggests that it is not possible to identify preference and scale heterogeneity separately when heterogeneity is random (Hess & Rose, 2012). Instead, scholars suggest applying a mixed logit with full correlation with a restricted covariance term and modelling welfare estimates in WTP-space to address confounding random scale effects (Hess & Train, 2017; Scarpa et al., 2008).

However, this approach has not been used in this dissertation. Instead, the models selected were the CL and RPL (chapter 3), the RPL and LC model (chapter 4) and the RPL, SML and GMXL (chapter 5). Marginal welfare changes were estimated in
preference space. This was decided to keep methodology consistent across chapters to allow for comparison of the model performance and welfare estimates. Additionally, calculating WTP in WTP-space aims to reduce exceedingly large WTP estimations to bias overall estimation (Scarpa et al., 2008), whereas no outliers in WTP values were estimated in the CE data.

Second, the performance of the models was assessed using Goodness-of-Fit indicators. Although this is in line with methods used in other studies (Christie & Gibbons, 2011; Keane & Wasi, 2012), this method has been criticised as improvements in model fit may be attributed to econometric differences rather than the models performance, particularly in cases of confounding scale and preference heterogeneity parameters (Beck, Rose & Henscher, 2013). Therefore, in this study multiple Goodness-of-Fit indicators were utilised simultaneous, consisting of AIC, BIC, Hannan-Quin and Log-Likelihood statistics. Additionally, the RPL, SML and GMXL were estimated comparatively due to the inclusion of different parameters accounting sources of heterogeneity in the models, which could assist in identifying confounding heterogeneity parameters.

Apart from modelling choices, the degree of scale heterogeneity is also influenced by CE design. The complexity of the choice task can lead to less determined selection by respondents, and therefore increase scale heterogeneity. Complexity is positively related to the number of attributes and the range of attribute levels per alternative and the number of alternatives in any given choice card (Beck et al., 2013). Another behavioural element that can impact respondents' selection of alternatives during the CE is the acceptability of the alternatives included. If a respondent is forced to choose among options they find unacceptable, the utility expressed in their choices becomes more erratic and can contribute to heterogeneity (Rose, Beck & Hensher, 2015). Therefore, the CE design specified choice cards that minimised complexity and allowed respondents to opt-out of any trade off presented to them in the choice card. With regard to complexity, choice cards were composed of three alternatives, which each consisted of three attributes. In addition, the attributes were indicated by visual indicators (eco-labels and price tags) rather than text to simplify the processing of information in the decision-making process.

The next chapter will assess the Irish publics' WTP for more sustainably produced salmon, where the increase in sustainability is a result of a shift from monoculture
to IMTA production process and the public is informed of the production process through a rated eco-label. In this study, the eco-label is tested as a tool to inform and educate consumers and assist in differentiating finfish produced in an IMTA system from monoculture finfish. The design of the eco-label will be described more detailed in the following chapters and its effectiveness is assessed in the discussion section.
Chapter 3

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

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 eco-label 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.

3.1 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 (Naylor et al., 2000). Other environmental impacts consist of the intensive use of drugs and chemicals (Cabello, 2006), the spreading of diseases and parasites (Frazer, 2007), emissions of organic waste (Talbot & Hole, 1994), escapees (Pillay, 2004) and the intrusion of nets and sound into the natural environment (McCarty, 2004). 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) (Tacon & Metian, 2008); 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 (Tveteras, 2002). Environmental safeguards include regulatory, control and monitoring procedures such as in place at the European and national level (Read and Fernandes, 2003). 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 (McMahon, 2000; Wilson, Magill & Black, 2009). 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 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 (Chopin, Cooper, Reid, Cross & Moore, 2012; Jeffery et al., 2014). 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 (Chopin, 2006). 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 (Barrington et al., 2009). Additionally, higher profits may be made if production costs are lower through nutrient cycling (Chopin et al., 2012) or if consumers are willing to pay a price premium for aquaculture products.
Chapter 3

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 (Shuve et al., 2009). 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 (2006), in the US West coast by Yip et al. (2016) and in Canada by Barrington et al. (2009). 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 (Martínez-Espiñeira et al., 2015). 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 eco-labels have been found to be preferred by consumers (Brécard et al., 2012; Bronnmann & Asche, 2016b; Jaffry et al., 2004; Uchida et al., 2014), but research on preferences for aquaculture eco-labels is limited to Roheim, Sudhakaran and Durham (2012) and Yip et al. (2016). Aquaculture products are viewed distinctly different from wild-caught products, where wild-caught is generally preferred over farmed produce (Roheim et al., 2012). Yet within the aquaculture market, consumers prefer Closed Containment (CC) and IMTA systems over monoculture production, with strongest preferences expressed for IMTA (Yip et al., 2016).

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 3.2 and the survey containing the CE is then outlined in section 3.3. The Irish publics’ attitudes
and WTP are reported in section 3.4 while section 3.5 draws conclusions and sets out policy recommendations.

3.2 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 (Hoyos, 2010; Louviere & Henscher, 1982; Louviere & Woodworth, 1983). This approach is consistent with other applied literature in seafood valuation, such as Yip et al. (2016), Jaffry et al., (2004), Uchida et al., (2014), Roheim et al., (2012), Brécard et al., (2012) and (Johnston, Wessells, Donath, & Asche, 2001). The CE approach is rooted in consumer theory and the concept of utility maximization as described by Lancaster's consumer theory (Lancaster, 1966). According to Lancaster (1966), 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 respondent 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 (Hanley, Wright & Adamowicz, 1998; McFadden, 1973). 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

\[ U_{ij} = V_{ij}(X_{ij}) + e_{ij} = \beta_{ij} \]  

where \( V_{ij} \) is typically specified as being a linear index of \( X_{ij} \) and \( \beta_{ij} \) reflects the utility associated with that attribute (Andreoni, 1990). 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 \( \beta_{ij} \) 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

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

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 (Hensher, Rose and Greene, 2005). 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 (\( \beta \)). This implicit price reflects the respondents’ WTP for a relative change in the attribute, given the changes in the other attributes (Hynes, Tinch and Hanley, 2013). Implicit values for a product attribute \( x \) are derived by:

\[ WTP_x = -\frac{\beta x}{\hat{p}_m} \]  

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 (Andropoulos, Damingos, Comiti & Fischer, 2015; Pek & Jamal, 2011). The marginal WTP for the different attributes in our model (the implicit prices) and the welfare impact from a move from \( x^0 \) to \( x^1 \) (where \( x^0 \) 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, 1984):

\[
CS = -\frac{1}{\beta_m} \ln[\sum \exp(\beta x^1)] - \ln[\sum \exp(\beta x^0)] \tag{4}
\]

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

\[
CS = \int \left[ -\frac{1}{\beta_m} \ln[\sum \exp(\beta' x^1_\beta)] - \ln[\sum \exp(\beta' x^0_\beta)] \right] f(\beta) d(\beta) \tag{5}
\]

This integral is also approximated by simulation from draws of the estimated distributions for the random parameters in our chosen model (Pek & Jamal, 2011). 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.

### 3.3 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 appendix B, before moving to the choice experiment. In the survey, respondents were introduced
to the term ‘eco-label’ and explained that “[eco-labels]… show consumers that a product fulfils certain sustainability criteria. The idea behind using eco-labels on fish products is that people can choose 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 eco-labels. 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.

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

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 appendix C. 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 (Chambers, Lobb, Butler, Harvey & Bruce-Traill, 2007; Jaffry et al., 2004; Salladarré, Guillotretou, Perraudeau & Monfort, 2010) and in some cases this preference is found to be stronger than for organic attributes (Yue & Tong, 2009). 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 (Whitmarsh & Wattage, 2006; Yip et al., 2016) and for eco-labels reflecting sustainability (Asche, Larsen, Smith, Sogn-Grundvåg & Young, 2015; Sogn-Grundvåg, Larsen and Young, 2013; Uchida et al., 2014) 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 eco-label was designed that resembles the EU energy rating label (EU, 2010), which is common on the Irish market and therefore familiar to Irish respondents. The example choice card in appendix C shows that the eco-label consists 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.

The eco-label 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 eco-labels 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 (Roheim et al., 2012). This label is therefore simplified to values ranging from A-D. This is comparable to the effect of IMTA as described by Martínez-Espiñeira et al. (2015). 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.

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 (Carlsson, Frykblom & Lagerkvist, 2005b; Cummings & Taylor, 1999). Respondents were also given information in relation to the choice attributes. On the eco-label 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 eco-label and given a definition of the sustainability ratings.

Table 2 Summary statistics of sample

<table>
<thead>
<tr>
<th>N = 500</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographic variables</strong></td>
<td>Mean</td>
</tr>
<tr>
<td>Male (proportion)</td>
<td>0.44</td>
</tr>
<tr>
<td>Age</td>
<td>42.2</td>
</tr>
<tr>
<td>Married/partner (proportion)</td>
<td>0.64</td>
</tr>
<tr>
<td>3rd level education (proportion)</td>
<td>0.45</td>
</tr>
<tr>
<td>Self-stated ‘income below average’ (proportion)</td>
<td>0.68</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Attitudinal variables</strong></th>
<th>Mean</th>
<th>Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overfishing recognition (proportion)</td>
<td>0.92</td>
<td>0.27</td>
</tr>
<tr>
<td>Have you ever heard of the term integrated aquaculture (proportion)</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Economic benefits from aquaculture (Likert scale 1-5)</td>
<td>4.26</td>
<td>0.87</td>
</tr>
<tr>
<td>Impact from aquaculture (Likert scale 1-5)</td>
<td>3.89</td>
<td>0.94</td>
</tr>
<tr>
<td>Believe IMTA has economic potential (proportion)</td>
<td>0.86</td>
<td>0.34</td>
</tr>
<tr>
<td>Believe IMTA has environmental potential (proportion)</td>
<td>0.8</td>
<td>0.4</td>
</tr>
<tr>
<td>Respondent uses eco-labels (proportion)</td>
<td>0.58</td>
<td>0.49</td>
</tr>
</tbody>
</table>

1 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?”

2 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

3 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

4 When you are buying seafood, do you look at eco-labels to decide which product you want to buy?

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 (Johnston et al., 2001; Roheim et al., 2012), attitudinal variables were excluded from the model. Approaches for including latent variables into discrete choice models are criticized as they can lead to inconsistent and biased estimators and can be misleading (Ashok, Dillon & Yuan, 2002; Terza, 1987). 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 appendix C. An efficient Bayesian experimental design based on the minimisation of the Db error criterion was used to vary attributes and levels (Louviere, Henscher & Swait, 2000). D-efficiency is one of the most common approaches for measuring the efficiency of experimental designs used in the literature (Ferrini & Scarpa, 2007).

3.4 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 (Census of Ireland, 2011). 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 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, much

---

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 (Ashok, Dillon and Yuan, 2002; Terza, 1987).
### Table 3
Results of Conditional Logit and Random Parameter Logit Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Conditional Logit Coefficients</th>
<th>Random Parameter Logit Coefficients</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficients</td>
<td>Coefficients</td>
<td></td>
</tr>
<tr>
<td><strong>Random parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustainability C</td>
<td>0.27***</td>
<td>0.42***</td>
<td>0.30***</td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td>(0.28)</td>
<td>(0.24)</td>
</tr>
<tr>
<td>Sustainability B</td>
<td>0.58***</td>
<td>0.88***</td>
<td>0.64***</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.15)</td>
<td>(0.12)</td>
</tr>
<tr>
<td>Sustainability A</td>
<td>1.34***</td>
<td>2.24***</td>
<td>2.29***</td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td>(0.10)</td>
<td>(0.09)</td>
</tr>
<tr>
<td>Irish Produced</td>
<td>1.10***</td>
<td>1.53***</td>
<td>1.97***</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.12)</td>
<td>(0.12)</td>
</tr>
<tr>
<td><strong>Nonrandom parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td>-0.17***</td>
<td>-0.24***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.01)</td>
<td></td>
</tr>
<tr>
<td>ASC</td>
<td>-2.96***</td>
<td>-3.95***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.21)</td>
<td>(0.27)</td>
<td></td>
</tr>
<tr>
<td><strong>Interactions with Status Quo Alternative</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>-0.29***</td>
<td>-0.43***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td>(0.12)</td>
<td></td>
</tr>
<tr>
<td>3rd Level Education</td>
<td>-0.02</td>
<td>-0.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td>(0.12)</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.02***</td>
<td>0.03***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.01)</td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>-0.26***</td>
<td>-0.29**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td>(0.12)</td>
<td></td>
</tr>
<tr>
<td>Income below Average</td>
<td>-0.52***</td>
<td>-0.58***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td>(0.12)</td>
<td></td>
</tr>
<tr>
<td><strong>Information criteria</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>-3545</td>
<td>-3199</td>
<td></td>
</tr>
<tr>
<td>AIC</td>
<td>7112</td>
<td>6427</td>
<td></td>
</tr>
<tr>
<td>BIC</td>
<td>7193</td>
<td>6538</td>
<td></td>
</tr>
</tbody>
</table>

*Notes: values in parenthesis indicate the standard errors.

***, ** indicates significance at p < 0.01, p < 0.05

1 Sustainability attributes were included in the model as natural log; 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 (Carlsson et al., 2005).
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.

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 (Hynes et al., 2008) 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 Chi2 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 \( \beta x / \beta m \), where \( \beta x \) is the attribute coefficient and \( \beta m \) 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.

Table 4  Mean and confidence interval of marginal WTP per attribute across the Conditional Logit and Random Parameter Logit

<table>
<thead>
<tr>
<th>Variable</th>
<th>Conditional Logit</th>
<th>Random Parameter Logit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean WTP</td>
<td>95% CI</td>
</tr>
<tr>
<td>Sustainability C</td>
<td>€ 1.59</td>
<td>€ 0.73</td>
</tr>
<tr>
<td>Sustainability B</td>
<td>€ 3.45</td>
<td>€ 2.49</td>
</tr>
<tr>
<td>Sustainability A</td>
<td>€ 7.91</td>
<td>€ 7.08</td>
</tr>
<tr>
<td>Location</td>
<td>€ 6.53</td>
<td>€ 5.86</td>
</tr>
</tbody>
</table>

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

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.
Chapter 3

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 eco-label).

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

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

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

3.5 Discussion & 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 eco-labels on a regular basis to select their salmon. Low eco-label use rates were paired with low recognition rates for the main eco-labels on the seafood market. This may relate to the fact that the scarce uptake of marine eco-labels 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 (Bush, Toonen, Oosterveer & Mol, 2013; Karl & Orwat, 1999).

Indeed, potential may exist for the development of an eco-label 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 eco-labels, the proposed label has several advantages. A common criticism of eco-labelling concerns the pass-fail mentality (Lavallee & Plouffe, 2004), 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 supra-national 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 (Abreu et al., 2009). 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 (Diana et al., 2013; Troell et al., 2009), 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 eco-labels across countries (Johnston et al., 2001b), 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.
Chapter 4

Estimating the Public’s Preferences for Sustainable Aquaculture: A Country Comparison

Integrated Multi-Trophic Aquaculture (IMTA) is an alternative to the monoculture of fin fish species, in which several species are combined in the production process. This can have environmental advantages such as a lower environmental impact through nutrient cycling and natural filters; and can have economic advantages consisting of increased efficiency, product diversification and potential price premiums. In this paper, a choice experiment (CE) was conducted through an online survey in Ireland, the UK, Italy, Israel and Norway, to assess how the public makes decisions on what type of salmon or sea bream to buy based on the attributes of the product. Analysis assessed the Willingness-to-Pay (WTP) for more sustainable produced seafood using a Latent Class multinomial logit modelling approach. In the experiment, an eco-label was used to distinguish between regularly produced (monoculture) products and sustainably produced (IMTA) products. The general public in each country showed a positive attitude towards the development of such an eco-label and towards the payment of a price premium for the more sustainably produced salmon or sea bream.

4.1 Introduction

Seafood production is increasingly challenged in the context of human population growth, increasing global per capita seafood demand and diminishing wild fish stocks (FAO, 2014; Jacquet & Pauly, 2007; Pauly et al., 2002). Aquaculture is viewed by many as an alternative to wild fisheries and in recent years the aquaculture industry has shown considerable growth. However, in 2014 the annual European aquaculture industry increased by 0.5 percent against a growth of 7 percent globally (Lane et al., 2014). Due to the international character of the seafood market, the EU is currently looking into the marketing of the seafood industry at the transnational level through educating the public and stimulating producers to shift towards sustainable production methods. One of the proposed strategies is the use of an eco-label for seafood products that indicates the degree of sustainability of the production of the
seafood product (European Union, 2013).

Integrated Multi-Trophic Aquaculture (IMTA) has also been proposed by academics and policy and industry actors to reach the dual aim of economic growth and environmental sustainability (Chopin et al., 2001; Department of Agriculture Food and the Marine, 2015; Jeffery et al., 2014). Multiple experiments have been conducted with IMTA; in the Far East, aquatic species have traditionally been co-cultured for centuries and in recent years IMTA has been implemented experimentally in modern industrial forms in Canada (Chopin & Robinson, 2006), Israel (Chopin et al., 2008) and the Netherlands (Groenendijk et al., 2016). However, despite this call for IMTA integration in the European industry, IMTA has not been adopted on an industrial scale. In an IMTA system, multiple species from different trophic levels are combined in the production process. The species are selected based on their function in the ecosystem and economic value. Combining them has the advantage of allowing for nutrient cycling in the production process. On the one hand, this allows for environmental benefits, as the added species extract organic and inorganic wastes that would otherwise be discarded from the fed finfish cages (Abreu et al., 2011; Hayashi et al., 2008; Neori et al., 2004; Ridler et al., 2007). Additionally, bivalves consume sea lice copepods (Bartsch et al., 2013), the main parasitic infection contributed to intensive salmon farming (Costelloe, 2009). The inclusion of bivalves in an aquaculture production system could contribute to the mitigation of such parasites thereby limiting the environmental impact of the farm. On the other hand, IMTA has potential economic benefits, as nutrient cycling may reduce feed costs per unit biomass. Some research results suggest that IMTA systems may have higher growth rates for the lower trophic species (Ridler et al., 2007).

In addition, products from an IMTA system can produce higher profits than monoculture products as the public may have willingness-to-pay (WTP) for products from an IMTA farm as opposed to a monoculture farm. Research has indicated that the public indeed values an IMTA approach to fish farming (Barrington et al., 2009; Shuve et al., 2009; Whitmarsh & Wattage, 2006; Yip, Knowler, & Haider, 2012). A small-scale study in New York concluded that IMTA produce outperformed monoculture salmon on the main seafood purchase determinants of product quality, freshness and taste (Shuve et al., 2009). Regarding the public’s preferences for IMTA produce, several studies identified a positive WTP for salmon produced in an
environmentally friendly manner in Scotland (Whitmarsh & Wattage, 2006), the US Pacific Northwest (Yip et al., 2012) and Canada (Barrington et al., 2009). Higher marginal WTP should translate to additional revenue, which could function to cover potentially additional costs to IMTA production practices, particularly in the short run, as opposed to monoculture production (Abreu et al., 2011; Ridler et al., 2007; Troell et al., 2009).

However, an essential element in the valuation of IMTA products is the public’s ability to distinguish between monoculture and IMTA products (Martínez-Espiñeira et al., 2015; Shuve et al., 2009). Both industry and non-industry actors have proposed eco-labelling to create bottom up pressure to reform production systems to prevent the over-exploitation of natural stocks (Johnston et al., 2001b). Eco-labelling is an increasingly used tool that can change purchasing behaviour by educating the public on the environmental impact of purchasing decisions. Eco-labelled seafood has been found to be preferred over unlabelled seafood in several studies (Brécard et al., 2012; Bronnmann & Asche, 2016; Jaffry et al., 2004; Johnston et al., 2001; Roheim et al., 2011; Salladarré et al., 2010; Uchida et al., 2014; Wessells et al., 1999). Despite aquaculture products being perceived distinctly different from wild-caught products (Roheim et al., 2011), according to our knowledge, research on preferences specifically for aquaculture eco-labels is limited to Roheim et al. (2011) and Yip et al., (2012). Individuals prefer wild products over farmed products, even when these farmed products are certified (Roheim et al., 2011). Yet within the aquaculture market, products produced in CC (Closed Containment) and IMTA systems are preferred over monoculture production, with strongest preferences expressed for IMTA (Yip et al., 2012). Further research on public preferences for aquaculture labelling and production methods is essential if environmental labelling is to be used as a tool to internalize any external costs from the aquaculture industry.

In this paper, we explore the market potential of IMTA across five countries, Ireland, UK, Norway, Italy and Israel, by estimating the public’s preferences for the products of sustainable aquaculture. Specifically, we answer the question: is the public willing to pay a price premium for fish cultured sustainably in European and Israeli farms? If so, then part of the European marketing strategy (European Union, 2013) should include the promotion of the sustainability and production location attributes. In this study, preferences are elicited using a choice experiment (CE) that asked respondents
from the five countries to choose from among fish with different levels of sustainability, different locations of production and different prices. The WTP for the sustainability and location attributes was estimated based on the choices. The CE approach was taken due to its capacity to capture diversity among the countries and to enable a cross-country comparison. This adds to the current dearth of multinational research on preferences for IMTA.

Current aquaculture growth is taking place in a context of rising awareness and public concern over food production, specifically on issues such as food safety, food quality, health impacts, environmental sustainability and animal welfare (Aarset et al., 2004). Against this background, several seafood consumer awareness eco-labels have been developed such as the Earth Island Institute’s Dolphin Safe label and Marine Stewardship Council (MSC) labels. Eco-labels consist of a physical label on a product, indicating that it fulfils the criteria defined for sustainable production, thus communicating the environmental effect of production of the good (Jacquet & Pauly, 2007). This differentiates eco-labelled seafood products from unlabelled products, with the aim of stimulating environmentally friendly purchasing behaviour in order to increase demand for certified products, hence decreasing the environmental impact of the fast-growing industry (Roheim, 2008).

The economic impact of eco-labelling is influenced by several factors. First, it depends on the degree of one’s altruism (Andreoni, 1990). Individuals weigh their utility for attributes related to self-interest, such as health, to their utility for attributes outside of their individual interest, such as sustainability (Brécard et al., 2012). Second, WTP is influenced by an individuals’ income. As individuals with a high income have a lower marginal utility for income (Tirole, 1988), their price sensitivity will be low and their WTP will be higher (Brécard et al., 2012). This implies that in the creation of the model and interpretation of model results, the income level of respondents must be taken into consideration to account for the difference in price sensitivity. Third, information plays a role in the value individuals attribute to a sustainability eco-label. Individuals are more likely to use eco-labelled products when they have a higher degree of environmental awareness, are concerned about the environment and feel a responsibility towards contributing to its maintenance (Ek & Söderholm, 2008). Lastly, one’s WTP for a seafood product with a sustainability eco-label is influenced by the perception of the product. Individuals will weight a product with their preferred level
of sustainability against other products and attributes such as quality and value for money (Brécard et al., 2009). This has been accounted for in the experiment design deployed in this paper by including an opt-out option in every choice card.

4.2 Materials and Methods

Sample, Questionnaire and Data

Data was retrieved by ICM Research, an independent survey firm in the UK, who distributed the survey online among a population of randomly selected contracted clients. After selection, this sample was stratified according to the proportions of age, sex and region in each country, to ensure a representative sample. A sample of 2520 surveys was collected from five countries; Ireland (n = 500), Israel (n = 500), Italy (n = 508), Norway (n = 501) and the United Kingdom (n = 511). The countries were selected based on their geographical location and the characteristics of their aquaculture industries, aiming to include countries with both Atlantic and Mediterranean production sites. In the Atlantic area, the countries selected were Ireland, the UK and Norway. Ireland and the UK were selected as aquaculture production countries, with Ireland being characterized by its focus on the niche market of organic salmon aquaculture. Norway is included as European but non-EU member state that is characterized by its intensive large-scale salmon production. Outside of the Atlantic area, Italy and Israel were chosen as key sea bream farming countries operating in the Mediterranean area.

Respondents to the survey were all in the market as potential fish consumers. The choice experiment was part of a broader survey. Respondents were first told what the survey was about and given background information on what IMTA was and how it operated. It is recognized that providing respondents information about IMTA before the choice experiment can alter the expressed preferences. However, considering the lack of familiarity of respondents with IMTA, the CE could not be conducted without a basic understanding of the production method to allow a well-informed decision for every choice card presented. The survey consisted of four parts. The first part asked respondents about their perception of the aquaculture industry and marine environmental problems, followed by a section on seafood consuming behaviour, focusing on respondents’ use of eco-labels to make informed purchasing decisions. In the third part, respondents were presented with the choice experiment. In the final
part respondents were asked about their socio-demographic indicators.

*The Choice Experiment Methodology*

The choice experiment (CE) method is a stated preference approach widely used to estimate the public’s preferences and willingness to pay (WTP) for changes in environmental quality or new products. Choice experiments consist of a set of choice cards, each containing a set of alternatives from which respondents select their most preferred alternative. Each alternative consists of a combination of attributes that vary on attribute levels. In making their choices, respondents have to weigh the utility they derive from the different combination of attribute levels presented in each alternative. The assumption underlying this method is that respondents make fully rational decisions and therefore maximise their utility in every choice (Nick Hanley et al., 1998).

Choice cards often include two elements that assist the modelling process. A baseline alternative that reflects the status quo is often included in the choice cards. The inclusion of this alternative is necessary to mimic actual purchasing decisions when a new product enters the market; a consumer can choose to opt-out of a purchase altogether. This allows the statistical models to generate more welfare-consistent estimates (Holmes & Adamowicz, 2000). The choice alternatives also include a monetary attribute. This allows the elicitation of an implicit price for each parameter, which reflects the respondents’ WTP for a relative change in the attribute, given the changes in the other attributes (Hynes et al., 2013). The status quo alternative is always associated with a zero prize as no product is purchased in that decision. The aim of the choice experiment is to derive marginal values for attribute levels from the respondents’ choices.

The choice experiment in this paper was designed to assess the public’s marginal WTP for the attributes associated with IMTA products. In the choice experiment, respondents were presented with eight choice cards each, with each choice card consisting of three alternatives; two purchasing options and one opt-out option (no purchase). An example of a choice card for Ireland is given in appendix C. The purchasing options were presented as a fillet of salmon for the Northern Atlantic countries and Sea Bream for the Mediterranean countries, as those are the main farmed species in each region. Respondents were first asked to “imagine that you walk
into a supermarket and fresh (unfrozen) salmon [sea bream] is on your shopping list. The supermarket has several types of salmon [sea bream]. The packs are identical in size and quality, but some salmon [sea bream] is produced locally, some is produced abroad, and some is produced in a way that is better for the environment. They also vary in price. You are asked to indicate which of the salmon [sea bream] presented you would buy”.

Respondents were then told what attributes they would have information on in the choice situation and to consider what they could afford to pay given their groceries budget. The attributes and attribute levels are described in Table 6. A pilot study conducted to determine the main attributes to present for seafood products found that a production location indicator was important in several sample countries. Literature suggests that consumers prefer locally produced food over imported produce (Chambers et al., 2007; Weatherell, Tregear & Allinson, 2003) and that consumers’

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Attribute Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>National waters</td>
<td>The product is farmed in national waters</td>
</tr>
<tr>
<td>Location</td>
<td>Outside of national waters</td>
<td>The product is farmed outside national waters</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Sustainability Level A</td>
<td>A 30% increase in environmental sustainability due to a move towards an IMTA production system</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Sustainability Level B</td>
<td>A 20% increase in environmental sustainability due to a move towards an IMTA production system</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Sustainability Level C</td>
<td>A 10% increase in environmental sustainability due to a move towards an IMTA production system</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Sustainability Level D</td>
<td>Monoculture production</td>
</tr>
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<td>Ireland</td>
<td>€11</td>
<td>Low price in national market</td>
</tr>
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<td></td>
<td>€9.08</td>
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</tr>
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</tr>
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<td></td>
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</tr>
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<td>Israel</td>
<td>€17.50</td>
<td>Average price in national market</td>
</tr>
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<td>Italy</td>
<td>€14.42</td>
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<td>Norway</td>
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<td>€18.14</td>
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<td>UK</td>
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<td>High price in national market</td>
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<td></td>
<td>€14.32</td>
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<td>Price per kg</td>
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<td></td>
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<td>Status quo alternative price</td>
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<td>Alternative</td>
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<td></td>
</tr>
<tr>
<td>Price</td>
<td>€0</td>
<td></td>
</tr>
<tr>
<td>Alternative</td>
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<td></td>
</tr>
</tbody>
</table>
WTP for sustainability is partially influenced by attitudes towards other labels present in the market (Adberrazak & Youssef, 2009). The experiment therefore includes production location as an attribute.

The sustainability attribute reflects the change in environmental pressure due to a change to an IMTA production system. Research has indicated that consumers have a WTP for sustainability in seafood, suggesting that production method should be included in the CE design (Roheim et al., 2011). Previous studies estimating WTP for specific production methods included an eco-label reflecting the production system (Yip et al., 2012). However, we decided against this approach for two reasons. First, the change in environmental pressure due to a shift to an IMTA production system can vary greatly, depending on species selection and the amount of the extractive species added to the production process, but also on environmental conditions, such as strength and direction of water currents (Barrington et al., 2009; Troell et al., 2009). A singular eco-label would not confer such variations to individuals and therefore not inform individuals on environmental effects. Second, a common critique towards eco-labels is their dichotomous nature, which does not contribute to informing the public on the environmental impact of the product, but rather is limited on a defined set of indicators. Neither does it stimulate producers to continue to develop innovations to decrease environmental pressure once the eco-label has been obtained. Indeed, by providing consumers with imperfect information, eco-labels can stimulate greenwashing (Brécard et al., 2012). Therefore, the inclusion of an IMTA label was not considered a fitting method to confer information to the public. Rather, a rating eco-label was used.

A rated eco-label approach was also used by Martínez-Espiñeira et al. (2015) who estimated WTP for sustainability in food production processes and suggested by Aarset et al. (2004) as a more viable approach to create bottom-up market incentives to shift to more sustainable production methods. In line with Martínez-Espiñeira et al. (2015), the label design rates the environmental impact of the more sustainable production systems relative to conventional monoculture farms. The label design was based on the EU energy rating label (European Union, 2010). This label is common on the European market for electronic appliances to indicate the amount of energy necessary to run an appliance in comparison to the product group. Several EU countries are using such environmental rating labels to inform consumer choices. The
label used in the CE presents four levels of sustainability, ranging from A–D. The D label reflects the status-quo, or the environmental pressure resulting from monoculture production techniques. Respondents were informed 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 best and D being worst for the environment. The labels show how much the environmental pressure of producing the salmon in the package has decreased from what we currently consider normal aquaculture (monoculture). Every level has a step of a 10% improvement in environmental sustainability.” The labels A therefore being equivalent to a 30% decrease in environmental pressure. This information was shown on the labels to the respondents prior to the choice experiment.

Lastly, a monetary attribute was included in the CE to reflect a market situation and to enable the statistical derivation of the public’s WTP for the other attribute levels. The CE price levels are based on the price range found in a survey of supermarket prices in each country. Based on these price ranges, a low, medium and high price were selected for each sample country. Within the model, the medium price level was taken as a base case. After the selection of the attributes and attribute levels, sixteen profiles were blocked into 4 versions of eight choice cards. Each choice card contained two alternatives and one opt-out option. The number of choice cards per respondent was limited to eight to avoid respondent fatigue. Variation in the attribute levels was achieved by using an efficient Bayesian experimental design based on the minimisation of the Db error criterion (Louviere, Henscher, & Swait, 200). D-efficiency is a common approach for measuring experimental design efficiency (Ferrini & Scarpa, 2007). A pilot study (n = 201) indicated that the attribute levels were appropriate as respondents selected the full price range when taking the choice experiment and indicated that they found the price range realistic when interviewed.

**Modelling Approach**

Discrete choice modelling is rooted in the concept of utility maximization. Lancaster, (1966) states that individuals derive utility, not from the consumption of a good, but from the set of attributes embodied by the good. The value of a good is therefore comprised of the bundle of attributes that the good holds. In a choice experiment, the
value of specific attributes is elicited through statistical analysis. The Random Utility Model (RUM), developed by Mc Fadden (McFadden, 1973) forms the basis for the statistical derivation of respondents’ utility from the choice experiment data. The RUM states that the utility an individual derives from the consumption of a good consists of an observable and unobservable component. This can be expressed as

\[ U_{in} = U(Z_{in}, S_n) + \epsilon(Z_{in}, S_n) \]  \[6\]

where \( U_{in} \) reflects the utility of alternative \( i \) as perceived by individual \( n \) in choice set \( C \). Alternative \( i \) will be chosen over alternative \( j \) if \( U_i > U_j \). This utility is comprised of two parts. First, the observable component \( (U) \) consist of the CE attributes \( (Z_{in}) \) and socioeconomic characteristics of the respondents \( (S_n) \), which can be captured by the model. Second, the unobservable component \( (\epsilon_n) \) reflects unmeasured variations that fall outside the influence of the experiment. Utility cannot be estimated precisely due to the existence of the latent unobservable component, but utility measures can be maximised by minimising the error terms. The design of the CE aims to capture as much of the public’s utility derived from the product as possible in the CE attributes, thus minimising the unobservable component. In the modelling process, the error term can be minimized by including information about the respondent and choice context indicators in the model, thereby including the influence of these terms on the choices made into the model.

Multiple econometric techniques to elicit utility from CE data have been developed. The basic discrete choice model is the conditional logit (CL). However, the CL is limited in that it carries the independence from irrelevant alternatives (IIA) assumption and it does not control for unobserved preference heterogeneity, i.e., variations of preferences across the sample. Therefore, other models have been developed, of which the most prominent ones are the random parameter logit (RPL) and the latent class (LC) model. Both models account for preference heterogeneity, albeit in different ways and relax the IIA assumption. The RPL generalizes the CL by allowing the coefficients of observed variables to vary randomly over people rather than being fixed (Henscher & Greene, 2003). In contrast, the LC model assesses the source of preference heterogeneity by identifying underlying latent groups from the data set. Both the RPL and LC models have been created for this study, but this paper presents the results of the LC analysis, as this model gave a better fit with regards to statistical information criteria, as will be elaborated on in the next section.
The LC model specifies that the mixing of preference intensities takes place over a finite group of \( c \) preference classes (Hynes et al., 2013). Members of each class have similar preferences that are not directly observable from the CE data, i.e., they are latent. The parameters of \( u \), expressed as \( \beta \), can be estimated by the LC model while assessing preference heterogeneity sources across classes of respondents. The LC model assumes that preferences vary across the classes based on a non-parametric distribution. Following Greene & Hensher (2002), suppose \( \beta \) takes \( c \) possible values labelled \( \beta_1, \ldots, \beta_c \) with probability \( \text{prob}_c \) reflecting the LC model estimates. The choice probability can be expressed as

\[
\text{Prob}_{ni} = \sum_{c=1}^{C} \frac{\text{prob}_c \times \exp(\beta_C x_{ni})}{\sum_j \exp(\beta_C x_{nj})}
\]

where the expected probability of alternative \( i \) being chosen by any respondent is dependent upon the expected value of the class probability. Class probability, expressed as \( \text{prob}_c \) is estimated in each LC model, along with the parameters of \( u \) (expressed as \( \beta \)).

The number of classes in the model is assessed using information criteria (IC) statistics for each of the models. There is no common accepted IC to determine the correct number of classes (Nylund, Asparouhov, & Muthen, 2007) so several IC are used in combination. In this case we examined the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC) and Hannan Quinn Information Criterion (HQ) statistics. These IC penalise for additional parameters to be included to determine the classes. The LC model has been used repeatedly in environmental economics (Shen & Saijo, 2007; van der Naald & Cameron, 2011) and, more specifically, for consumer preferences in seafood (Mauracher, Tempesta & Vecchiato, 2013; Nguyen, Haider, Solgaard, Ravn-Jonsen & Roth, 2015) and sustainability of seafood production (Brécard et al., 2012; Yip et al., 2012).

The LC model was run for the pooled data set, containing the CE data of all the countries, and for each individual country. The model output is reported for the pooled and individual country level models. The model was additionally run on a subset of the CE data, excluding instances where sea bream was the product specified (Italy and Israel), as one could argue that the consumers’ perceptions of production and preferences can vary across seafood species. As the results were similar in trends,
coefficient strengths and marginal WTP estimates for CE attributes, the results of the full pooled data set including all country data are reported in this paper. (Results of the model, excluding the seabream CE data, are available from the authors upon request).

It should also be noted that there exists a high degree of heterogeneity in international responses towards seafood eco-labels. Several studies reviewed by Brécard et al. (2012) point out numerous factors that determine the public’s WTP. A number of these factors are the influence of culture, socioeconomic status, social norms, customs, political and moral values, institutions, political interests and political awareness (Berglund & Matti, 2006; Frey & Stutzer, 2006; Torgler & Garcia-Valinas, 2007). Country specific dummies have been included in the model specification of the pooled data set to account for the effect of variations of these elements across the states. The comparison of several countries through a CE allows the researcher to assess if sustainability in the aquaculture production process is more valued in certain countries than others.

4.3 Results

Table 7  Summary statistics of choice experiment respondents

<table>
<thead>
<tr>
<th>Demographic Variables</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Min.</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (proportion)</td>
<td>0.46</td>
<td>0.50</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Married/partner (proportion)</td>
<td>0.61</td>
<td>0.49</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Third-level education (proportion)</td>
<td>0.44</td>
<td>0.50</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Age (years)</td>
<td>41.1</td>
<td>12.72</td>
<td>18</td>
<td>65</td>
</tr>
<tr>
<td>Self-stated ‘income below average’ (proportion)</td>
<td>0.50</td>
<td>0.50</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attitudinal variables</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Min.</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you ever heard of the term IMTA? (proportion)</td>
<td>0.14</td>
<td>0.35</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Respondent uses eco-labels (Likert scale 1–4)</td>
<td>1.86</td>
<td>0.92</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

Summary statistics for the entire sample of respondents (2,520) are shown in Table 7. Overall, the sample was comparable to the national proportions in terms of gender, marital status, age and income. Even though 14% of the sample indicated they had heard of IMTA previously, a follow-up question asking for a description of IMTA resulted in no adequate description of IMTA being provided, suggesting that the true proportion of consumers familiar with IMTA is lower. This shows that consumers are not familiar with IMTA, regardless of whether or not IMTA experiments are taking place in the sample country. The majority of respondents indicated use of eco-labels either sometimes, most of the time, or always (1.86 average out of Likert 1–5).

### Table 8 Criteria for number of classes

<table>
<thead>
<tr>
<th></th>
<th>Classes</th>
<th>Log.Lik.</th>
<th>AIC</th>
<th>BIC</th>
<th>HQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pooled</td>
<td>2</td>
<td>−15,821</td>
<td>31,703</td>
<td>31,948</td>
<td>31,783</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>−14,937</td>
<td>29,968</td>
<td>30,340</td>
<td>30,089</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ireland</td>
<td>2</td>
<td>−3058</td>
<td>6162</td>
<td>6307</td>
<td>6213</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>−2882</td>
<td>5834</td>
<td>6054</td>
<td>5912</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Israel</td>
<td>2</td>
<td>−2876</td>
<td>5799</td>
<td>5943</td>
<td>5850</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>−2727</td>
<td>5524</td>
<td>5744</td>
<td>5602</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Italy</td>
<td>2</td>
<td>−3265</td>
<td>6575</td>
<td>6720</td>
<td>6626</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>−3151</td>
<td>6371</td>
<td>6592</td>
<td>6450</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>−2911</td>
<td>5916</td>
<td>6212</td>
<td>6021</td>
</tr>
<tr>
<td>Norway</td>
<td>2</td>
<td>−2933</td>
<td>5911</td>
<td>6056</td>
<td>5963</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>−2840</td>
<td>5750</td>
<td>5970</td>
<td>5828</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>−2598</td>
<td>5290</td>
<td>5586</td>
<td>5395</td>
</tr>
<tr>
<td>UK</td>
<td>2</td>
<td>−3077</td>
<td>6200</td>
<td>6345</td>
<td>6251</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>−2894</td>
<td>5858</td>
<td>6079</td>
<td>5936</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>−2782</td>
<td>5658</td>
<td>5955</td>
<td>5764</td>
</tr>
</tbody>
</table>

Notes: Numbers in bold are maximised criterion for model selection

The choice experiment data was analysed using NLOGIT6 statistical software. The search for the most appropriate specification (in terms of number of classes in model)
consisted of modelling data assuming different numbers of latent classes for the individual country data sets and the pooled data set. The aim of this search was to develop a model that minimises the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC) and Hannan Quinn Information Criterion (HQ) statistics. These statistics are measures of how well the model expresses variation in observed data. In the interpretation of the model results, differences in preferences as expressed by differences in the attribute level parameter across the classes. Statistics of model performance are listed in Table 8. The pooled model and the models for Ireland and Israel failed to converge when specified with 4 classes. Interestingly, all statistics indicated the same class selection for each country, leading to the selection of a latent class (LC) model with three classes for the pooled data, three classes for Ireland and Israel and four classes for Italy, Norway and the UK. It has been shown that the different criteria can indicate different optimum class numbers and the researcher needs to then make a judgement call based on other factors such as variable significance across classes (Hynes et al., 2013).

Cross Country Models

Table 9, Table 10, Table 11 and Table 13 resent the individual country latent class models while the pooled cross country model is presented in Table 14. A set of consumer profiles based on the results of the latent class models are also presented in Table 15. Weighted marginal WTP estimates for the CE model attributes of production location and sustainability levels are presented in Table 16. Finally, an overview of the marginal WTP estimates per class in each of the country specific models and the combined pooled model is given in Appendix D.
Table 9  Model Ireland

<table>
<thead>
<tr>
<th>Ireland (n = 500)</th>
<th>Latent Class 3 Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Choice</strong></td>
<td>Class 1</td>
</tr>
<tr>
<td>Location</td>
<td>1.597 ***</td>
</tr>
<tr>
<td></td>
<td>(0.195)</td>
</tr>
<tr>
<td>Sustainability C</td>
<td>0.774 ***</td>
</tr>
<tr>
<td></td>
<td>(0.225)</td>
</tr>
<tr>
<td>Sustainability B</td>
<td>0.95 ***</td>
</tr>
<tr>
<td></td>
<td>(0.24)</td>
</tr>
<tr>
<td>Sustainability A</td>
<td>1.87 ***</td>
</tr>
<tr>
<td></td>
<td>(0.254)</td>
</tr>
<tr>
<td>Price</td>
<td>−0.467 ***</td>
</tr>
<tr>
<td></td>
<td>(0.042)</td>
</tr>
<tr>
<td>Opt-out Alternative Specific</td>
<td>−11.956 ***</td>
</tr>
<tr>
<td>Constant (ASC)</td>
<td>(2.11)</td>
</tr>
</tbody>
</table>

*Interaction terms with ASC*

| Male             | −0.092 | 1.489 *** | −0.009 |
|                 | (0.767) | (0.425) | (0.15) |
| Third level Education | −0.168 | 0.869 *** | 0.253 * |
|                  | (0.838) | (0.336) | (0.149) |
| Age              | 0.002 | 0.01 | 0.038 *** |
|                  | (0.048) | (0.017) | (0.006) |
| Married          | 0.391 | −0.455 | −0.27 * |
|                  | (0.971) | (0.333) | (0.156) |
| Income           | 0.037 | 0.056 | −0.093 |
|                  | (1.021) | (0.309) | (0.148) |
| Class Probability | 0.393 *** | 0.123 *** | 0.484 *** |
|                  | (0.035) | (0.032) | (0.03) |

*: P <0.1; **: P <0.05; ***: P <0.01
The latent class model output for the Irish data contained three latent classes, where the highest probability assigned was for class 3 (48%), followed by class 1 (39%) and class 2 (12%). The model showed significant positive consumer preference for seafood produced in Irish waters for the first (1.6, \( P < 0.01 \)) and third (1.4, \( P < 0.01 \)) classes. The second class showed a negative preference for the Irish produced attribute, but this coefficient was insignificant. With regard to sustainability in seafood production, Irish respondents showed a positive preference towards products with sustainability label C in class 1 (0.7, \( P < 0.01 \)) and class 2 (0.9, \( P < 0.01 \)), towards label B in class 1 (0.9, \( P < 0.01 \)) and class 2 (0.9, \( P < 0.01 \)) and towards label A in class 1 (1.9, \( P < 0.01 \)), class 2 (1.2, \( P < 0.01 \)) and class 3 (1.8, \( P < 0.01 \)).
### Table 10  Model Israel

**Israel**

*(n = 500)*

<table>
<thead>
<tr>
<th>Choice</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td>1.87 ***</td>
<td>1.114 ***</td>
<td>0.625 ***</td>
</tr>
<tr>
<td></td>
<td>(0.238)</td>
<td>(0.089)</td>
<td>(0.233)</td>
</tr>
<tr>
<td><strong>Sustainability C</strong></td>
<td>0.947 ***</td>
<td>0.494 ***</td>
<td>0.993 **</td>
</tr>
<tr>
<td></td>
<td>(0.257)</td>
<td>(0.112)</td>
<td>(0.39)</td>
</tr>
<tr>
<td><strong>Sustainability B</strong></td>
<td>1.742 ***</td>
<td>1.332 ***</td>
<td>1.252 ***</td>
</tr>
<tr>
<td></td>
<td>(0.333)</td>
<td>(0.134)</td>
<td>(0.415)</td>
</tr>
<tr>
<td><strong>Sustainability A</strong></td>
<td>2.77 ***</td>
<td>2.076 ***</td>
<td>2.824 ***</td>
</tr>
<tr>
<td></td>
<td>(0.362)</td>
<td>(0.132)</td>
<td>(0.39)</td>
</tr>
<tr>
<td><strong>Price</strong></td>
<td>$-5.879$ $**$</td>
<td>$-0.366 *<strong>$ $</strong>$</td>
<td>$-0.407 *<strong>$ $</strong>$</td>
</tr>
<tr>
<td></td>
<td>(0.279)</td>
<td>(0.035)</td>
<td>(0.073)</td>
</tr>
<tr>
<td><strong>Opt-out Alternative Specific Constant</strong></td>
<td>$-5.879$ $*$</td>
<td>$-5.645 *<strong>$ $</strong>$</td>
<td>$-1.622 *$ $**$</td>
</tr>
<tr>
<td>(ASC)</td>
<td>(737)</td>
<td>(0.621)</td>
<td>(0.927)</td>
</tr>
</tbody>
</table>

**Interaction terms with ASC**

<table>
<thead>
<tr>
<th></th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Male</strong></td>
<td>5.931</td>
<td>0.308</td>
<td>$-0.668 **$</td>
</tr>
<tr>
<td></td>
<td>(128.6)</td>
<td>(0.271)</td>
<td>(0.282)</td>
</tr>
<tr>
<td><strong>Third level Education</strong></td>
<td>18.478</td>
<td>$-0.201$</td>
<td>$-0.256$</td>
</tr>
<tr>
<td></td>
<td>(622.73)</td>
<td>(0.259)</td>
<td>(0.291)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>$-3.983$</td>
<td>0.023 **</td>
<td>0.03 ***</td>
</tr>
<tr>
<td></td>
<td>(351.6)</td>
<td>(0.01)</td>
<td>(0.011)</td>
</tr>
<tr>
<td><strong>Married</strong></td>
<td>24.793</td>
<td>$-0.097$</td>
<td>$-0.683 **$</td>
</tr>
<tr>
<td></td>
<td>(120.8)</td>
<td>(0.305)</td>
<td>(0.331)</td>
</tr>
<tr>
<td><strong>Income</strong></td>
<td>21.07</td>
<td>0.186</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>(531.63)</td>
<td>(0.282)</td>
<td>(0.362)</td>
</tr>
<tr>
<td><strong>Class Probability</strong></td>
<td>$0.323 ***$</td>
<td>$0.527 ***$</td>
<td>$0.15 ***$</td>
</tr>
<tr>
<td></td>
<td>(0.023)</td>
<td>(0.048)</td>
<td>(0.019)</td>
</tr>
</tbody>
</table>

*: P <0.1; **: P <0.05; ***: P <0.01
The preferred model for the Israel data contained three classes, where the highest-class probability was for class 2 (53%) and smaller probabilities for class 1 (32%) and class 3 (15%). Respondents from Israel showed a positive preference for nationally produced aquaculture produce in all classes (class 1: 1.89, P < 0.01; class 2: 1.1, P < 0.01; class 3: 0.6, P < 0.01). Across all classes, positive preferences for more sustainable aquaculture production were expressed that increased as sustainability levels increased, from label C (class 1: 0.9, P < 0.01; class 2: 0.5, P < 0.01; class 3: 1, P < 0.01) to B (class 1: 1.7, P < 0.01; class 2: 1.3, P < 0.01; class 3: 1.3, P < 0.01) to A (class 1: 2.8, P < 0.01; class 2: 2.1, P < 0.01; class 3: 2.8, P < 0.01). Israeli respondents expressed negative preferences for the price attribute (class 2: −0.04, P < 0.01; class 3: −0.04, P < 0.01), although this was insignificant for class 1 (−5.9, P > 0.1). With regard to the opt-out option, respondents showed a negative preference towards the opt-out option in class 2 (−5.6, P < 0.01) and class 3 (−1.6, P < 0.05), but this remained insignificant in class 1 (−5.9, P < 0.1). The interaction terms were insignificant in class 1. In class 2, the elderly opted out more (0.02, P < 0.5) and in class 3, respondents that opted out were more likely to be female (−0.7, P < 0.05) and unmarried (−0.7, P < 0.05).
Table 11 Model Italy

<table>
<thead>
<tr>
<th>Choice</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>2.59 ***</td>
<td>3.774 ***</td>
<td>0.77 ***</td>
<td>1.129 ***</td>
</tr>
<tr>
<td></td>
<td>(0.324)</td>
<td>(0.212)</td>
<td>(0.101)</td>
<td>(0.208)</td>
</tr>
<tr>
<td>Sustainability C</td>
<td>0.749 **</td>
<td>0.769 **</td>
<td>1.186 ***</td>
<td>0.481</td>
</tr>
<tr>
<td></td>
<td>(0.321)</td>
<td>(0.342)</td>
<td>(0.166)</td>
<td>(0.432)</td>
</tr>
<tr>
<td>Sustainability B</td>
<td>1.479 ***</td>
<td>0.46</td>
<td>2.537 ***</td>
<td>0.847 **</td>
</tr>
<tr>
<td></td>
<td>(0.386)</td>
<td>(0.292)</td>
<td>(0.166)</td>
<td>(0.352)</td>
</tr>
<tr>
<td>Sustainability A</td>
<td>2.37 ***</td>
<td>0.867 ***</td>
<td>3.83 ***</td>
<td>2.298 ***</td>
</tr>
<tr>
<td></td>
<td>(0.357)</td>
<td>(0.193)</td>
<td>(0.139)</td>
<td>(0.298)</td>
</tr>
<tr>
<td>Price</td>
<td>−1.063 ***</td>
<td>−0.093 **</td>
<td>−0.252 ***</td>
<td>−0.371 ***</td>
</tr>
<tr>
<td></td>
<td>(0.105)</td>
<td>(0.045)</td>
<td>(0.022)</td>
<td>(0.053)</td>
</tr>
<tr>
<td>Opt-out Alternative</td>
<td>−2.958</td>
<td>−0.097</td>
<td>−4.326 ***</td>
<td>−2.518 ***</td>
</tr>
<tr>
<td>Specific Constant</td>
<td>(ASC)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>−2.958</td>
<td>−0.097</td>
<td>−4.326 ***</td>
<td>−2.518 ***</td>
</tr>
<tr>
<td>Interaction terms with ASC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>−0.144</td>
<td>−0.698 ***</td>
<td>0.354 **</td>
<td>0.615 ***</td>
</tr>
<tr>
<td></td>
<td>(0.00001)</td>
<td>(0.26)</td>
<td>(0.167)</td>
<td>(0.154)</td>
</tr>
<tr>
<td>Third-level Education</td>
<td>0.058</td>
<td>−1.316 ***</td>
<td>0.27 *</td>
<td>−0.124</td>
</tr>
<tr>
<td></td>
<td>(0.00001)</td>
<td>(0.309)</td>
<td>(0.159)</td>
<td>(0.157)</td>
</tr>
<tr>
<td>Age</td>
<td>−1.939</td>
<td>0.013</td>
<td>0.057 ***</td>
<td>0.029 ***</td>
</tr>
<tr>
<td></td>
<td>(0.00002)</td>
<td>(0.012)</td>
<td>(0.008)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>Married</td>
<td>0.126</td>
<td>0.477 **</td>
<td>−0.02</td>
<td>0.384 **</td>
</tr>
<tr>
<td></td>
<td>(0.00001)</td>
<td>(0.236)</td>
<td>(0.179)</td>
<td>(0.188)</td>
</tr>
<tr>
<td>Income</td>
<td>−0.55</td>
<td>−0.328</td>
<td>−1.39 ***</td>
<td>−0.538 ***</td>
</tr>
<tr>
<td></td>
<td>(0.0001)</td>
<td>(0.315)</td>
<td>(0.214)</td>
<td>(0.196)</td>
</tr>
<tr>
<td>Class Probability</td>
<td>0.18 ***</td>
<td>0.224 ***</td>
<td>0.448 ***</td>
<td>0.144 ***</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.016)</td>
<td>(0.035)</td>
<td>(0.017)</td>
</tr>
</tbody>
</table>

*: P <0.1; **: P <0.05; ***: P <0.01
The Italian sample was divided into four latent classes, with the probability of class 3 being the largest (45%), followed by class 2 (22%), class 1 (18%) and class 4 (14%). Overall, preferences for the attributes followed similar patterns, although differences exist between the classes in terms of attribute coefficient significance. Italian respondents have a positive preference for aquaculture produced in national waters across all classes (class 1: 2.6, \( P < 0.01 \); class 2: 3.8, \( P < 0.01 \); class 3: 0.8, \( P < 0.01 \); class 4: 1.1, \( P < 0.01 \)). Respondents predominantly show a preference for aquaculture products with higher sustainability labels, although some differences exist. In class 1 and 3, preference is significant and positively related to sustainability across label C (class 1: 0.7, \( P < 0.05 \); class 3: 1.2, \( P < 0.01 \)), label B (class 1: 1.5, \( P < 0.01 \); class 3: 2.5, \( P < 0.01 \)) and label A (class 1: 2.4, \( P < 0.01 \); class 3: 3.8, \( P < 0.01 \)). Although the model produced statistically insignificant results on label C (class 4) and label B (class 2), respondents expressed a positive and significant preference for aquaculture products with the highest sustainability label (A) across all classes. Respondents had a negative preference for products with a higher price across all classes. Preferences were negative for the opt-out option in the choice cards, although these were insignificant in class 1 (−3, \( P > 0.1 \)) and class 2 (−0.1, \( P > 0.1 \)). The interaction terms between demographic groups and the opt-out option were insignificant in most cases. None of the interaction terms were significant in class 1, while in other classes respondents were more likely to opt out when they were male (class 2: −0.7, \( P < 0.01 \); class 3: 0.4, \( P < 0.05 \); class 4: 0.6, \( P < 0.01 \)), educated below third-level education (class 2: −1.3, \( P < 0.01 \)), married (class 2: 0.5, \( P < 0.05 \); class 4: 0.4, \( P < 0.05 \)), over 45 years of age (class 3: 0.06, \( P < 0.01 \); class 4: 0.03, \( P < 0.01 \)) or had an income below the national average (class 3: −1.4, \( P < 0.01 \); class 4: 0.5, \( P < 0.01 \)).
Table 12 Model Norway

<table>
<thead>
<tr>
<th>Norway</th>
<th>Latent Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>(n = 501)</em></td>
<td>4 Classes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Choice</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>1.214 ***</td>
<td>0.044</td>
<td>1.19 ***</td>
<td>3.461 ***</td>
</tr>
<tr>
<td>(0.105)</td>
<td>(0.349)</td>
<td>(0.25)</td>
<td>(0.259)</td>
<td></td>
</tr>
<tr>
<td>Sustainability C</td>
<td>0.398 ***</td>
<td>0.77 *</td>
<td>1.103 **</td>
<td>0.242</td>
</tr>
<tr>
<td>(0.135)</td>
<td>(0.434)</td>
<td>(0.446)</td>
<td>(0.244)</td>
<td></td>
</tr>
<tr>
<td>Sustainability B</td>
<td>1.191 ***</td>
<td>0.002</td>
<td>3.035 ***</td>
<td>0.062</td>
</tr>
<tr>
<td>(0.157)</td>
<td>(0.547)</td>
<td>(0.465)</td>
<td>(0.204)</td>
<td></td>
</tr>
<tr>
<td>Sustainability A</td>
<td>2.001 ***</td>
<td>−0.138</td>
<td>4.442 ***</td>
<td>0.463 **</td>
</tr>
<tr>
<td>0.16437</td>
<td>(0.51)</td>
<td>(0.478)</td>
<td>(0.213)</td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td>−0.886 ***</td>
<td>−1.22 ***</td>
<td>−0.235 ***</td>
<td>−0.187 ***</td>
</tr>
<tr>
<td>0.056</td>
<td>(0.21)</td>
<td>(0.083)</td>
<td>(0.063)</td>
<td></td>
</tr>
<tr>
<td>Opt-out Alternative</td>
<td>−10.832 ***</td>
<td>−0.796</td>
<td>−5.397 ***</td>
<td>−1.367 *</td>
</tr>
<tr>
<td>Specific Constant</td>
<td>1.059</td>
<td>(1.612)</td>
<td>(1.146)</td>
<td>(0.712)</td>
</tr>
<tr>
<td>(ASC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Interaction terms with ASC

<table>
<thead>
<tr>
<th></th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>1.329 **</td>
<td>−0.872 *</td>
<td>0.223</td>
<td>−0.323</td>
</tr>
<tr>
<td>(0.566)</td>
<td>(0.479)</td>
<td>(0.391)</td>
<td>(0.253)</td>
<td></td>
</tr>
<tr>
<td>Third level</td>
<td>0.141</td>
<td>−2.494 ***</td>
<td>0.005</td>
<td>−0.399</td>
</tr>
<tr>
<td>Education</td>
<td>(0.464)</td>
<td>(0.49)</td>
<td>(0.459)</td>
<td>(0.292)</td>
</tr>
<tr>
<td>Age</td>
<td>−0.021</td>
<td>−0.14 ***</td>
<td>0.222 ***</td>
<td>0.002</td>
</tr>
<tr>
<td>(0.018)</td>
<td>(0.023)</td>
<td>(0.02)</td>
<td>(0.009)</td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>0.326</td>
<td>1.46 ***</td>
<td>−2.154 ***</td>
<td>0.05</td>
</tr>
<tr>
<td>(0.480)</td>
<td>(0.454)</td>
<td>(0.474)</td>
<td>(0.261)</td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td>−0.916</td>
<td>−1.411 **</td>
<td>−0.763 *</td>
<td>0.305</td>
</tr>
<tr>
<td>(0.585)</td>
<td>(0.703)</td>
<td>(0.411)</td>
<td>(0.276)</td>
<td></td>
</tr>
<tr>
<td>Class Probability</td>
<td>0.475 ***</td>
<td>0.091 ***</td>
<td>0.167 ***</td>
<td>0.267 ***</td>
</tr>
<tr>
<td>(0.014)</td>
<td>(0.024)</td>
<td>(0.026)</td>
<td>(0.025)</td>
<td></td>
</tr>
</tbody>
</table>

*: P <0.1; **: P <0.05; ***: P <0.01
The preferred model for the Norwegian data divided the respondents up into four latent classes, where class membership was the highest for class 1 (48%), followed by class 4 (27%), class 3 (17%) and class 2 (9%). Considerable preference differences were modelled across the Norwegian classes. National production location was preferred by class 1 (1.2, $P < 0.01$), class 3 (1.2, $P < 0.01$) and class 4 (3.5, $P < 0.01$), but remained insignificant for class 2. Sustainable aquaculture produce was preferred across all sustainability labels in class 1 (label C: 0.4, $P < 0.01$; label B: 1.2, $P < 0.01$; label A: 2, $P < 0.01$) and class 3 (label C: 1.1, $P < 0.05$; label B: 3, $P < 0.01$; label A: 4.4, $P < 0.01$). Preferences for the sustainability of aquaculture production were however insignificant for class 2 and class 4. All latent classes in the Norwegian data had a statistically significant preference for products with lower prices and a negative preference for the opt-out option, with the smallest class (2) being statistically insignificant for the alternative specific constant. With regard to the interactions between demographic variables and the alternative specific constant, Norwegian respondents were more likely to opt-out when male in class 1 (1.3, $P < 0.05$), when not having completed third-level education in class 2 (−2.5, $P < 0.01$), when under the age of 45 in class 2 (−0.1, $P < 0.01$) and over 45 in class 3 (0.2, $P < 0.01$), when married in class 2 (1.5, $P < 0.01$) and unmarried in class 3 (−2.2, $P < 0.01$) and when the respondent’s income is below the national average in class 2 (−1.4, $P < 0.05$).
### Table 13  Model United Kingdom

(n = 510) 

<table>
<thead>
<tr>
<th>Choice</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>1.40 ***</td>
<td>1.479 ***</td>
<td>0.02</td>
<td>0.609 ***</td>
</tr>
<tr>
<td></td>
<td>(0.195)</td>
<td>(0.387)</td>
<td>(0.233)</td>
<td>(0.092)</td>
</tr>
<tr>
<td>Sustainability C</td>
<td>0.935 ***</td>
<td>1.219 *</td>
<td>1.103 ***</td>
<td>0.224</td>
</tr>
<tr>
<td></td>
<td>(0.248)</td>
<td>(0.67)</td>
<td>(0.274)</td>
<td>(0.137)</td>
</tr>
<tr>
<td>Sustainability B</td>
<td>1.638 ***</td>
<td>2.17 ***</td>
<td>1.438 ***</td>
<td>0.905 ***</td>
</tr>
<tr>
<td></td>
<td>(0.326)</td>
<td>(0.798)</td>
<td>(0.375)</td>
<td>(0.162)</td>
</tr>
<tr>
<td>Sustainability A</td>
<td>2.664 ***</td>
<td>3.126 ***</td>
<td>2.227 ***</td>
<td>1.485 ***</td>
</tr>
<tr>
<td></td>
<td>(0.378)</td>
<td>(0.805)</td>
<td>(0.349)</td>
<td>(0.162)</td>
</tr>
<tr>
<td>Price</td>
<td>−1.129 ***</td>
<td>−0.37 ***</td>
<td>−0.972 ***</td>
<td>−0.107 ***</td>
</tr>
<tr>
<td></td>
<td>(0.112)</td>
<td>(0.132)</td>
<td>(0.105)</td>
<td>(0.027)</td>
</tr>
<tr>
<td>Opt-out Alternative</td>
<td>−12.034 ***</td>
<td>−3.074 ***</td>
<td>−0.968</td>
<td>−6.837 ***</td>
</tr>
<tr>
<td>Specific Constant (ASC)</td>
<td>(2.96)</td>
<td>(0.974)</td>
<td>(0.98)</td>
<td>(1.233)</td>
</tr>
</tbody>
</table>

**Interaction terms with ASC**

<table>
<thead>
<tr>
<th>Choice</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>−0.645</td>
<td>1.129 **</td>
<td>0.607 **</td>
<td>0.851 **</td>
</tr>
<tr>
<td></td>
<td>(0.794)</td>
<td>(0.532)</td>
<td>(0.304)</td>
<td>(0.346)</td>
</tr>
<tr>
<td>Third level Education</td>
<td>−0.756</td>
<td>−1.183 ***</td>
<td>−0.208</td>
<td>0.695 **</td>
</tr>
<tr>
<td></td>
<td>(0.604)</td>
<td>(0.427)</td>
<td>(0.393)</td>
<td>(0.305)</td>
</tr>
<tr>
<td>Age</td>
<td>0.023</td>
<td>0.057 ***</td>
<td>−0.067 ***</td>
<td>0.058 ***</td>
</tr>
<tr>
<td></td>
<td>(0.028)</td>
<td>(0.019)</td>
<td>(0.024)</td>
<td>(0.018)</td>
</tr>
<tr>
<td>Married</td>
<td>−0.783</td>
<td>2.746 ***</td>
<td>−2.202 ***</td>
<td>1.304 ***</td>
</tr>
<tr>
<td></td>
<td>(0.783)</td>
<td>(0.552)</td>
<td>(0.354)</td>
<td>(0.383)</td>
</tr>
<tr>
<td>Income</td>
<td>−0.328</td>
<td>1.534 ***</td>
<td>−0.507</td>
<td>1.143 ***</td>
</tr>
<tr>
<td></td>
<td>(0.981)</td>
<td>(0.398)</td>
<td>(0.318)</td>
<td>(0.386)</td>
</tr>
<tr>
<td>Class Probability</td>
<td>0.389 ***</td>
<td>0.098 ***</td>
<td>0.172 ***</td>
<td>0.342 ***</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.028)</td>
<td>(0.04)</td>
<td>(0.033)</td>
</tr>
</tbody>
</table>

*: P < 0.1; **: P <0.05; ***: P <0.01
Data from the British respondents were modelled assuming four classes, consisting of two classes with a class probability of 39% (class 1) and 34% (class 4) and two classes with lower class probabilities of 17% and 10%. British respondents showed a positive preference for aquaculture products produced in national waters (class 1: 1.4, $P < 0.01$; class 2: 1.5, $P < 0.01$; class 4: 0.6, $P < 0.01$), although this preference was statistically insignificant for class 3 (0.02, $P > 0.1$). Respondents also expressed a positive preference for products from more sustainable aquaculture production processes, across all labels; although label C was insignificant in class 2 ($P > 0.5$) and class 4 ($P > 0.1$). This suggests that these classes prefer only larger increases in sustainability. All classes showed a statistically significant negative preference for the price attribute ($P < 0.01$) and all but class 3 ($P > 0.1$) had a negative preference for selecting the opt-out option in the choice cards ($P < 0.01$). In terms of interaction terms, in no demographic group opted out significantly more on average in class 1. In class 2 however, respondents selected the “I would not purchase either” option significantly more when they were male (1.1, $P < 0.05$), when their highest completed education level was below third level (−1.2, $P < 0.01$) or if they were married (2.7, $P < 0.01$). In class 3, the opt-out was selected more by respondents that were male (0.6, $P < 0.05$), under 45 years of age (−0.1, $P < 0.01$) or unmarried (−2.2, $P < 0.01$). In class 4, respondents opted out more when male (0.9, $P < 0.05$), completed third level education or higher (0.7, $P < 0.05$), are over 45 years of age (0.1, $P < 0.01$) and have an income higher than the national average (1.1, $P < 0.01$).
Table 14  Model pooled data

<table>
<thead>
<tr>
<th>Pooled (n = 2520)</th>
<th>Latent Class 3 Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Choice</strong></td>
<td>Class 1</td>
</tr>
<tr>
<td>Location</td>
<td>1.126 ***</td>
</tr>
<tr>
<td></td>
<td>(0.046)</td>
</tr>
<tr>
<td>Sustainability C</td>
<td>0.482 ***</td>
</tr>
<tr>
<td></td>
<td>(0.054)</td>
</tr>
<tr>
<td>Sustainability B</td>
<td>1.039 ***</td>
</tr>
<tr>
<td></td>
<td>(0.066)</td>
</tr>
<tr>
<td>Sustainability A</td>
<td>1.734 ***</td>
</tr>
<tr>
<td></td>
<td>(0.066)</td>
</tr>
<tr>
<td>Price</td>
<td>−0.585 ***</td>
</tr>
<tr>
<td></td>
<td>(0.022)</td>
</tr>
<tr>
<td>Opt-out Alternative</td>
<td>−10.571 ***</td>
</tr>
<tr>
<td>Specific Constant (ASC)</td>
<td>(0.514)</td>
</tr>
<tr>
<td>Interaction terms with ASC</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>−0.304     *</td>
</tr>
<tr>
<td></td>
<td>(0.184)</td>
</tr>
<tr>
<td>Third level Education</td>
<td>0.178</td>
</tr>
<tr>
<td></td>
<td>(0.183)</td>
</tr>
<tr>
<td>Age</td>
<td>0.0343 ***</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
</tr>
<tr>
<td>Married</td>
<td>0.031</td>
</tr>
<tr>
<td></td>
<td>(0.187)</td>
</tr>
<tr>
<td>Income below average</td>
<td>0.276</td>
</tr>
<tr>
<td></td>
<td>(0.187)</td>
</tr>
<tr>
<td>Ireland</td>
<td>−6.053 ***</td>
</tr>
<tr>
<td></td>
<td>(0.513)</td>
</tr>
<tr>
<td>Italy</td>
<td>−0.019</td>
</tr>
<tr>
<td></td>
<td>(0.401)</td>
</tr>
<tr>
<td>Norway</td>
<td>1.940 ***</td>
</tr>
<tr>
<td></td>
<td>(0.285)</td>
</tr>
</tbody>
</table>
In the 3-class model for the pooled data set, 54% \((n = 1,161)\) of the respondents we assigned to the first class, 28% \((n = 705)\) to the second class and 18% \((n = 454)\) to the third class. The coefficients of all parameters are significant on the 1% level, with the exception of the third class, where the lower sustainability level \((c)\) was insignificant. The interaction terms with the opt-out ASC varied strongly between the classes.

**Consumer Profiling across Classes**

In table 15 consumer profiles based on the latent class parameters are described. Here it should be noted that the classes are not mutually exclusive but latent, meaning that respondents are assigned a probability of membership in each case. Respondents are thus not assigned 100% to any single class. Consumer profiling is based on the coefficient values in each class. A total of five consumer profiles were created. The profiles identified in the latent classes are (1) the “Green Buyer”, (2) the “Local Buyer”, (3) the “Determined Buyer”, (4) the “Flexible Buyer” and (5) the “Economic Buyer”.

### Table 15  Classification of preferred models of pooled and country data

<table>
<thead>
<tr>
<th></th>
<th>Green Buyer</th>
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<th>Flexible Buyer</th>
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Chapter 4

*The Green Buyer*

The first two profiles relate to the main CE attributes; production location and sustainability level. Respondents in the “Green Buyer” class are characterised by a strong preference for sustainable seafood production. The class represents a positive coefficient for the sustainability attributes, which translates into a WTP for the sustainability attributes that is significantly higher than in the other classes and compared to other attributes.

The second class from the pooled data model is labelled as the green buyer due to its positive preference for the sustainability attributes C, B and A (attribute coefficients (and standard error) of 0.48 (0.05), 2.02 (0.13) and 3.21 (0.14) respectively) and the comparatively low preference for production location. Elder people were more likely to select the opt-out (0.03 (0.004)), while highly educated respondents (−0.23 (0.09)), low income respondents (−0.24 (0.09)) and married respondents (−0.16 (0.09)) were less likely to select the opt-out. With regard to the country interactions, respondents from this class are more likely to select the opt-out when they are Italian (0.71 (0.16)), Norwegian (3.71 (0.23)) or British (0.76 (0.17)), compared to the base case.

Latent classes characterised by their high utility associated with sustainability are modelled for every country and represented a large proportion of the population of Ireland (class 3, probability 48%) and Italy (class 3, probability 45%) and smaller proportions for Norway (class 3, probability 17%), the UK (class 3, probability 17%) and Israel (class 3, probability 15%). The profile of the Green Consumer is represented by the largest proportion of respondents (class 2, probability 28%) and the only latent class to be modelled in every data set. The allocation towards green or local buyer profiles is based on the comparative coefficients of the sustainability attribute and on the height of the WTP for the individual attributes in the specific class. Although characterised by their preference for sustainability, the Irish, Israeli and Norwegian respondents in this profile also have a positive utility for national production location paired with their preference for higher sustainability.

*The Local Buyer*

The “Local Buyer” has a strong positive preference for seafood that is produced in national water, as opposed to imported seafood. This preference is elicited from a positive coefficient for the location attribute and a WTP for the location attribute that
is high, both in comparison to the other attributes as well as for the location attribute WTP in other classes.

Members of the third class from the pooled model had strong positive preferences for fish produced in national waters (3.14 (0.16)). The sustainability attribute coefficients did not show a clear preference pattern, although the highest sustainability attribute is significant (0.5 (0.13)). With regard to representativeness of the sample, male respondents in this class were more likely to select one of the purchasing decisions than women (0.5 (0.13)). Compared to the base case, male respondents from Ireland (−0.5, (0.13)), Italy (−3.31 (0.25)) and Norway (−3.33 (0.25)) are less likely to select the opt-out, while respondents from the UK select the opt-out significantly more (0.49 (0.24)). However, the preference for the opt-out is still negative for all countries, i.e., respondents from all countries prefer to select a purchasing option over the “I would not buy any of these products, even if this product was on my shopping list” option.

In the single country analysis, the profile of the local buyer can be attributed to 27% of the respondents, spread over Israel (class 2, probability 53%), the United Kingdom (class 4, probability 34%), Norway (class 4, probability 27%) and Italy (class 2, probability 22%). Although Irish respondents have among the highest WTP for nationally produced seafood in the sample, no latent class was allocated to the local buyer profile in the Irish model.

The Determined Buyer

The determined and flexible buyer profiles relate to the shopping habits of respondents and their resoluteness in making purchasing decisions. Respondents in the “Determined Buyer” profile are characterised by their determination to buy what is on their shopping list, regardless of the attributes of the product. This is reflected by a negative coefficient for the alternative specific constant in the model.

The first class from the pooled data model is labelled as ‘determined buyer’ due to its strong negative preference for the opt-out option (−10.57 (0.51)). The class is further characterised by positive coefficients for the national production location (1.13 (0.05)) and the sustainability attributes C, B and A (0.48 (0.05), 1.04 (0.07) and 1.73 (0.07) respectively). The country interactions terms in the pooled model indicate that Irish respondents have a stronger tendency to select one of the purchasing options (−6.05 (0.51)) compared to the base case of Israelis, whereas Norwegian and the British
respondents selected the opt-out option more (in 2 out of the 3 classes in the Norwegian case and for all classes in the UK case) in comparison to the base case (1.94 (0.29) and 2.64 (0.29), respectively). This means that the results of the model cannot be generalised over the Norwegian and British public as much as over the other sample countries, as they have selected the opt-out more. However, considering the strong negative coefficient for the constant, Norwegian and British respondents have a negative preference for the opt-out; i.e., they prefer to select a purchasing option over the opt-out option, but this preference is significantly weaker than in the other sample countries. This tendency is consistent for these countries across the different classes.

Across the individual country models, the profile of the determined buyer was allocated to latent classes in Ireland (class 1, probability 39%), Norway (class 1, probability 48%) and the United Kingdom (class 1, probability 39%), together accounting for 25% of the sample population. The modelled classes produced significant coefficients for all attributes, but were identified as determined buyer classes due to the strength of the negative coefficient for the opt-out ASC; it was over 6 times the nearest coefficient in the class in Ireland, over 5 times in the Norwegian class and 4.5 in the UK class. The modelling of these classes is based on the purchasing habits rather than preference for one of the attributes, but the respondents represented by these classes did display significant preferences for the CE attributes.

The Flexible Buyer

In contrast to the determined buyer, the “Flexible Buyer” shifts easily from one product to the other when the product attributes do not fit the respondents’ preferences. This is expressed by the absence of a significant negative coefficient for the alternative specific constant. The determined and flexible buyers can however still have strong preferences for the CE attributes, which should be recognised in the interpretation of the latent class models.

In the individual country models, a latent class flexible buyer are assumed for Israel (class 1, probability 32%) and Italy (class 1, probability 18%), together representing 10% of the total sample population. Classes were allocated to the flexible buyer profile based on their respondents’ tendency to switch to other (substitute) products and their lack of a preference for lower prices. They were allocated to the flexible profile due to insignificant coefficients for the constant, which reflects a lack of a detectable
preference for buying the type of product the respondent intended to buy when entering the shop. In the Israel class, no significant preference for lower priced products was visible. As the classification of these latent classes is based on shopping habits, it should be recognised that the classes in Israel and Italy both have significant positive coefficients for the CE attributes production location and sustainability, thus contributing to the WTP of those attributes.

The Economic Buyer

The “Economic Buyer” profile captures respondents’ price sensitivity. Respondents in this class have a preference for products with lower prices. Although not observed in the pooled data set, the economic buyer profile is allocated to classes in Italy (class 4, probability 14%) and Norway (class 2, probability 9%), together representing 5% of the total sample population. The economic buyer profile was allocated according to the negative preference for the price variable. The Italian class holds positive preferences for the sustainability and location attributes, but these preferences are only significant for the higher sustainability attribute levels. This suggests that these individuals pay extra only for larger increases in sustainability. In the Norwegian class 2, price was the only variable that was significant (at the 5% level). In terms of representativeness of the latent classes for the sample population, this profile is comparatively weakly represented.

<table>
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<tr>
<th>Model (# classes)</th>
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<th>Sustainability B</th>
<th>Sustainability C</th>
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<td>Pooled LC (3)</td>
<td>£ 6.02***</td>
<td>£ 6.89***</td>
<td>£ 4.16***</td>
<td>£ 2.45***</td>
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<td>£ 15.18***</td>
<td>£ 9.44***</td>
<td>£ 3.43***</td>
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<td>£ 10.97***</td>
<td>£ 5.21***</td>
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<td>Israel LC (3)</td>
<td>£ 3.41***</td>
<td>£ 10.29***</td>
<td>£ 5.23**</td>
<td>£ 3.27***</td>
</tr>
<tr>
<td>Norway LC (4)</td>
<td>£ 6.45***</td>
<td>£ 4.88***</td>
<td>£ 2.88***</td>
<td>£ 1.40*</td>
</tr>
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Table 16  Weighted Marginal WTP for CE Attributes Across Countries by the Preferred Models
Table 16 lists the marginal willingness-to-pay for the change in attribute levels. Estimates reported are weighted for the latent class membership probabilities. The public’s marginal WTP for seafood produced in national waters varies from €3.41 (in Israel) to €11.33 (in Italy) and is estimated at €6.02 for the pooled data set, ceteris paribus. The marginal WTP for the sustainability attributes vary from €1.40 (Norway) to €4.28 (Italy) for sustainability label C, from €2.88 (Norway) to €9.44 (UK) for sustainability label B and from €4.88 (Norway) to €15.18 (UK) for sustainability label A. The pooled data analysis produced estimates of €2.45, €4.16 and €6.89 per kilo of unfrozen product that has sustainability label C, B and A, respectively, ceteris paribus. The pattern in WTP estimate is comparable between countries. Marginal WTP for both sustainability and national production location is positive and increases as sustainability increases. This pattern holds over all countries. However, difference does exist in the magnitude of marginal WTP estimates. The average marginal WTP for CE attributes is the highest in the UK, followed by Italy, Ireland, Israel and lastly Norway.

4.4 Discussion

This paper presented the results of a latent class analysis of CE data with the aim of assessing the market potential of sustainable seafood production techniques, such as IMTA. Latent classes were modelled for data sampled in Ireland, Israel, Italy, Norway and the United Kingdom both separately and for the pooled data from all countries. Classes were allocated to consumer profiles according to the estimated attribute preference parameters signs and significance, leading to respondents in each class being labelled as green, local, determined, flexible, or economic buyers. More specifically, latent classes in the pooled data model were identified as green (28%), local (18%) and determined (54%) buyers. While these profiles remain dominant in the country data analysis, a number of smaller profiles were detected that remained unidentified under the three class model on the pooled data set.

The profiles of the green and local consumer reflect respondents’ preferences for the CE attributes sustainability and production location, whereas the determined and flexible profiles reflect how easily an individual shifts to an alternative product based on the product attributes. Interestingly, the proportion of the public assigned to the profile of green consumer (28%) is comparable to the proportion of consumers labelled green consumers by the OECD (2002) (27%). As the determined buyer class...
covers a relatively large proportion of the respondents in Ireland (39%), Norway (48%) and the UK (39%) the general public of the sampled countries seems to be characterised as determined buyers rather than as a flexible buyer.

The public’s WTP is positive for all CE attributes and across the sample countries and the pooled data, indicating that the public is willing to pay a price premium for products produced in a more sustainable method such as IMTA. Marginal WTP for the locally produced attribute is estimated in the pooled data at €6.02, ceteris paribus, indicating a willingness to pay a price premium for seafood products that are produced in national waters. The results also indicate that the public is willing to pay a price premium for products that are produced more sustainably. This WTP increases as the degree of sustainability increases by decreasing the environmental impact by 10% (€2.45—sustainability label C), 20% (€4.16—sustainability label B) or 30% (€6.89—sustainability label A) per kilo of product.

Price premiums are mentioned as a method of stimulating seafood producers to shift to more sustainable production techniques such as IMTA (Chopin et al., 2010). However, this is conditional upon the additional profits going to producers, rather than to retailers. Considering the international character of the seafood market and the power of retailers in the market, some form of governance may be necessary if bottom-up pressure by the public is to steer the industry to become more sustainable. The EU may well be the best suited institution to govern seafood market steering policies in Europe, as it holds some transnational power and can create a standardised instrument that transcends national market boundaries and works at the European level (Read & Fernandes, 2003) in contrast with the fragmented approach of national governments.

Given the strong competition in the globalised seafood market, the European aquaculture industry can match the global industry only when it creates a valuable market position for itself. For example, the Irish salmon industry recovered from a decline in production after a combination of disease and negative market conditions by carving out a high-value niche market for organic salmon (Grealis et al., 2017). The European aquaculture industry could come closer to matching global growth rates by creating a similar niche for its products. Production methods such as IMTA could expedite the development of such a sustainable niche market.
The significant WTP for more sustainable forms of aquaculture does not in itself guarantee higher profits for producers that switch to such production methods. This will also depend on the marginal costs of providing higher sustainable levels in production. Given the potential synergies across the products produced in an IMTA system with possible reduction in costs associated with feed loss and waste processing (plus increasing demand for sustainable produced food), the marginal cost could actually decrease in the long run but this remains an area for future research. Further research is also needed in terms of the pooled model specification. The model presented controls for non-observed heterogeneity in mean preferences. In this type of cross-country study however, consumers may interpret and process choice tasks and situations differently (Train & Weeks, 2005). Control for this scale heterogeneity could improve the fit of the pooled model.

The creation of an eco-label as demonstrated in this survey could simultaneously fulfil multiple functions; for the public, they provide previously hidden information on the environmental impact of a product, allowing them to maximize their utility; for a producer, they provide the opportunity to differentiate their product and increase their market value; while governments use eco-labels as a policy instrument to stimulate environmentally friendlier production to reach policy goals. An increasing proportion of the European public is aware of the environmental impact of seafood production and is willing to pay a price premium for more sustainable products. Public awareness and willingness-to-pay analysis can therefore be considered a tool to stimulate the European aquaculture industry while facilitating blue growth and reaching the goal of ‘Good Environmental Status’. Simultaneously, an EU eco-label guarantees the public that the product observes EU production standards, which, as Magennis, Jordan, Caraher, & Maloney (2007) point out could reassure those individuals reluctant to purchase seafood that is imported from countries where regulations are perceived as insufficient.

Furthermore, an eco-label as proposed in this paper provides information to the public on the degree of environmental impact. A common criticism towards eco-labels is that they do not provide information on the degree of environmental improvement, and green grading schemes have been proposed by scholars (Aarset et al., 2004). A sustainability grading label provides this information to the public and continually stimulates producers to decrease the environmental impact of their production
process, so as to reach a higher eco-label tier. Lastly, a lack of knowledge and trust in regulatory organisations, paired with distrust towards the food industry, and ignorance and scepticism about the independence of certifiers, has been identified as elements that are decreasing the eco-label impact (Aarset et al., 2004). A grading label as proposed has the advantage of consumer familiarity and trust, as this is a widely used and accepted label across EU countries.

Seafood preferences for sustainability and production location can be generalized over countries in terms of preference patterns, but WTP estimates were heterogeneous in degree. Differences among countries can have implications for the success of eco-labelling programs. Differences in socioeconomic status, knowledge on environmental issues, price sensitivity or the perceived importance of other seafood attributes that the eco-label competes with may all impact on the success of a new eco-label (Johnston et al., 2001b). These differences highlight the need for flexible implementation of cross border eco-labelling programs, as well as the need for education of the European public on environmental issues and their role as responsible consumers. Finally, 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. The results presented here highlight the fact that consumers are willing to pay a price premium for the additional sustainability IMTA systems could provide, although the location of such systems will also remain an important consideration in any purchasing decision.
Chapter 5

Scale Heterogeneity in Consumer Preferences for Sustainable Seafood: Assessing the Effect of Model Choice on WTP Estimations in Discrete Choice Analysis

This paper assesses the effect of accounting for preference as well as scale heterogeneity on Willingness-to-Pay (WTP) estimations for increased sustainability of salmon production techniques. Using data from a choice experiment conducted through an online survey across Ireland, the UK and Norway, in which an eco-label was used to distinguish between the environmental impact of production techniques, model output and WTP estimations were compared using Mixed Logit, Generalized Mixed Logit and Scaled Logit Models. The results showed that the general public indicated a positive attitude toward eco-labels indicating the sustainability of seafood production and a positive WTP for more sustainably farmed salmon and for salmon produced in national waters. The comparison between models demonstrates that model choice impacts welfare effect estimations for more sustainably produced seafood. Accounting for preference heterogeneity has a relative strong impact on welfare effect estimations, whereas accounting for scale heterogeneity, although improving model fit, does not have a significant effect on welfare estimations.

5.1 Introduction

In 2014 annual European aquaculture industry growth was lagging at 0.5% compared to 7% average global growth (Lane et al., 2014). Simultaneously the industry is being challenged on the environmental impact attributed to intensive monoculture production systems (Burridge et al., 2010; Cabello, 2006; Cabello et al., 2016; Cotter et al., 2000; Frazer, 2007; Pillay, 2004; Talbot & Hole, 1994; Toranzo, Magariños, & Romalde, 2005). The lagging growth and environmental challenges of the industry have caused the European Union (EU) to try to stimulate sustainable aquaculture
production processes (SEP 2015). This is in addition to addressing the environmental issues while expanding production volume and creating market stability to fulfil the rising European demand for seafood (DG Fisheries 2014).

Integrated Multi-Trophic Aquaculture (IMTA) has been suggested by scholars, industry actors and policy actors as one method that can contribute to the dual aims of aquaculture industry growth and fulfilling the environmental goals set out by the EU (Chopin, 2008; Jeffery et al., 2014; Lane et al., 2014). However until now, there has been no large-scale uptake for industrial production (Troell, Joyce, Chopin, Neori, Buschmann, et al. 2009) despite IMTA experiments across Canada, South Africa, Israel, Chile, China (Chopin et al., 2008) and the Netherlands (Groenendijk et al., 2016), amongst others. Interest in IMTA systems is expected to increase in Europe (Lane et al. 2014; SEP 2015) as an alternative to monoculture production. IMTA is an aquaculture system in which fed aquaculture (e.g. salmon) is integrated with the addition of other species (e.g. seaweed, mussels, lobster or sea cucumber) to create a production system that combines organic and inorganic extractive aquaculture. This introduces an element of nutrient cycling to the production process, which has multiple benefits, both environmentally (Bartsch et al., 2013; Hadley, Wild-Allen, Johnson, & Macleod, 2016) and economically (Shpigel, Ari, Shauli, Odintsov, & Ben-Ezra, 2016). Additionally, products from IMTA farms may produce higher profits than monoculture products as research suggests that consumers have a higher willingness to pay (WTP) for fish produced through more sustainable production systems (van Osch, Hynes, Freeman, & O’Higgins, 2019; Whitmarsh & Wattage, 2006). This higher consumer WTP can play a role in the development of the aquaculture industry, as a price premium can lead to additional revenue, which could assist in covering the costs associated with shifting from monoculture to IMTA (Troell, Joyce, Chopin, Neori, Buschmann, et al. 2009). A rated Europe-wide eco-label for aquaculture products, indicating the degree of sustainability in aquaculture production could play a role in informing the public and improve the industry’s competitiveness and societal acceptance of EU aquaculture (European Commission, 2013c).

One useful method for investigating preferences for prospective market goods is to undertake a discrete choice experiment (CE). This choice modelling approach breaks down a good into its different attributes and allows the good to take different levels for each attribute. By observing how consumers choose different bundles of these
attributes, inferences can be made on which attributes most affect their choices and by including a cost or price attribute then WTP amounts for change in attribute levels can also be inferred (Hanley & Barbier, 2009; Louviere et al., 2000). Another aspect of this choice modelling approach is that heterogeneity of consumer choices can be also modelled, specifically preference heterogeneity and scale heterogeneity. Preference heterogeneity is defined as the extent to which consumers’ tastes and preferences vary across consumers (Price, Feick & Higie 1989), whereas scale heterogeneity is the standard deviation of utility over different choice situations per individual. Scale heterogeneity can be thought of as the variance of the variance term (ɛ) across respondents (Fiebig et al., 2010; Greene & Hensher, 2010). In the context of CEs, scale heterogeneity reflects the degree of respondents’ certainty or consistency in their expressed preferences. Therefore, the inclusion of scale heterogeneity into choice experiment analysis integrates any variation of the degree of randomness in the completion of CE choice tasks in the model. Heterogeneity has received increasing attention in resource economics in order to better understand respondent’s choices for sustainable goods (Louviere & Eagle, 2006; Louviere et al., 1999, 2008; Louviere et al., 2002).

Multinomial logit (MNL) choice models are well established in assessments of consumer preferences for seafood. Using discrete choice analysis, a positive WTP for IMTA products was identified across Canada (Troell et al. 2009), Scotland (Whitmarsh & Wattage, 2006), the US Pacific Northwest (Yip et al., 2016) and Europe (van Osch et al., 2019). However, these studies focused on preference heterogeneity and paid little to no attention to the role of scale heterogeneity. MNL has been criticised as it is restricted by its underlying independence of irrelevant alternatives (IIA) assumption (Luce, 1959) which specifies that preference homogeneity across respondents is assumed. Yet research indicates that preferences often exhibit preference heterogeneity (Amador, González & De Dios Ortúzar 2005; Espino, Martín & Román 2008) and failing to include it may lead to biased coefficients and eventually biased welfare measurements that can lead to poor policy recommendations (Train, 2003). As attention for preference heterogeneity in CE modelling increased, several extensions to the MNL model have developed that incorporate heterogeneous tastes over observed and unobserved attributes.

The Random Parameter Logit (RPL) model (Train, 1998) is an alternative modelling
approach which drops the assumption that preferences are homogeneous across individuals. The relaxation of the IIA assumption allows preferences to vary across respondents (Train, 1998). RPL has been applied to seafood valuation studies for sustainable seafood (Bronnmann & Asche 2016; McClenachan, Dissanayake & Chen 2016; van Osch et al. 2017) and estimations of consumers’ WTP for eco-labels on the seafood market (Uchida et al., 2014). However, the RPL does not take scale heterogeneity into account, while research indicates that a proportion of the preference heterogeneity captured in the RPL random parameters may be better expressed as scale heterogeneity in the scale term (Louviere et al. 2008; Louviere and Meyer 2007). The RPL is therefore considered a poor approximation if scale heterogeneity is present within the CE data (Fiebig et al., 2010).

The Scaled Multinomial Logit (SMNL) model was developed to take into account scale heterogeneity across CE data. The inclusion of scale heterogeneity is especially relevant in stated preference studies, as CE respondents can differ in their interpretation of choice tasks and information presented in the survey, and vary in the amount of attention paid to choice tasks and the level of choice certainty (Train & Weeks, 2005). Thus it would be expected that the scale of the error term could be greater for some consumers than for others.

Fiebig et al. (2010) developed an extension on the MNL in the Generalised Multinomial Logit Model (GMNL) based on the suggestion of Keane (2006) to combine RPL and SMNL into one model. The GMNL can be regarded as a RPL including both scale and preference heterogeneity (Hole & Yoo, 2014). This model has been demonstrated to improve model fit based on model information criterion as it accounts for respondents that exhibit extreme or near-random preferences in CE (Fiebig et al., 2010).

This paper uses CE data on consumer preferences for sustainable aquaculture production to address how WTP estimates are dependent on the inclusion of preference and scale heterogeneity in discrete choice analysis. For the CE the sustainability of aquaculture products was determined by the production process. Production is specified as either monoculture, which is commonly used, or Integrated Multi-Trophic Aquaculture (IMTA), which is an alternative production technique deemed more sustainable as it introduces a nutrient cycling element to the salmon rearing process (Barrington et al., 2009). Multiple models exist that elicit the value
consumers attribute to product attributes. As discussed above these models vary in the sources of heterogeneity they include and in the methods by which they take heterogeneity into account in the analysis. One of the main contributions of this paper is that it addresses the issues of preference and scale heterogeneity in discrete choice modelling of the preferences of European consumers for sustainable aquaculture salmon. A RPL model is used comparatively to the SMNL model, which takes into account scale heterogeneity, and the Generalised Mixed Logit (GMXL) model, which takes into account both scale and preference heterogeneity. The CE data used assessed consumer preferences for salmon, considering production location and production techniques, with a focus on the environmental impact of aquaculture production techniques, particularly for the European aquaculture industry.

The rest of the paper is organised as follows: the next section will elaborate on the theory behind the models applied for this analysis. Section 5.3 sets out the CE design and the survey that contained the CE. The results of the analysis are presented in section 5.4 along with the WTP estimates for sustainable aquaculture practices and the results are summarised and discussed in section 5.5.

5.2 Theoretical Framework

*Foundations of discrete choice analysis*

Discrete choice analysis is founded on utility maximisation (Debreu, 1959), Lancaster’s Theory of Value (Lancaster, 1966) and the Random Utility Model (RUM) (McFadden, 1973). Despite utility theory stipulating that consumers aim to maximise their utility in every purchasing decision, Lancaster (1966) proposes that consumers derive utility from product attributes rather than from directly from product consumption. The utility of a product can therefore be separated into partial utilities associated with product characteristics. The RUM was developed by McFadden (1973), who recognised that utility is a latent concept that cannot be observed directly (Manski 1977; Phaneuf 2005). McFadden (1973) expressed utility as

\[ U_{jn} = V_{jn}(x_p, s_n) + \epsilon_{nj} \]  

[8]

In function 8, subject \( n \) chooses among alternatives according to a utility function \( (U_{jn}) \) which consists of two main segments. The first component \( (V_{jn}) \) consists of an observable part that expresses the utility captured by the model through inclusion of
the attributes ($X_j$) and a selection of socio-economic indicators ($S_n$). The second component ($\epsilon_{nj}$) consists of a random non-observable error term which reflects variations that are not captured by the CE and therefore remain excluded from the model. The development of discrete choice models aims to capture as much of the variation of the data possible within the model and minimise the error term. Several econometric models of respondents’ decision-making processes have been developed based on the theoretical concepts of RUM.

**Econometric models**

Multiple econometric models have developed for CE data analysis. The Multinomial Logit (MNL) model is the basic discrete choice model widely applied in CE analysis. However, MNL does not facilitate the modelling of variation of individual preferences due to the independence from irrelevant alternatives (IIA) assumption and therefore does not control for heterogeneity. Models developed from MNL that do account for heterogeneity have relaxed the IIA assumption. The RPL, SML and GMXL models are among the models that account for sources of heterogeneity through varying approaches.

Preference heterogeneity is included by the RPL model (Train, 1998). RPL generalizes the MNL by relaxing the IIA and allowing coefficients to vary randomly over respondents. Thereby the RPL captures more variation of the data in the deterministic component of the model and minimises the error term ($\epsilon_{nj}$) (Train, 1998). The RPL model can be expressed as:

$$U_{nj} = \beta X_{nj} + \eta X_{nj} + \epsilon_{nj}$$  \[9\]

where the respondent’s utility ($U_{nj}$) consists of three parts. $X_{nj}$ is the vector of the mean attribute utility weights in the population and, due to the relaxing of the IIA assumption, now includes $\beta$, which is the vector of coefficients that are unobserved for the respondents and varies across the respondents. $\eta X_{nj}$ reflects the variation across the respondents, with $\eta$ being the vector of person n-specific deviation from the means, signifying the individuals preference relative to the average in the population.

Scale heterogeneity is integrated by the SMNL model (Fiebig et al., 2010) through including the component of the error term reflecting the scale heterogeneity into the deterministic part of the model. The SMNL as specified by Fiebig et al. (2010) can be
expressed as

\[ U_{njt} = (\beta \sigma_n) x_{njt} + \epsilon_{njt} \]  

[10]

where the respondents’ utility \((U_{njt})\) is expressed as the utility of person \(n\) from choosing alternative \(j\) on choice scenario \(t\). It is vital to recognise that the idiosyncratic error \((\epsilon_{njt})\) in equation [9] is assumed to include a normalized scale term. The SMNL introduces \(\beta \sigma_n\), which is a vector of utility weights where \(\beta\), the random parameter coefficient, is scaled proportionally across respondents \((n)\) according to the heterogeneity in their expressed preferences \((\sigma)\).

The GMXL model includes both preference and scale heterogeneity in the deterministic part of the model by adding extensions as the parameters \(\gamma\) and \(\tau\). Fiebig et al. (2010) specifies the GMXL as

\[ U_{njt} = [\sigma_n \beta + \gamma \eta_n + (1 - \gamma)\sigma_n \eta_n] X_{njt} + \epsilon_{njt} \]  

[11]

where utility \(U_{njt}\) is composed of \(X_{njt}\) and \(\epsilon_{njt}\). The element \(\gamma \eta_n\) is a mixing parameter. It is a value between 0 and 1 which reflects the degree of interaction between the model parameter for scale heterogeneity \((\sigma_n)\) and parameter heterogeneity \((\eta_n)\). The element \(\sigma_n \beta\) is the scaling factor which scales \(\beta\) proportionally for each respondent \(n\) by \(\sigma\) and hence reflects the individual-specific scale of the idiosyncratic error. A scale parameter value of \(\tau = 0\) implies that no scale heterogeneity is detected and a value over 1 implies the presence of scale heterogeneity. Similarly, the parameter \(\gamma\) reflects the absence or existence of preference heterogeneity, where a value over 1 indicates that the model is hybrid while a GMXL with a \(\gamma = 0\) implies the scaled multinomial model is used.

Model specification

The model specification aims to maximise the proportion of variation in the data captured by the observable part of the model, so that the stochastic part of the model is minimised and the population utility is modelled as accurately as possible for the given data set. The modelling process rests on the assumption on utility maximisation, which specifies that respondents always choose the option that provides the most benefits, i.e. maximises utility. For the RPL model, the choice probabilities are estimated by
where choice probabilities are estimated by simulating the choice probability that respondent \( n \) chooses option \( j \) over option \( i \) by averaging simple logit over draws, given \( D \) draws \( \{ \eta^d \}_{d=1,...,D} \).

The models are identical with regard to the inclusion and specification of variables, in order to facilitate comparison of the models in terms of fit and WTP estimates, considering the inclusion of preference heterogeneity, scale heterogeneity and a combination of the two. The models reported include interacting the terms of the Alternative Specific Constant (ASC3) with the dummy variables of countries where the CE was undertaken to capture national effects. Surprisingly, the models did not converge when including dummy variables for country membership or when running the model without including a variable that reflects country membership.

It should also be noted that the parameters were specified as having a Normal distribution. In situations where WTP is positively related to the variable of interest and utility is not expected to enter negative space, the distribution is often specified as LogNormal. However, all models produced a better fit for Normal parameter specification and this approach is in line with earlier research on public preferences for sustainable aquaculture production (van Osch et al., 2019).

**WTP estimations**

The CE aims to assign a monetary value to the attribute levels included in the experiment. Marginal values for the attribute levels, reflecting the respondents’ WTP for a relative change in one attribute against a relative change in another attribute, are derived using the function

\[
WTP_x = \frac{\beta_x}{\beta_m} \]

Implicit values for attribute \( x \) are derived from dividing the attribute parameter (\( \beta_x \)) by the monetary attribute (\( \beta_m \)) and inverting the sign (Hynes, Tinch and Hanley 2013). This was based on individual-specific WTP estimates for the RPL and GMXL and, as no individual-specific information was available for the scaled model, value was calculated through simulation with 10,000 random draws on the SML model coefficients.
5.3 Choice Experiment Data

Sample

The data used to demonstrate the modelling effect of preference and scale heterogeneity consists of CE data on consumer preferences for sustainability in salmon production across Europe. CE data was retrieved by an independent survey firm, ICM Research, through an online survey among a population of randomly selected contracted clients. The randomly selected sample was stratified according to demographic variables such as age, gender and region in each sample country.

Data was retrieved from Ireland (n=500), Norway (n=501) and the United Kingdom (n=511), providing a sample of 1,512 potential salmon consumers from the main salmon producing countries in Europe that are characterised by either a niche market of organic production (Ireland and the UK) or intensive large-scale production (Norway). The original survey data also contained CE data from Italy and Israel, but this data was omitted. The CE design in Italy and Israel was adapted to the national industry; the choice cards reflected choices across attributes for sea bream rather than salmon. Data from these countries is omitted to avoid any bias effects of preferences varying across species.

The survey consisted of four parts. The first section assessed respondents’ overall knowledge of aquaculture practises and their attitudes towards it. The second section informed respondents on aquaculture production techniques that are deemed more sustainable. It is recognised that this information may bias selection in the CE, but due to low familiarity of respondents with aquaculture and sustainable production techniques, some basic information was necessary to ensure informed decision-making in the CE. A section on purchasing behaviour followed, focusing particularly on the use of eco-labels. Finally, questions of demographics were included to ensure that socioeconomic factors could be included in the analysis.

Choice experiment design

CEs are a widely used tool in environmental economics to assess public preferences and estimate WTP for changes in public goods, such as changes in environmental quality. In a CE, respondents are presented with several choice cards and asked to select their most-preferred option on each choice card from several alternatives. Each
alternative consists of several attributes (i.e. production location, sustainability level, price) that change in attribute levels across the choices presented. In selecting their most preferred option from the alternatives, the respondent will have to weigh the utility they attribute to a change in attribute A for the utility attributed to a change in attribute B. The CE design includes two elements that assist the modelling process; (1) an opt-out (status quo) option is included in each choice card along with the alternatives to allow for realistic choice behaviour and (2) a monetary indicator (price) is included as one of the attributes, allowing the modeller to use the repeated weighting of relative changes in attributes to estimate a monetary value to the attribute levels. The usefulness of CE’s lies in this ability to produce estimates of marginal values for separate (market or non-market) attributes and estimates of welfare effects of attribute changes.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Attribute level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Location</td>
<td>National Waters</td>
<td>The product is farmed in national waters</td>
</tr>
<tr>
<td></td>
<td>Outside of national waters</td>
<td>The product is farmed outside of national waters</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Sustainability Label A</td>
<td>A 30% increase in environmental sustainability due to a move towards an IMTA production system</td>
</tr>
<tr>
<td></td>
<td>Sustainability Label B</td>
<td>A 20% increase in environmental sustainability due to a move towards an IMTA production system</td>
</tr>
<tr>
<td></td>
<td>Sustainability Label C</td>
<td>A 10% increase in environmental sustainability due to a move towards an IMTA production system</td>
</tr>
<tr>
<td></td>
<td>Sustainability Label D</td>
<td>Monoculture production</td>
</tr>
<tr>
<td>Price per kg</td>
<td>Ireland: € 11</td>
<td>Low price in national market</td>
</tr>
<tr>
<td></td>
<td>Norway: € 7.80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UK: € 11.16</td>
<td></td>
</tr>
<tr>
<td>Price per kg</td>
<td>€ 17.50</td>
<td>Average price in national market</td>
</tr>
<tr>
<td></td>
<td>€ 9.76</td>
<td></td>
</tr>
<tr>
<td>Price per kg</td>
<td>€ 18.14</td>
<td>High price in national market</td>
</tr>
<tr>
<td></td>
<td>€ 11.70</td>
<td></td>
</tr>
<tr>
<td>Price per kg</td>
<td>€ 24.50</td>
<td>Status quo alternative price</td>
</tr>
<tr>
<td></td>
<td>€ 11.70</td>
<td></td>
</tr>
<tr>
<td>Price per kg</td>
<td>€ 25.11</td>
<td></td>
</tr>
<tr>
<td>Price per kg</td>
<td>€ 0</td>
<td></td>
</tr>
<tr>
<td>Price per kg</td>
<td>€ 0</td>
<td></td>
</tr>
<tr>
<td>Price per kg</td>
<td>€ 0</td>
<td></td>
</tr>
</tbody>
</table>
The choice experiment was designed to assess the public’s marginal WTP for more sustainable salmon production techniques such as IMTA. Respondents were presented with 8 choice cards each, an example of which is depicted in appendix C. Each choice card presented three alternatives; two purchasing decisions depicted as a fillet of salmon and one opt-out option (no purchase). Respondents were instructed to "imagine you walk into a supermarket and fresh (unfrozen) salmon is on your shopping list. The supermarket has several types of salmon. The packs are identical in size and quality, but some salmon is produced locally, some is produced abroad, and some is produced in a way that is better for the environment. They also vary in price. You are asked to indicate which of the salmon presented you would buy". Respondents were informed on the attributes included in the CE and to consider which option they would select given their budget.

Table 17 provides an overview of the CE attributes respondents received information on. The attribute production location was included as literature suggests that consumers prefer locally produced food over imported produce (Chambers et al., 2007; Feldmann & Hamm, 2014; Weatherell et al., 2003) and existing production location indicators can influence responsiveness to other labels (Adberrazak & Youssef, 2009). A pilot study demonstrated that a production location indicator indeed influenced respondents’ decision making, so a production location indicator distinguishing whether salmon was produced in national waters or imported was included in the CE design to include the location effect in the analysis.

The attribute sustainability was included as an indicator for the environmental impact of the production technique used. Research indicates that consumers have a positive WTP for sustainability in seafood production (Roheim, Asche, & Insignares Santos, 2011). Respondents were informed that the impact would vary depending on the production technique used and requested to assume that a drop in environmental pressure is due to a shift from monoculture towards IMTA which is deemed more sustainable. A rated eco-label was developed to indicate the environmental pressure to respondents in the CE. The alternative approach of using an eco-label that specifies the production process (e.g. monoculture or IMTA) such as used by Yip, Knowler, and Haider (2012) was deemed not applicable for this study for 2 reasons. Firstly, the pilot study showed a lack of familiarity of respondents with aquaculture production processes such as IMTA. Secondly, there is a high variability of IMTA production processes and the selection of specie or site can greatly impact the associated
environmental impact of a shift from monoculture to IMTA (Barrington et al., 2009; Troell et al., 2009) Instead a rated eco-label was used. This approach is in line with Martínez-Espiñeira et al. (2015) and suggested by Aarset et al. (2004) as viable approach to creating bottom-up pressure to influence uptake of new technologies by the aquaculture industry. The eco-label was based on the EU energy rating label (EU 2010), which is common on the European market and would be familiar to the respondents in EU countries. The eco-label consists of sustainability labels ranging from A-D rates, where D resembles the no-chance scenario associated with monoculture salmon farming practices (0% change in environmental pressure) and the C-A labels resemble increases in environmental sustainability by incremental 10% reduction in environmental pressure, with A being the greatest reduction.

A monetary attribute was included in the CE to enable respondents to make a trade-off between the attributes and allow derivation of the respondents’ WTP for the other attributes. The price levels were adjusted for the prices on the national markets based on a survey of supermarket prices in each country. For each country a low, medium and high price were selected. In the modelling process the medium price level was taken as base case to statistically derive the WTP estimates. The CE design was then blocked into four versions of eight choice cards per respondent to avoid respondent fatigue. Variation in the attribute levels was determined through D-efficiency, a commonly used approach to optimise the efficiency of experimental design (Ferrini & Scarpa, 2007). An efficient Bayesian experimental design aimed to minimise the Db error criterion (Louviere et al., 2000). A pilot study (n=201) indicated that the choice tasks and attribute level specification were defined realistically as respondents selected all attribute levels and indicated no issues when questioned.

5.4 Results

The analysis using RPL, SML and CMXL models were performed using NLOGIT4. A total of three models were run, from which preference and scale heterogeneity effects were assessed. A common functional form with identical model specification and attributes was included in all models to allow for model comparison without additional attributes confounding interpretation. This form ran consistently across all models and additionally produced the best goodness-of-fit across the models.
Estimation results

Table 18 presents an overview of the goodness-of-fit measures of the Log-likelihood, Akaike Information Criterion (AIC) and McFadden R² statistics. These statistics reflect the relative distance between the true likelihood function of the data and the fitted likelihood functions produced by the model and would penalise the addition of variables in relation to the change in model fit they incur. As such, a lower score indicates a better fit of the model to the true distribution of the data. Considering the models have a common functional form, it is evident that differences exist in the model fit across models. The SML performs the poorest with regard to model fit consistently across the Log Likelihood, AIC and McFadden Pseudo R² scores (-10390, 20799 and 0.218, respectively), followed by the RPL (-9976, 19977 and 0.249, respectively) and with the GMXL (-9671, 19370 and 0.272, respectively) performing best on the goodness-of-fit metrics used.

<table>
<thead>
<tr>
<th>Model</th>
<th>Log likelihood function</th>
<th>Aikake Information Criterion</th>
<th>McFadden Pseudo R-squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPL</td>
<td>-9976</td>
<td>19977</td>
<td>0.249</td>
</tr>
<tr>
<td>GMX</td>
<td>-9671</td>
<td>19370</td>
<td>0.272</td>
</tr>
<tr>
<td>SML</td>
<td>-10390</td>
<td>20799</td>
<td>0.218</td>
</tr>
</tbody>
</table>
Table 19  Results of RPL, GMX and SML Models

<table>
<thead>
<tr>
<th></th>
<th>RPL</th>
<th>SML</th>
<th>GMX</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient (SE)</td>
<td>Standard Deviation (SE)</td>
<td>Coefficient (SE)</td>
</tr>
<tr>
<td><strong>Random parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National Production</td>
<td>1.365*** (0.071)</td>
<td>2.105*** (0.073)</td>
<td>1.202*** (0.058)</td>
</tr>
<tr>
<td>Sustainability C</td>
<td>0.338*** (0.058)</td>
<td>0.938*** (0.087)</td>
<td>0.375*** (0.063)</td>
</tr>
<tr>
<td>Sustainability B</td>
<td>0.723*** (0.069)</td>
<td>1.184*** (0.084)</td>
<td>0.967*** (0.068)</td>
</tr>
<tr>
<td>Sustainability A</td>
<td>1.577*** (0.079)</td>
<td>2.08*** (0.079)</td>
<td>1.749*** (0.075)</td>
</tr>
<tr>
<td><strong>Non-random parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td>-0.339*** (0.008)</td>
<td>-0.53*** (0.018)</td>
<td>-0.359*** (0.09)</td>
</tr>
<tr>
<td>ASC3</td>
<td>-5.237*** (0.136)</td>
<td>-12.027*** (0.346)</td>
<td>-5.424*** (0.142)</td>
</tr>
<tr>
<td>NOASC3</td>
<td>2.203*** (0.101)</td>
<td>5.578*** (0.265)</td>
<td>2.312*** (0.109)</td>
</tr>
<tr>
<td>UKASC3</td>
<td>2.463*** (0.106)</td>
<td>6.978*** (0.215)</td>
<td>2.537*** (0.119)</td>
</tr>
<tr>
<td><strong>Variance parameter</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TauScale</td>
<td>1.343*** (0.019)</td>
<td>1.12*** (0.096)</td>
<td></td>
</tr>
<tr>
<td><strong>Weighting parameter</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamma</td>
<td>63.036 (337.334)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sigma</td>
<td>0.964 (1.77)</td>
<td>0.987 (1.434)</td>
<td></td>
</tr>
</tbody>
</table>

***, **, * indicate significance at 1%, 5%, 10% level respectively

Estimation results are shown in Table 19. Although Fiebig et al. (2010) indicated that inclusion of ASC interactions can produce estimation problems, interaction terms between sample country and the Alternative Specific Constant (ASC3) were included.
in the model. This was decided as the SML and GMXL models did not converge without these variables. With regard to the distribution of the models, CE parameters such as sustainability would follow a lognormal distribution when utility is positively related to sustainability and does not go into negative space. Even though these conditions are met for the GMXL, the model with the parameters specified as being normally distributed provided a better fit of the model with regard to the distribution of the data according to the model fit indicators of log-likelihood, AIC, BiC and Hannan Quinn. All parameter estimates were the expected sign and significant at the 1% confidence level. Models indicate a utility that is positive for nationally produced salmon and positively related to the sustainability of salmon production, with utility increasing for salmon with a higher sustainability eco-label rating.

The RPL model provides a positive coefficient for salmon produced in national waters as opposed to international waters (1.365) as well as for products with higher sustainability labels (label C: 0.338, label B: 0.722, label A: 1.577). The standard deviation of the RPL model is significant at the 1% significance level for all random parameter attributes; national production (2.105) and sustainability levels (C: 0.938, B: 1.184, A: 2.08). These values indicate, firstly, that preferences for the random parameters indeed vary across the population and secondly, that preferences enter negative space, which could explain the better fit of models where parameters were specified as normally distributed. The non-random parameters are as expected, with a negative utility for price (-0.339) and the opt-out option (-5.237) at the 1% significance level.

The SML model provides information on broad heterogeneity across individuals in addition to the estimated utility for consumer preferences. The model produces parameter estimates that are statistically significant at the 1% level for the national production location attribute (1.202) and produces a utility positively related to sustainability, across sustainability labels C (0.375), B (0.967) and A (1.749). The non-random parameters are as expected, with a negative utility for price (-0.53) and the opt-out option (-12.027) at the 1% significance level. The scale parameter (TauScale) is significant at the 1% confidence level. This statistic varies across respondents rather than across choices and represents the average scale heterogeneity across the sample. The magnitude of Tau (1.343) reflects the sample average value over the Halton draws with the average being taken into two directions. The population expected value of
Chapter 5

Tau is around 1 as specified by the model and any deviation from this number will be due to sample variability. The model results of a TauScale value higher than 1 indicates that the scale of the idiosyncratic error term varies across respondents so scale heterogeneity is indeed present in the population.

The GMXL accommodates heterogeneity in both the random ($\gamma$) and scale ($\tau$) parameters. It includes the distribution parameter, which reflects the effect of (both preference and scale) heterogeneity on the model estimates. The model produced positive coefficients for salmon produced nationally (1.472) and salmon produced more sustainably, with utility increasing as sustainability labels indicated higher sustainability across label C (1.003), label B (1.785) and label A (2.77). All coefficients are significant at the 1% level. The standard deviation of the random parameters is however insignificant, which will be elaborated on in the discussion section.

Table 20 Marginal WTP for Product Attributes for Pooled Data across Models

<table>
<thead>
<tr>
<th></th>
<th>RPL</th>
<th>SML</th>
<th>GMXL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (confidence interval)</td>
<td>Mean (confidence interval)</td>
<td>Mean (confidence interval)</td>
</tr>
<tr>
<td>National production</td>
<td>€ 4.07 (€ 0.77 - € 7.37 )</td>
<td>€ 2.27 (€ 2.14 - € 2.39)</td>
<td>€ 4.32 (€ 1.84 - € 6.80)</td>
</tr>
<tr>
<td>Label A</td>
<td>€ 4.69 (€ 1.05 - € 8.32 )</td>
<td>€ 3.30 (€ 3.14 - € 3.45)</td>
<td>€ 7.26 (€ 4.59 - € 9.92)</td>
</tr>
<tr>
<td>Label B</td>
<td>€ 2.14 (-€ 0.78 - € 5.06)</td>
<td>€ 1.82 (€ 1.60 - € 2.05)</td>
<td>€ 4.55 (€ 2.81 - € 7.23)</td>
</tr>
<tr>
<td>Label C</td>
<td>€ 0.99 (-€ 1.43 - € 3.41 )</td>
<td>€ 0.71 (€ 0.48 - € 0.94)</td>
<td>€ 1.48 (€ 0.91 - € 3.86)</td>
</tr>
</tbody>
</table>

1 Country specific results are presented in appendix E

The non-random parameters are as expected and consistent with other results, with the price coefficient (-0.359) being negative and significant at the 1% confidence level. The interaction terms of country of residence and the status quo options are all significant at the 1% confidence level. The scale parameter (TauScale) is higher than 1 (1.12) and significant at the 1% confidence level, signifying that scale heterogeneity is present in the population.
Willingness to pay measures

The willingness to pay estimates are summarised separately for the estimated WTP for marginal changes in the CE attributes (Error! Reference source not found.) and the estimated marginal WTP for products containing combinations of attribute levels (Table 21). The country specific estimations of WTP for changes in CE attributes can be found in Appendix E. Marginal WTP was estimated using Krinsky and Robb (1986, 1991) estimators. The estimates reported are the averages of the respondent-individual estimates, with exception of the SML results as this did not produce individual specific estimates leading to the reporting of model averages. Rather, the reported WTP estimates of the SML are based on the average of attribute estimates.

Table 21 WTP for Attribute Combinations across RPL, GMXL and SML Models

<table>
<thead>
<tr>
<th>Combination</th>
<th>Attribute Levels</th>
<th>WTP for Attribute Level Combination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>Sustainability Label</td>
<td>RPL</td>
</tr>
<tr>
<td>Location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>National</td>
<td>A</td>
<td>€8.75</td>
</tr>
<tr>
<td>National</td>
<td>B</td>
<td>€6.21</td>
</tr>
<tr>
<td>National</td>
<td>C</td>
<td>€5.06</td>
</tr>
<tr>
<td>International</td>
<td>A</td>
<td>€4.69</td>
</tr>
<tr>
<td>International</td>
<td>B</td>
<td>€2.14</td>
</tr>
<tr>
<td>International</td>
<td>C</td>
<td>€0.99</td>
</tr>
</tbody>
</table>

The RPL takes the preference heterogeneity into consideration. The estimates of the marginal WTP for salmon produced in national waters varies across the countries from € 2.29 in the UK to € 5.24 in Ireland. The WTP estimation for national production location in the pooled data set is estimated at € 4.07, which falls in the 95% confidence interval of all individual country estimates. The estimates for the marginal WTP for
the eco-label are consistent across the countries and are positively related to the level of sustainability indicated, signifying a positive preference for a sustainability increase. Each of the estimates here are based on the marginal WTP moving from the D eco-label (Monoculture production). The estimates for salmon products with sustainability label C varies from € 0.91 (Ireland) to € 1.03 (Norway and UK), with a WTP of € 0.91 for the pooled data set. Salmon products with sustainability label B had a higher WTP, ranging from € 2.02 (Norway) to € 2.27 (Ireland), ceteris paribus, with an estimated € 2.14 for the pooled data set. The marginal WTP for products with sustainability label A range across the countries from € 4.13 (Norway) to € 5.62 (Ireland). The marginal WTP for the pooled data set was estimated at € 4.69. The country-specific marginal WTP estimates fall within the confidence intervals of the pooled data estimate for all countries and across all labels (C – A), so no significant differences exist across the countries.

The SLM model takes into account the scale heterogeneity of respondents and hence produces different results. It produces a marginal WTP of salmon produced in national waters estimated at € 2.27. The marginal WTP for the sustainability labels is positively related to the degree of sustainability reflected, at € 0.71 (label C), € 1.82 (label B) and € 3.30 (label A).

The GMXL model includes both scale and preference heterogeneity. The WTP for salmon produced in national waters is estimated between € 0.99 (UK) and € 6.24 (Ireland) for the individual countries and € 4.32 for the pooled data set. The WTP estimate for the UK deviates from the other countries as the WTP estimate falls outside the 95% confidence interval of the WTP estimates of the pooled data, although the 95% confidence intervals of the estimates overlap. The WTP estimates for salmon with sustainability label C vary from € 2.06 (UK) to € 2.63 (Ireland), and an estimated WTP of € 0.99 for the pooled data set. WTP for products with a sustainability label B was estimated from € 3.88 (UK) to € 5.46 (Ireland) and € 4.55 for the pooled data set. The highest sustainability label (A) had a WTP estimate varying from € 5.78 (UK) to € 9.27 (Ireland), with an estimation of € 7.26 for the pooled data set.

The WTP estimates for national production location are all positive, both for the pooled data set and the individual country data sets, although in the Mixed Logit and the GMXL models the lower 95% confidence interval enters negative space when isolating the UK data. Overall, the mixed logit WTP estimates are consistent across the
countries and demonstrate a positive relationship between WTP and the level of sustainability that is consistent across the countries. The same pattern is visible in the WTP estimates from the SML model. However, the estimates from the SML model are lower than the estimates from the other two models. The estimates from the GMXL model follows the same pattern, but indicates a higher WTP than the estimates of the other models. Thus, the estimates of the models can be deemed comparable in direction and proportional WTP estimates, but produce different magnitudes of WTP estimates.

5.5 Discussion

This paper contrasts methods of addressing heterogeneity in discrete choice analysis using CE data on consumer preferences for farmed salmon alternatives. Three commonly applied logit model extensions that address heterogeneity issues, albeit in different ways, were selected to analyse the CE data; namely the RPL, the SML and the GMXL. The models are applied with identical specification and welfare estimates are presented for each of them to assess how model choice affects WTP estimations.

The existence of scale heterogeneity in the CE data is established as the indicators for scale heterogeneity (Tau) indicate scale heterogeneity at the 1% confidence level in both the SML and the GMXL models. The existence of scale heterogeneity could indicate that the researchers’ decision to include (exclude) preference or scale heterogeneity may impact WTP estimations and lead to biased estimations. Therefore, the model fit and model coefficients are examined closer to assess heterogeneity sources.

A common approach to assess model fit is to compare goodness-of-fit indicators. The models provided considerately different fits to the variability observed in the data. A comparison of the goodness-of fit indicators (Log likelihood function, Akaike information criterion and McFadden Pseudo $R^2$) across the models showed an increase in fit from SML (lowest), to RPL and the GMXL for which the best fit was indicated. Interestingly, the models were identically ranked across all model fit indicators. This suggests that models focusing on scale heterogeneity (SML) provide a poorer reflection of the true data distribution in comparison to models taking into account preference heterogeneity (RPL). In terms of model fit a model accounting for a combination of preference and scale heterogeneity (GMXL) is preferable, whereas a
model accounting for preference heterogeneity is preferred over a model accounting for scale heterogeneity.

Two elements of the model output should be highlighted. First, the significance at the 1% confidence level of the standard deviations in the RPL indicates that the utility for production location and sustainability level indeed varies across the population. This is especially interesting considering the inclusion of the interaction terms of the ASC3 and the country of residence. The fact that population utility variation exists despite including this variable suggests that preferences may vary according to factors outside the model. This supports our use of the SML and GMXL to explore additional sources of preference heterogeneity. Second, the model coefficients indicate that the RPL and GMXL models are comparable in outcome for all parameters with exception of the sustainability parameters. Interestingly, the reverse was true for the SML and RPL models, where model coefficients were comparable for the sustainability parameters only. This variation could imply an uneven distribution of heterogeneity sources across the model parameters.

Differences in WTP estimates across the models were considerable, with the SML producing the lowest estimates and the GMXL the highest. The environmental premium associated with more sustainably farmed salmon was estimated using CE data from Ireland, Norway and the UK. Results were obtained for consumer preferences for salmon being produced in national waters and salmon with a rated sustainability eco-label (rating A-D) reflecting the environmental pressure of its production. The pooled data set produced marginal WTP estimates for the RPL of €4.07 for nationally farmed salmon and €0.99, €2.14 and €4.69 for salmon that is produced 10%, 20% or 30% more sustainably, respectively. The SML model gives lower WTP estimates of €2.27 for nationally produced salmon and €0.71, €1.82 and €3.30 for salmon produced 10%, 20% and 30% more sustainably, respectively. The GMXL model gives the highest WTP estimates at €4.32 for salmon farmed in national waters and €1.48, €4.55 and €7.26 for 10%, 20% and 30% more sustainable salmon, respectively. The relative differences in WTP estimates are consistent across individual attributes and welfare estimates for products with combinations of attribute levels. Additionally, differences between individual country WTP estimates are visible, as WTP estimations were slightly higher for respondents from Ireland and lower for respondents from the UK. The differences between the welfare changes
estimated demonstrate the importance of accounting for sources of heterogeneity in CE data, as that decision can have a considerable effect on WTP estimates and therefore on research conclusions and recommendations.

By comparing the output of several methods addressing heterogeneity, this study indicates that welfare effect estimations are indeed affected by model choice. Both goodness-of-fit indicators and the magnitude of the difference between the WTP estimates from the RPL model and the SML model suggest that preference heterogeneity has a stronger impact on WTP than scale heterogeneity. Based on these results, it could be argued that accounting for scale heterogeneity in combination with preference heterogeneity by using the GMXL is preferred over models accounting for one source of heterogeneity. In contrast, the SLM provides a relatively poor fit in terms of goodness-of-fit, whereas the RPL model performs better. This suggests that failure to accounting for scale heterogeneity will lead to less bias than failure to account for preference heterogeneity. This is supported consistently across the welfare effects estimations and goodness-of-fit indicators.

The generalisations of this study are limited by the use of one single CE data set, but these findings are in line with other research (Fiebig et al., 2010; Greene & Henscher, 2010) and add to the current literature assessing models assessing heterogeneity issues in discrete choice analysis. The GMXL has been criticised for not correctly distinguishing scale heterogeneity from other sources of heterogeneity (Hess & Rose, 2012). Contrary to that view Greene & Henscher (2010) identify scale and taste heterogeneity within the GMXL separately. It is argued that scale and taste heterogeneity cannot be disentangled and are instead confounded within the data (Scarpa, Thiene & Train, 2008).

Multiple elements of the GMXL in this study leads to caution in interpretation of the model results. First, the insignificance of the standard deviations in the GMXL model may be due to two reasons. The model allows for variability to be accounted for in the random and scale parameters. Hence, the variation in the data is partially being accounted for in additional variables, leaving less variance available for the covariates and instead is being accounted for in the random and scale parameters. It may however also be due to the confounding effect between the sources of the heterogeneity. Second, the stark variation in the WTP estimates across models indicates that bias may be present. Although the model selection is based on
goodness-of-fit indicators, Beck, Rose & Henscher (2013) suggest that improvements in goodness-of-fit indicators may in fact be attributed to econometric differences rather than an increase in the models representation of the variation in the data. Hess & Train (2017) advocate for the use of a mixed logit with full correlation instead. Therefore, further study into the effectiveness of GMXL models is required.
Chapter 6

Discussion & Conclusion

This chapter provides a summary of the research presented in this thesis and a discussion of the key findings, particularly in relation to the research aims defined in the introduction. The overarching goal is to provide estimations of the publics’ WTP for sustainable aquaculture production methods. Different modelling techniques were utilised to produce WTP estimations that take into account varying econometric elements existent in the data, particularly latent groups and types of heterogeneity.

The thesis has set out the research context (6.1) after which the results of the analyses estimating the publics’ WTP are presented. First, a case study of Ireland using CL and RPL methods is described, after which the results of the WTP analysis of the pooled data set using RPL and LC models are given (6.2). The use of eco-labels as a tool to communicate environmental impact of food production to consumers is assessed (6.3). Differences in model performance are discussed, both for the models applied in 6.2 as well as models including scale heterogeneity (6.4). Finally, the research weaknesses (6.5) and final recommendations (6.6) are given.

6.1 Research Context

The multidisciplinary context of IMTA adoption in the European aquaculture industry becomes evident when outlining the main elements influencing IMTA uptake. The sample countries exhibit large differences in the development and regulation of aquaculture. Aquaculture industries in all sample countries have in common that they are impacted by environmental factors and market factors, particularly competition. However, they exhibit large differences in specie selection, climate and environmental factors such as storms (in the Atlantic) and draughts (in Israel) which can cause crop losses and alter production levels.

Simultaneously, aquaculture production activities are criticised for having a negative environmental impact (Ariel & Olesen, 2002; Cabello et al., 2016; McCarty, 2004; Nylund et al., 2003; Rimstad, 2011; Talbot & Hole, 1994) that can be minimised
by innovating production techniques and creating appropriate monitoring and governance procedures. With regards to innovation, IMTA experiments have demonstrated to both lower the environmental impact (Bartsch et al., 2013; SEPEA, 2017; Skår & Mortensen, 2007; Troell et al., 2003; Troell et al., 1997) and have economic benefits (Barrington et al., 2009; Chopin et al., 2004, 2010; Ridler et al., 2007). It may however not be a solution to mitigate all aquaculture impacts; partially because not all impacts are affected by shifting from monoculture to IMTA systems, but more importantly because the benefits associated with IMTA cannot be linearly scaled up from experimental to large-scale commercial sites (Troell et al., 2009). However, the results from experiments look promising in partially mitigating impacts and improving aquaculture production technologies and stimulating IMTA uptake could be part of appropriate industry governance.

Political factors play a role in industry regulation; particularly EU membership and the willingness of governments to promote environmental protection and sustainability affects how the industry is regulated and environmental impact is reduced. The governance of aquaculture practices can no longer be treated as a national matter. Despite regulation being formulated at the national level, it is heavily influenced by international and European legislation. On the international level UNCLOS has the strongest impact (UN, 1982), while the European legislation exerts influence over aquaculture development through multiple strategies. Regulations impacting aquaculture the strongest are the Marine Strategy Framework Directive (MSFD) (European Union, 2008), the Blue Growth Strategy (European Commission, 2012b, 2017b), the Habitats Directive (European Council, 1992) and the Maritime Spatial Planning (MSP) platform (European Commission, 2013b), each addressing a different aspect of aquaculture production. The Blue Growth Strategy is however believed to be the most applicable to IMTA uptake, as it is directly related to the balance between industry growth and environmental protection.

Since 2000 the EU has taken a more integrated and holistic approach through the use of Directives and creating the IMP (Apitz et al., 2006). Directives are based on the principle of subsidiarity, meaning that goals are specified at the European level, but the specific action to be taken is left to the state or region. Similarly, the IMP functions as an umbrella strategy; setting out coordination actions to develop an
integrated and coherent European policy. EU marine policy has developed from a compartmentalised system towards an integrated approach which stresses the need for the ecosystem approach, integrated management and regional cooperation. The EU framework facilitates high-level regulation while respecting national sovereignty, which is in line with the use of market instruments such as eco-labels. A literature study indicated that European consumers have a positive approach towards eco-labels for seafood and decreasing the environmental impact of seafood production (Brécard et al. 2009, 2012; Bronnmann & Asche 2016; Jaffry et al. 2004; Johnston et al. 2001; Roheim, Asche, and Insignares Santos 2011; Salladarré et al. 2010; Uchida et al. 2014; Wessells et al. 2016).

Three research goals were defined in this thesis that aimed to assess consumers’ WTP for IMTA products across Europe. The overall goal was to identify the market potential of IMTA on the European seafood market by assessing consumers’ knowledge of seafood production, attitudes towards aquaculture and their estimate their preferences for sustainable aquaculture production. The first research goal was to estimate the Irish consumers’ WTP for IMTA salmon. Ireland is a particularly interesting case for IMTA development as it has developed a high value niche market in the past. Therefore, it is assessed separately in chapter 3, using the survey data retrieved in Ireland. The results are further discussed in section 6.2. The second research goal was to estimate the European consumers’ WTP for IMTA finfish and it was described in chapter 4. RPL and LC models were estimated on the pooled data set as well as on the individual country data. Details on the research results are described in section 6.2. The third research goal aims to assess the effect of the selection of econometric models that take into account preference and/or scale heterogeneity. A comparative approach was taken and several econometric models (RPL, SLM and GMXL) were used on the CE data for the salmon producing sample countries to estimate their WTP and assess the models and model fit. The analysis is reported on in chapter 5 and the results are summarised in section 6.3.

### 6.2 Key Findings on Public WTP for Sustainable Seafood

The initial approach in modelling the publics’ WTP for sustainability in seafood production processes across Europe was to isolate one of the sample countries and estimate the public’s WTP of a singular sample country before estimating the WTP
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of the European public. The first country assessed is Ireland, after which the pooled CE data was used to model the public WTP across Europe.

WTP in Ireland

The first paper (chapter 3) presents a case study that was conducted on the Irish public estimating the environmental premium associated with sustainably farmed salmon. The analysis utilised CE data retrieved from Irish respondents and assessed preferences and willingness to pay for CE attributes using Conditional Logit and Random Parameter Logit models. Specifically, it focused on respondents' utility for the degree of sustainability and local production labels on salmon. The study resulted in marginal WTP estimates of €6.33 for salmon produced in Irish waters, and €1.72, €3.65 and €9.26 for 10%, 20% and 30% more sustainably produced salmon, respectively. Although both CL and RPL models were utilised, the results presented in this paper are based on the RPL model on the grounds that it provides a better fit as indicated by goodness-of-fit indicators. Based on this case study, the Irish public can be seen to have a WTP positively related to local production and the degree of sustainability of their seafood.

In addition to estimating consumers' WTP, factors affecting purchasing activities were included in the analysis; more specifically, respondents' knowledge on marine environmental problems, public attitudes towards these issues and socioeconomic indicators. The aim of this inclusion is to identify underlying factors influencing purchasing decisions and special interest goes out to the role of eco-labels as a tool to inform consumers in purchasing decisions. The analysis demonstrates that the Irish public acknowledges marine environmental impacts associated with aquaculture. The Irish public is unfamiliar with IMTA, but after receiving information on its techniques and expected implications they regard it as a potential solution for marine environmental problems.

With regard to seafood purchasing decision making, the Irish public considers themselves too uninformed to make a responsible decision when purchasing salmon and desires to receive more information on environmental pressure resulting from salmon production. However, analysis of the use of tools and information available to consumers on the marketplace indicated low familiarity with and little use of seafood eco-labels. This apparent contradiction can be explained by issues
commonly identified in the analysis of eco-labels, such as market saturation and a lack of transparency, which can incite consumer confusion and reduce trust in eco-labels (Bush et al., 2013; Karl & Orwat, 1999).

This initiatory analysis focused on the Irish salmon market, but preferences are expected to vary across countries (Johnston et al., 2001b). Therefore, the analysis expanded her WTP estimation models using the pooled data set, including data from all sample countries to account for variations in preferences.

**WTP across Europe**

The second paper (chapter 4) presents the results of the analysis of the pooled CE data and thereby covers Ireland, Italy, Israel, Norway and the UK. This paper adopts a latent class modelling approach, as this type of model identifies underlying groups within the data. It thereby provides more information on differences in consumer preferences across the sample countries. Latent classes were modelled on data from each sample country separately and for the pooled data. The results show WTP estimates that were positive for the CE attributes (with exception of the monetary attribute, as is expected) consistently across the individual sample countries as well as for the pooled data set. The publics’ marginal WTP for locally produced seafood is € 6.02. The publics’ marginal WTP for increased sustainability was estimated as € 2.45, € 4.16 and € 6.89 per kilo of unfrozen product with sustainability label C, B and A, respectively.

Additionally, the latent class approach allows classes to be allocated to consumer profiles that are defined according to the utility for attributes, the alternative specific constant and several interaction terms. Respondents were labelled as either green, local, determined, flexible, or economic buyers. Green and local buyers were characterised by a utility that is relatively high compared to other variables for the sustainability and national production attributes, respectively. The determined, flexible and economic buyers were characterised by their shopping behaviour in terms of shifting to alternative products. The aim of identifying these classes is to gain insight in consumer preference variations across latent groups and how these vary across the sample countries. Additionally, underlying factors influencing seafood purchasing decision making were identified. Latent classes in the pooled data were identified as determined (54%), green (28%) and local (18%) buyers. These
three latent class profiles were also dominant in the analysis of the individual sample country data, yet some smaller profiles were detected that remained unidentified in the pooled model under the model specification with the best fit. The typical European consumer was characterised as a determined buyer, as this class was represented most dominantly in the European sample countries in comparison with other types (Norway (48%), Ireland (39%) and the UK (39%)).

The contribution of the study to the academic literature

The papers presenting public WTP for sustainability in seafood production (chapter 3 and 4) directly fulfil the demand from academics to expand knowledge on the market value of IMTA to assess its potential for future aquaculture industry development (Chopin et al. 2010). This research demonstrates that the European public has a positive WTP for more sustainably produced seafood. These findings are in line with the positive preferences identified, both outside of the European market (Barrington et al, 2010; Yip et al, 2016) as within the European borders (Whitmarsh & Wattage, 2006).

The aquaculture industry has suffered from a bad reputation with regard to its environmental sustainability (Barrington et al. 2010; Yip et al. 2016), while research has indicated that social acceptability is vital to successful industry development (Barrington et al. 2010). The European public has indicated in this research that it is increasingly aware of the environmental impact of seafood production and considers IMTA as a more sustainable alternative than monoculture production methods. However, even those respondents that are familiar with eco-labels on the European market and use eco-labels regularly perceive differentiation on sustainability attributes as being difficult.

The European public indicated it values information tools such as a seafood eco-label. The European aquaculture industry could benefit from carving out a valuable market position for itself to match the global growth rates. A sustainable aquaculture production market, such as one based on IMTA production techniques, may therefore be able to stimulate European aquaculture to approach global aquaculture growth rates, while information provision to European consumers on the environmental impact of aquaculture products could provide consumers with the
tools to maximise their utility.

6.3 **Seafood Eco-labels**

Potential may exist for the development of an eco-label as presented in the survey. The labelling scheme used in this research is hypothetical, yet it is based on an existing mandatory energy-rating label for electronic goods and buildings that is widely in use in Europe. Under the hypothetical eco-label, an aquaculture product would receive a label reflecting the environmental impact of its production, ranging from A-D. These ratings reflect the environmental impact of aquaculture production. The base case (label D) consists of the impact of production under the status quo (monoculture), whereas labels C, B and A reflect a reduction in environmental pressure of 10%, 20% and 30%, respectively.

The eco-label as presented in the survey has multiple perceived benefits. Common eco-labelling schemes are criticised for their pass-fail approach (Lavallee & Plouffe, 2004) as they do not provide information on the degree of environmental impact. However, grading eco-labels continue to provide incentive to innovate production processes to reach a higher tier and have been proposed by researchers such as Aarset et al. (2004) to stimulate sustainable industry development. Additionally, the effectiveness of eco-labels is criticised due to distrust towards the food industry and ignorance and scepticism towards the independence of certifiers (Aarset et al., 2004), which can be accelerated by a lack of transparency of certification (Sherman, 2012). A rated eco-label with a format that is familiar and trusted to the European public is more likely to be effective.

This is in line with the survey data, as respondents indicated to use eco-labels (1.86 average to indicate eco-label use sometimes, most of the time or always on a Likert scale 1-5) but a majority expressed a positive attitude towards an eco-label as presented in the survey.

This research has identified incentives from multiple actors in the European aquaculture industry for the eco-label as presented in the survey. This eco-label is in line with the EU plans for the future sustainable development of the European aquaculture industry. Research in this thesis has also indicated a preference for the rated eco-label as well as a positive WTP for the attributes it reflects. Additionally,
the industry would benefit through product diversification and improving the completion position of European competition position. IMTA products could potentially be more profitable than monoculture products, but this remains dependent on environmental factors, optimisation of the production process and adequate channelling of WTP towards producers. The first two will require further development of environmental and economic assessment models, but for transboundary standardisation of the eco-label and the development of tools to regulate additional revenue from consumers’ price premiums the EU is best-suited institution to govern Europe-wide seafood market steering policies.

6.4 Heterogeneity in Seafood Preference Models

The research in chapter 3 and 4 demonstrates that differences exist between the models assessing public WTP for seafood preferences. These differences can be attributed to both the inclusion of additional sample countries and the selection of econometric models. The analyses included controls for non-observed heterogeneity in the mean preferences, yet respondents may interpret and process choice tasks and information differently (Train & Weeks, 2005), leading to scale heterogeneity. More recent literature suggests that scale heterogeneity may influence WTP models in addition to preference heterogeneity and lead to biased results (Fiebig et al., 2010) and controlling for scale heterogeneity could improve the model.

Scale heterogeneity

The third paper (chapter 5) modelled WTP estimates for salmon consumers across Europe while contrasting methods of addressing heterogeneity. It utilised CE data from the salmon producing countries in the dataset; Ireland, Norway and the UK. In the paper, three logit model extensions were applied; the RPL, the SML and the GMXL. These extensions include a different type of heterogeneity and do so by different methods. More specifically, the RPL addresses preference heterogeneity, while the SML includes scale heterogeneity and GMXL takes into account both preference and scale heterogeneity. This paper adds to current literature by comparing models addressing heterogeneity types, as there is a dearth of research on seafood preferences taking into account scale heterogeneity.

Scale heterogeneity was identified in the CE data by the indicator for scale
heterogeneity ($\tau$) in both the SML and GMXL models. The magnitude of $\tau$ (>1) and its significance (1%) indicate that scale heterogeneity was indeed present in the CE data and these results suggested that the decision to include scale heterogeneity in modelling WTP affected the final WTP estimations.

The WTP estimates were considerably different across the models. The RPL model on the pooled data set produced marginal WTP estimates of € 4.07 for salmon produced in national waters and € 0.99, € 2.14 and € 4.69 for salmon with an eco-label indicating a decrease in environmental pressure of 10%, 20% or 30%, respectively. The scaled mode gave lower WTP estimates of € 2.27 for nationally produced salmon and € 0.71, € 1.82 and € 3.30 for salmon produced 10%, 20% and 30% more sustainably, respectively. The Generalised Mixed Logit model produced the highest WTP estimates at € 4.32 for salmon farmed in national waters and € 1.48, € 4.55 and € 7.26 for 10%, 20% and 30% more sustainable salmon, respectively. The pattern within these variations indicated lower WTP estimates for the SML and higher WTP estimates based on the GMXL model, indicating the potential effect of including sources of heterogeneity in estimating welfare effects. Differences between WTP estimates exist between the models, suggesting that the decision to use a model that includes (excludes) heterogeneity can lead to biased results. However, WTP estimates cannot be compared across the papers, as the models were run on different data selections within the CE data. This is demonstrated by the variation in the WTP estimates that were based on the RPL that was applied with identical specification across all papers. This variation can be explained by both data selection and model selection. Given that these effects cannot be isolated, the decision was made to focus on the first two papers to assess the effect of preference heterogeneity and the last paper to assess the effect of including scale.

Comparing preference heterogeneity & scale heterogeneity

With regard to preference heterogeneity, the RPL and LC models have different approaches to control for unobserved preference heterogeneity. The RPL takes into account preference heterogeneity by allowing the coefficients of observed variables to vary randomly across respondents, whereas the LC model assesses the source of preference heterogeneity by identifying latent groups. Although the RPL model was an improvement to the CL model in terms of model fit and providing output on the distribution of the preferences across the sample, the LC approach allowed for
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comprehensive insight into variations of preferences within the sample. The inclusion of scale heterogeneity extensions in the model provided considerably different model fits to the variability observed in the data. A comparison of the goodness-of-fit indicators across the models showed an increase in fit from SML (lowest), to RPL and the GMXL for which the best fit was indicated. It should also be noted that the Goodness-of-Fit indicators were consistent across all models. This indicates that welfare effect estimations are indeed affected by model choice. Both goodness-of-fit indicators and the magnitude of the difference between the WTP estimates from the RPL model and the SML model suggest that preference heterogeneity has a stronger impact on WTP than scale heterogeneity. The preferred model accounts for both scale and preference heterogeneity, such as a hybrid model like the GMXL. However, the relatively poor fit of the SLM compared to the RPL in terms of goodness-of-fit suggests that not accounting for scale heterogeneity will lead to less bias than not accounting for preference heterogeneity. This is supported consistently across the welfare effects estimations and goodness-of-fit indicators.

The generalisations of this study are limited by the use of one single CE data set. However, these findings are in line with other research (Fiebig et al., 2010; Greene & Henscher, 2010) and add to the current literature assessing models assessing heterogeneity issues in discrete choice analysis.

Where findings fit in with academic literature

The WTP estimates of the models accounting for scale heterogeneity are in line with other research that identified positive WTP for sustainable or IMTA produced seafood (Fiebig et al., 2010; Greene & Henscher, 2010). This is with exception of the WTP estimate of the highest sustainability attribute, which is higher than other estimations.

These results are interpreted in the context of the debate surrounding the GMXL model. Despite the GMXL model producing separate parameters for preference heterogeneity and scale heterogeneity and scholars interpreting these parameters as being distinct (Greene & Hensher, 2010). It has also been suggested that the GMXL is incapable of distinguishing scale heterogeneity from other sources of heterogeneity (Hess & Rose, 2012). It is argued that scale and taste heterogeneity cannot be disentangled and are, instead, confounded (Scarpa, Thiene & Train, 2008).
Therefore, care is taken in the identification of a better performing model. Goodness-of-fit indicators are a commonly used tool to determine the model, as they reflect the degree to which the variability in the data is reflected by the model. Even though some publications are based on a singular indicator, in this study several indicators, being the AIC, BIC, Hannan Quinn statistic and Log-likelihood were compared to each other. These indicators consistently indicated to prefer the GMXL model. However, despite the prevalence of goodness-of-fit indicators, Beck, Rose & Henscher (2013) suggest that in the case of the GMXL model, improvements in goodness-of-fit indicators may in fact be attributed to econometric differences rather than an increase in the models representation of the variation in the data, so one must remain cautious in the interpretation of GMXL model results. This caution is raised further by the RPL model providing a more intuitive model that is simpler and provides stronger significance in the model parameters. The use of a mixed logit with full correlation has been suggested instead (Hess & Train (2017). While models including scale heterogeneity are still being developed it is advisable to continue to interpret these models critically and consider other methods for accounting for heterogeneity sources.

6.5 Research Limitations

Despite designing the CE and modelling the WTP estimations with care, certain limitations are evident and should be acknowledged in this thesis. These limitations evolve around the type and scope of the data, as well as the modelling process.

First, the analysis for all chapters is based on cross-sectional data. This means that the CE data is collected at a single point in time and can be regarded as a snapshot. As a result, neither does cross-sectional data allow the analysis of any trends in preferences over time, nor does it guarantee representativeness. Admittedly, more information on consumer awareness for sustainable seafood, consumer preferences and purchasing behaviour could be retrieved from time-series data, but the research was limited due to practical elements, such as the time-frame of the research, funds available for data collection and data collection being in the hands of external partners (IDREEM consortium).

Second, the eco-label has been specified generally, with the sustainability rates being defined as proportional improvements of 10% of the total environmental pressure under monoculture. This lack of quantification of the sustainability rates to
respondents before the CE could have affected the interpretation of the choice tasks. An exact definition of the sustainability rates expressed by the eco-label is hindered by a lack of aquaculture impact assessments that can take into account the wide range of issues required to make an adequate sustainability assessment. Such an assessment for any aquaculture facility would include consumption of fossil fuels, production of waste and by-products and impacts on non-fishery components of marine ecosystems. The assessment of an IMTA system would have to be extended by the effect of species selection and any elements affecting the optimization of the production process. It is expected that the development of impact assessments for IMTA farms can assist in future design of the eco-label.

Third, hypothetical choice bias can occur due to the hypothetical nature of the CE. Hypothetical choice bias describes the tendency of respondents to unintentionally alter their selection behaviour based on the knowledge that their CE choices don’t have real-life consequences. The CE design included a cheap talk script to minimise hypothetical bias, in line with the approach by Cummings and Taylor (1999). A cheap talk script explains the concept of hypothetical bias to the respondent prior to completing the CE, which assists in making respondents aware of hypothetical bias and self-correcting for it. Experiments have proven cheap talk scripts to minimise hypothetical bias (Carlsson et al., 2005).

6.6 Policy recommendations

The Blue Growth Strategy is the EU’s long term strategy to support sustainable growth in the marine sector (European Commission, 2017b). It has the dual aim of harvesting Europe’s oceans to increase economic growth, while increasing the sustainability of its ocean usage to secure unceasing economic growth. The EU-wide blue economy, i.e. economic activity in the EU related to or based on marine resources, represents roughly 5.4 million jobs and generates a gross added value of 500 billion euro annually (European Commission, 2012b).

The strategy focuses on five maritime sectors that are considered high-potential, among which the aquaculture sector. The Blue Growth strategy aims at removing barriers to the market rather than restricting the market with additional regulations. For example, it aims to reduce bureaucratic barriers so market forces can correct
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market failures (European Commission, 2017a).

With regards to the development of the aquaculture sector, the strategy aims to strengthen the aquaculture sector by improving space usage through marine spatial planning (European Commission, 2017a) and improving the sectors image through marketing and information tools, such as labelling and marketing partnerships among fish farmers. The Commission also plans to continue to adopt standards to improve the welfare of farmed fish, as that topic received increasing attention in recent years (European Commission, 2017c). Community legislation on food safety was being redrafted, especially with regards to the use of antibiotics and dioxins. Additionally, the Blue Growth Strategy aims to reduce negative environmental impacts, such as toxic algal blooms, animal deceases and sea lice infestations (European Commission, 2009). More recently, the Commission have spoken of reducing administrative burdens to facilitate investment and growth, as well as promoting the sustainability of EU aquaculture products (European Commission, 2017a).

IMTA promotion is appropriate in the context of Blue Growth, as the development plans of European aquaculture on both national and EU level stimulate sustainable industry growth while emphasizing the ecosystem approach and integrated management to facilitate environmental protection. IMTA adoption by the industry is in line with this dual aim, as experiments with IMTA indicate an overall reduction in environmental impact and potential increase in productivity (although dependent on production setup). Simultaneously, IMTA adoption can contribute to states’ environmental protection measures, either to fulfil EU aims or to confer to nationally imposed sustainability standards (such as defined by Norway). The identification of the environmental-economic win-win attributed to IMTA has so far not led to large-scale uptake by producers. This research therefore suggests a pathway to IMTA adoption that is in line with Blue Growth.

A key aim of the Blue Growth Strategy is the provision of information to consumers through marketing tools. Mandatory information on aquaculture products sold within the EU market consist of the specie name, production method, production location, best before date, allergens and whether it has been defrosted. Particularly, labelling is expected to be an essential tool to distinguish food from products it may be confused with in the absence of production information (EC, 2018). The eco-label
can be utilised as a policy instrument that stimulates environmental friendly production techniques.

Eco-labels include consumers in market governance through potentially altering purchasing decision-making. The benefits of a rated eco-label will however vary across actors. Consumers of aquaculture products benefit from an eco-label as it allows them to include previously hidden information on the environmental impact of seafood in their purchasing decision, thus supporting utility maximisation. This is especially valuable considering that this research demonstrated that consumers experience a lack of tools and information to make informed purchasing decisions. Simultaneously, producers benefit from the eco-label through the opportunity to differentiate their products on the sustainability attribute and thereby increasing the market value of products that fulfil sustainability criteria. Finally, the EU can utilise the eco-label as a regulatory tool that stimulates the industry to adopt more sustainable production techniques and stimulating industry growth, while respecting the sovereignty of member states in the regulation of their national industries in line with the EU’s integrated approach.

This research confirmed that the European public is willing to pay a price premium for more sustainably produced seafood as indicated by the eco-label. The preferred model (Generalised Mixed Logit) led to consumer WTP estimations at € 1.48, € 4.55 and € 7.26 for 10%, 20% and 30% more sustainable salmon, respectively. Although these levels are unsubstantiated in terms of the method and degree of environmental improvements, these results indicate a positive WTP that is positively related to the degree of sustainability in seafood production. Additionally, assessing the underlying factors that influence seafood purchasing decision making, the LC model identified the European consumer to be determined (54%) (i.e. not altering purchasing plans while shopping), green (28%) (i.e. reducing environmental impact) and local (18%) (i.e. avoiding imported goods) buyers. The typical European consumer can therefore be characterised as a determined buyer that is increasingly aware of the environmental impact of seafood production and wishes to minimise impact.

The success of an eco-label as proposed in this thesis is dependent on several factors involving the public and the EU. The public will need to be educated to stimulate eco-label use. The adoption of new eco-labels depends on consumers’ motivation,
Eco-label use and trust in the organisation endorsing the label (Thøgersen et al., 2010). This thesis revealed that European consumers wish to receive more information on the environmental impact of their seafood purchases. The European consumer is used to eco-labels, as a majority indicated to use eco-labels at least sometimes when purchasing seafood, and welcomed an EU wide rated eco-label for the seafood market. These results suggest that the requirements for eco-label adoption by European consumers are fulfilled. However, consumers will need to be informed on the meaning and responsible organisation of the label. Additionally, further knowledge of environmental issues surrounding aquaculture production would make for more informed decision-making when purchasing seafood.

The EU is an appropriate actor to create and implement a rated eco-label on the European market, foremost due to her initiation and realisation of the energy rating label on which this label is based. Moreover, within the context of Blue Growth the EU has created food labelling standards to provide consumers with information required to make an informed choice on their health and nutrition information (EC, 2018). Additionally, the EU is commended for its regulation and control of the environmental impacts of the aquaculture industry (Read & Fernandes, 2003) and as an international body with a degree of power over European nation-states she can facilitate centralisation and standardisation of the eco-label. Centralisation entails that the EU can initiate measures to ensure that the added revenue from consumers’ WTP does not stay with the retailer, but is instead directed towards aquaculture producers to function as an incentive to shift towards IMTA systems and cover any additional costs. Reasons for inclusion of the EU also include the trust enjoyed by the current energy rating label and the role of the EU in its management, as transparency and accountability are key elements in eco-label adoption.

6.7 Future research

Additional research is required on several areas to facilitate IMTA uptake. The key areas requiring further exploration are the environmental and economic effects of IMTA adoption. The development of the sustainability rating eco-label requires more research to adequately quantify the sustainability rating.

There is a need for a more quantitative assessment of the extent to which IMTA can mitigate the environmental impacts related to aquaculture production. Experiments
with IMTA indicate the potential for the mitigation of environmental issues and some of these include quantitative models. However, these effects cannot be linearly scaled up from experimental to large-scale commercial sites (Troell et al., 2009). Quantification of environmental effects is a necessity to create adequate and effective policy tools to stimulate IMTA adoption.

The development of tools to model the economic effects of IMTA adoption is necessary. In terms of understanding the effects of IMTA on the supply side, it is advisable to continue the development of EIA’s and bio-economic models for these factors under IMTA to facilitate more informed decisions by aquaculture producers. There is a particularly strong need to model any changes in production costs associated with IMTA systems. Such information could facilitate offsetting estimated environmental price premiums as presented in this thesis to additional material and employment costs associated with IMTA production systems. Input-output models are useful to inform investors and producers on the financial implications of shifting to IMTA systems on a farm-level. Additionally, such models can identify potential financial bottlenecks to IMTA adoption and the areas where financial support tools can be assigned by policy makers most effectively.

A deeper understanding of the effects of IMTA adoption is required to quantify the eco-label ratings. The definition and quantification of the sustainability ratings is dependent on research findings on the environmental effects of shifting towards IMTA production systems. A first step would consist of identifying indicators for environmental pressure related to aquaculture activities. One suggested approach to quantify the environmental impact of IMTA is to apply the indicators for GES as defined in context of the MSFD by the European Commission (2010). These indicators are directly relevant to the aquaculture industry (Ferreira et al., 2011), as they include biodiversity, escapees, eutrophication, sea floor integrity, hydrographical alterations to the ecosystem, contaminants, food safety and marine litter and underground noise (European Commission, 2010). A sustainability rating labelling scheme could incorporate market signals into the seafood sector and incentivise the aquaculture sector to move towards more sustainable practices.
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Appendices
Appendix A

Legislative Context of the Aquaculture Industry

International Legislation

International law can considerably influence national laws governing marine activities by formulating the rules for marine activities, such as marine resource management, environmental protection, marine economic activities and scientific research. International law consists of a complex body of rules and agreements that binds nations in their international relations with others and consists of treaties, international custom, the general principles of law as recognized by nations, the decisions of judicial bodies and academic writings (ICJ (art.38)). National governments can enter into such agreements, but these have no legal bearing until they are included into national law.

The most influential pieces of international law that currently affect the governance of Ireland’s maritime territory consist of the United Nations Conventions on the Law of the Sea (UNCLOS). The aim of the UNCLOS is to create a unified legal framework for the governance of the world’s oceans, focusing on nations’ rights on marine resources and UNCLOS III (United Nations, 1982) is the most current version. Ireland was active in the proceedings in areas that concerned topics of direct interest, but her participation in the creation of international legislation complicated over time, especially when national and international legal competences mixed with those on the European level (Long, 2007).

The EU legislative system was, as mentioned in chapter 2, initially fragmented, consisting of several pieces of legislation that each covered a different aspect of marine activity. The main pieces of legislation affecting aquaculture development
are the following.


The MSFD focuses on the environment and is the EU’s strategy to protect the marine environment by reaching Good Environmental Status (GES) by 2020. It has an ecosystem-based approach to manage anthropogenic activities to enable the sustainable use of marine resources for economic and social activities. In order to reach GES, member states are expected to develop strategies based on GES indicators specific to their waters, track the progress of these indicators over time and report these to the Commission (EU, 2008).

The MSFD affects aquaculture development indirectly as no measures are imposed directly on the industry. However, national strategies should stipulate the measures designed to achieve or maintain GES in the waters of the states’ territory (Article 11) in which aquaculture activities take place. Specific elements related to aquaculture activities whose negative impact on GES are recognised are nutrient and organic matter enrichment (EU, 2008) and the introduction of non-indigenous species (European Commission, 2010a). The latest progress report from the Commission indicates that the MSFD has indeed stimulated regional collaboration and information sharing across EU member states, yet improvement on the coherence of activities is desired (European Commission, 2014b).

1. The Blue Growth Strategy

The Blue Growth Strategy focuses more on the economic aspects of the marine. The EU-wide blue economy, *i.e.* economic activity in the EU related to or based on marine resources, represents roughly 5.4 million jobs and generates a gross added value of 500 billion euro annually (European Commission, 2012b). The Blue Growth Strategy is the EU’s long term strategy to support sustainable growth in the marine sector (European Commission, 2017b). It has the dual aim of harvesting Europe’s oceans to increase economic growth, while increasing the sustainability of its ocean usage to secure unceasing economic growth.

The strategy focuses on five maritime sectors that are considered high-potential, among which the aquaculture sector. The Blue Growth strategy aims at removing barriers to the market rather than restricting the market with additional regulations.
For example, it aims to reduce bureaucratic barriers so market forces can correct market failures (European Commission, 2017a).

With regards to the development of the aquaculture sector, the strategy aims to strengthen the aquaculture sector by improving space usage by marine spatial planning through integrated coastal zone management (European Commission, 2017a) and improving the sectors image through marketing and information tools, such as labelling and marketing partnerships among fish farmers. The Commission plans to adopt standards to improve the welfare of farmed fish, as that topic received increasing attention in recent years (European Commission, 2017c). Community legislation on food safety was being redrafted, especially with regards to the use of antibiotics and dioxins. Additionally, the plan aims to reduce negative environmental impacts, such as toxic algal blooms, animal deceases and sea lice infestations (European Commission, 2009). More recently, the Commission have spoken of reducing administrative burdens to facilitate investment and growth, as well as promoting the sustainability of EU aquaculture products (European Commission, 2017a).

2. The Habitats Directive

The Habitats Directive aims for the conservation of a wide range of animal and plant species and habitat types within the European continent with the final aim of sustainable development (European Council, 1992). The promotion of biodiversity takes into account the economic, social and cultural activities linked to these resources, as well as region-specific needs.

Member states are free in their method of improving the status of habitats and species under the Habitat Directive, but are obliged to report to the Commission every 6 years. These reports include a description of the conservation status of species and habitats, any actions taken to improve the status of endangered species and the identification of any threats to improving the status of fragile species.

The Habitats Directive has led to the creation of Natura2000, a network of connected special protection areas, which has been beneficial to the protection of coastal regions. However, assessing the effect of the Habitat Directive on the marine environment is challenged by the complexity of marine ecological systems and a lack
of data (European Union, 2008). Aquaculture is recognised as one of the main threats to the marine environment and any actions regulating the direct impacts of the marine is believed to have a positive impact on the environmental status of the marine environment (European Commission, 2015c).

3. The Marine Spatial Planning framework (MSP)

Increasing conflict between users of European coastal regions challenges the implementation of these policies and the development of the aquaculture industry in European waters (Borg, 2007). The MSP is created as a response to the increasing demand for maritime space for economic, recreational and cultural activities as well as a need for space for environmental conservation strategies. It aims to align the fragmented spatial plans for the use of marine space in European waters (European Commission, 2014a). In the context of the MSP, EU member states are to create maritime spatial plans for the development of the marine sector, including aquaculture that is both economically and environmentally sustainable. These plans must take into account multiple elements of marine space usage and are to be reviewed by the Commission.

Marine spatial planning is a significant element of the sustainable development of the aquaculture sector; as the location and production process of the farm determines the intensity and type of spatial conflict with other users and the environmental impact that will have to be addressed. The optimisation of the type and siting of aquaculture operations is a spatial issue that requires inclusive, coordinated and strategic planning (Lester et al., 2018). The decision of the farmer whether or not to utilise monoculture or IMTA production techniques will have consequences for the spatial requirements of the farm, and therefore the feasibility of realising the farm. MSP aims to create coherence across multiple elements that directly involve IMTA, including environmental, economic and social aspects of marine activity. Therefore, it is suggested that MSP provides a promising avenue for IMTA development.

4. Integrated Maritime Policy (IMP)

The IMP can be considered the “umbrella-regulation” for European maritime action. It aims to integrate the separate elements from the previously discussed EU policies,
thereby increasing coordination and synergy across environmental and economic policy areas. More concretely, the IMP stimulates the continuous development of integrated sea-basin strategies in combination with increasing cooperation through data-sharing and stakeholder inclusion. Additionally, any actions aiming to protect marine and coastal resources as stipulated in MSFD are consolidated (European Union, 2011).

With regard to the significance of the IMP to the development of the aquaculture industry, the importance of the economic elements to the IMP, i.e. the Blue Economy, was stressed by the European Ministers for maritime policy and the European Commission. This included the importance of innovation in aquaculture and particularly the introduction of new aquaculture products, such as algae, to be utilised for the further development of the blue biotechnology sector (European Council, 2012).

Furthermore, the European Commission aims to stimulate aquaculture to counteract the effects of the decline in fisheries while economically sustainably supporting the coastal communities (European Commission, 2012b). An analysis is conducted to assess the methods and technology by which the industry can develop in line with the Blue Growth Strategy (European Commission, 2012a). This analysis includes a spatial analysis methodology, in line with the MSP. Additionally, the European Commission’s Joint Research Centre (JRC) has developed the European Aquaculture Performance Indicators (EAPI). These indicators described governance, economic, social and environmental sustainability of aquaculture, with the aim of identifying bottlenecks for the development of the aquaculture industry and determine actions to address them (European Commission, 2012a). Considering the effect of fish farms on overfishing being dependent on the production technologies utilised (Naylor & Burke, 2005), the environmental impact should be taken on board in these assessments and this may well provide scope for the development of IMTA as a less impactful means of increasing production and job creation without pressuring wild fish stocks.

Integrated ocean management

One method to stimulate cohesion across policy fields is integrated ocean management; a framework that incorporates tools such as the ecosystem approach
and marine spatial planning into a unified framework. Integrated ocean management allows for the adoption of more efficient approaches in dealing with issues that are hard to deal with in a fragmented system of overlapping jurisdictional demands. The development of marine aquaculture in European waters is developed in line with the integrated coastal management approach (Fernandes & Read, 2001).

Integrated ocean management in the European coastal regions aims to integrate, amongst other, UNCLOS, the MSFD, the Habitats Directive and the IMP (European Commission, 2013b). It does not modify the acquis in any way, but rather distributes the power of the EC over multiple issues more equally in one management plan. Spatial planning and stakeholder inclusion are the key elements in integrating the multiplicity of policy goals (European Commission, 2013b). Additionally, integrated management requires the harmonization of existing laws and the application of independent scientific advice in policy formulation and implementation, aiming for sustainable development in terms of both economic and coastal resource management (Long, 2007).

The approach is assessed positively for its ability to apply the ecosystem based approach and allowing for the balancing of environmental, economic, social, cultural and recreational aspects of coastal management (Douvere & Ehler, 2009; Long, 2006). However, criticism also exist with regard to informational obstacles and the high complexity of the issues at hand. This combination can prevent actors from fully engaging and can lead to a science-policy gap (Shipman & Stojanovic, 2007). Also, scholars suggest that the jurisdictional framework of the EU is inadequate to implement integrated measures as the distribution of legal competences across multiple governance levels prevents a strategic framework to be stipulated (Long, 2006). Yet, the integrated management approach is stimulated for regions across the EU and Norway for marine resource management (Norwegian Ministry of Fisheries and Coastal Affairs, 2009), with regional cooperation being one of the key aspects.

Regional Cooperation

The stimulation from the EU to regional transnational cooperation is evident through the integrated management plans. These plans have a regional focus and each covers one of the marine “eco-regions” that have been defined in Europe. Regional cooperation is considered beneficial as it facilitates the optimisation of
systems through the sharing of data and best practises, the promotion of cooperation and beneficial partnerships, the reduction of risks and more effective environmental resource protection through facilitating the ecosystem approach (Douvere & Ehler, 2009). The first pursuit of macro-regional management was the creation of the Baltic Sea region (European Council, 2009), which indeed demonstrated positive outcomes, but a lack of organisational structure in the EU hindered progress (Studzieniecki, 2016).

European legislation on marine resource management has initiated multiple cooperation programs that stretch across EU borders and stimulate regional cooperation. Under the MSFD the Common Implementation Strategy (CIS) was developed; a coordination platform that facilitates regional cooperation, and under the Blue Growth Strategy regional cooperation schemes were proposed that aim for tailor-made instruments for separate European maritime regions, containing the Atlantic Action Plan for the Atlantic region and the Integrated Maritime Policy for the Mediterranean region (European Commission, 2017a).

The Atlantic Action Plan aims to ‘create sustainable and inclusive growth in coastal areas’ through consultation with the five Atlantic EU member states and focus on regional stakeholder inclusion and regional cooperation. The aquaculture industry can benefit through the sharing of information, market and industry research and improving the market position of European aquaculture products through the use of eco-labels and certification (European Commission, 2013a). The Integrated Maritime Policy for the Mediterranean region is structured differently as it is challenged by the diversity of the 20 Mediterranean countries that are unevenly developed economically and have different approaches towards resource management. It focuses on mobilising the countries to balance economic activity with environmental protection through the integrated management approach and cooperation (European Commission, 2013a).
Appendix B

The survey (English version)

Thank you for agreeing to take part in this survey.

Before you begin, you need to make sure that your browser is maximised (i.e. that it covers your whole screen). If necessary, you can do this by clicking the "maximise" button in the top, right hand corner of your browser window.

It's very easy to navigate through the questionnaire. Just click on the answer or answers that apply and use the next (>>) button to move on.

Please avoid using the browser buttons. You may need to use the scroll bar if you cannot see the whole screen at once.

To start the survey, use the next (>>) button below.

Please note, there is a momentary delay in our surveys between the appearance of a question and the possible responses. This is designed to allow you to consider each question thoughtfully before choosing a response.

Please enter your date of birth.

Please either type in your date of birth in the box below, or use the calendar to select it.

<<

>>
Legislative Context of the Aquaculture Industry

Which of these do you live in?

Please select one only:

- Scotland
- North East
- North West
- Yorkshire and the Humber
- East Midlands
- West Midlands
- Wales
- East of England
- London
- South East
- South West
- Northern Ireland
- Isle of Man
- Channel Islands

You have been selected to participate in this survey as part of a European research project on sustainable aquaculture. This survey consists of three parts. Part I asks about your perceptions of aquaculture. Part II asks you to choose between several seafood products with different characteristics. Part III consists of a number of questions about how you perceive fish products and how you shop for these products. In the third part you are asked a few questions about your position in society. The answers you provide will be treated anonymously and can in no way be traced back to you.

Your cooperation is much appreciated.

Please use the next button to continue when you are ready.
Aquaculture is the growing of fish on fish farms. These farms consist of large nets in oceans, lochs, rivers or estuaries, in which fish are grown and harvested once they are large enough. The amount of fish produced by aquaculture is growing worldwide.

How do you rate the benefits of aquaculture in your country?
Please select one only for each item.
Please use a scale from 1 to 5 where 1 means no benefit and 5 means major benefit:

**Economic boost in coastal areas**
- no benefit
- 1
- 2
- 3
- 4
- major benefit

**Prevention of overfishing of wild stocks**
- no benefit
- 1
- 2
- 3
- 4
- major benefit

**Reliable and affordable food source**
- no benefit
- 1
- 2
- 3
- 4
- major benefit

**Improved health and nutrition for consumers**
- no benefit
- 1
- 2
- 3
- 4
- major benefit

**Job creation**
- no benefit
- 1
- 2
- 3
- 4
- major benefit
Aquaculture is the growing of fish on fish farms. These farms consist of large nets in oceans, lochs, rivers or estuaries, in which fish are grown and harvested once they are large enough. The amount of fish produced by aquaculture is growing world-wide.

**How do you rate the impacts of aquaculture in your country?**

Please select one only for each item.
Please use a scale from 1 to 5 where 1 means no impact and 5 means major impact.

<table>
<thead>
<tr>
<th>Impact</th>
<th>Rating</th>
<th>Major Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spreads diseases and parasites</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Fish that escape from aquaculture eat wild fish</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Leads to overfishing, because it uses wild fish for food</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Impacts scenery</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Pollution from feed, wastes and treatments (e.g: antibiotics)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Animal welfare</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Conflicts with other marine users</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

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Test: q2

Have you *ever* heard of the term *integrated aquaculture*?

Please select one only:

- Yes
- No
- Don’t know

Test: q2a

You said you have heard of the term *integrated aquaculture*. What do you think it means? Explain in your own words below.

*Please type your answer in the box below.*
Below is an image of a basic integrated aquaculture system. Integrated aquaculture provides the by-products (e.g., waste from one aquatic species) as the input (e.g., fertiliser or food) for another species.
Do you think integrated aquaculture has the potential to ...?

Please select one only for each item.

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Maybe/ Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve waste management in aquaculture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduce possible disease outbreaks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Replenish natural stocks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improve food quality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase employment opportunities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improve community economies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase industry competitiveness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase food production</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improve the sustainability of aquaculture overall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduce environmental impact of fish farming</td>
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</tbody>
</table>
In this section, you will be asked to choose between two different fish products, salmon, to be specific. In the first questions you are asked to make a few choices. Imagine that you walk into a supermarket and fresh (unfrozen) salmon is on your shopping list. The supermarket has several types of salmon. The packs are identical in size and quality, but some fish is produced locally, some is produced abroad, and some is produced in a way that is better for the environment. They also vary in price. You are asked to indicate which of the salmon presented you would buy.

In previous studies we have observed that if choices are hypothetical, just as is the case in this survey, people tend to indicate that they would pay more than they actually would if faced with real prices. This difference between hypothetical and actual price paid is called 'hypothetical bias' and it has a big effect on the results of studies like this one. Therefore we ask you to assess the different products carefully and choose exactly as you would if you were standing in the supermarket.

A few things are important when you make your choice. First, the fact that the salmon is locally produced does not necessarily make it better for the environment. Second if the piece of fish is more expensive, and produced sustainably, you can assume that the higher price reflects the cost of more sustainable fish farming. Third, the farming method is the main thing that makes the fish more or less sustainable. One important indicator of sustainability is the amount of feed and fish waste discharged into the environment from the farms. As you've already been told, 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 best and D being 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. You should also note if the location of production is important to your choice (indicated by the map or flag on the image).

Please use the next button to continue when you are ready.
Legislative Context of the Aquaculture Industry

Test: q6Filter

Which group (1-4) is going to be asked about? FINAL

1
2
3
4

Test: p3q1intro

This part of the questionnaire consists of a number of questions about you, about how you perceive fish products and how you do your shopping. Please remember that there are no right or wrong answers, we are simply interested in your opinion.

Please use the next button to continue when you are ready.

Test: p3q1

Do you think that salmon is being overfished?

Please select one only.

Yes
No
Don't know

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Test: p3q2

Do you think that overfishing is a problem?

Please select one only.

- Yes
- No
- Don't know

Test: p3q3

These farms consist of large nets in oceans, lochs, rivers or estuaries, in which fish are grown and harvested once they are large enough. The amount of fish produced by aquaculture is growing world-wide.

Do you think that aquaculture is a good way to deal with the problem of overfishing?

Please select one only.

- Yes
- No
- Don't know
A number of possible side effects from aquaculture are listed below. Please indicate the things that you think have the biggest impact on the environment. You can tick as many boxes as you like.

Aquaculture is bad for the environment, because ...

Please select one only:

- It causes nutrient pollution
- It spreads diseases and parasites among wild animals
- It leads to overfishing, because it uses wild fish for food
- Fish that escape from aquaculture eat wild fish
- It sometimes uses nets, Wildlife gets tangled up in these nets
- It uses antibiotics and other drugs that spill out into the sea
- It causes fish waste to end up in the oceans
- I think none of these factors is a problem
Legislative Context of the Aquaculture Industry

Some fish products are better for the environment than others. One of the ways in which environmental friendly products are promoted is through labels on food products. These are called 'eco-labels' and they show consumers that a product fulfills 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. This stimulates producers to make the production process more environmental friendly.

We are going to show you a number of ecolabels. Please tick the box of any labels that you recognize.

Please select all that apply:

- [ ] I don't recognize any of the labels

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

Please select one only:

- [ ] Always
- [ ] Most of the time
- [ ] Sometimes
- [ ] Never
When you are buying seafood, do you think you are informed enough about the impact of seafood products on the environment to make a good choice?

*Please select one only.*

- I am informed too much
- I am informed enough to make a good choice
- I am informed too little to make a good choice

We are developing an ecolabel that shows the degree of environmental impact. This looks like the label that you might know from fridges or house insulation. An example of such an ecolabel is shown below.

Would this kind of ecolabel help you understand the environmental pressure caused by the production of seafood products?

*Please select one only.*

- Yes
- No
Below are a number of personality traits that may or may not apply to you. Please select how much you agree or disagree with the following statements. You should rate the extent to which each pair of traits applies to you, even if one characteristic applies more strongly than the other.

Please select one only for each item:

<table>
<thead>
<tr>
<th>Trait</th>
<th>Disagree strongly</th>
<th>Disagree moderately</th>
<th>Disagree a little</th>
<th>Neither agree nor disagree</th>
<th>Agree a little</th>
<th>Agree moderately</th>
<th>Agree strongly</th>
</tr>
</thead>
<tbody>
<tr>
<td>critical, quarrelsome</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dependable, self-disciplined</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>anxious, easily upset</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<tr>
<td>disorganized, careless</td>
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<td></td>
<td></td>
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<tr>
<td>calm, emotionally stable</td>
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<td></td>
</tr>
<tr>
<td>conventional, uncreative</td>
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<tr>
<td>extroverted, enthusiastic</td>
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</tr>
</tbody>
</table>
Legislative Context of the Aquaculture Industry

Test: p3q13

My marital status is …

Please select one only.

- Single
- Married or domestic partnership
- Widowed
- Divorced
- Separated

Test: p3q14

What is the highest degree or level of education you have completed? If you are currently enrolled, mark the highest degree received.

Please select one only.

- Trade/technical/vocational training
- Associate degree
- No schooling completed
- Nursery school to 8th grade
- High school graduate or equivalent
- Bachelor's degree
- Master's degree
- Professional degree
- Doctorate degree
Test: p3q15

Please describe your daily occupation.

Please select one only:
- Employed for wages
- Self-employed
- Out of work and looking for work
- Out of work but not currently looking for work
- Homemaker
- Student Military Retired
- Unable to work

Test: p3q16

The average net annual personal income in the UK is £31,967.
Is your income:

Please select one only:
- Similar to the average
- A bit below the average
- Much below the average
- A bit above average
- Much above the average
- Refused
Legislative Context of the Aquaculture Industry

Which of these age group and gender combinations best describes you?

Please select one age and gender combination only.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 to 40 years old</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41 to 55 years old</td>
<td></td>
<td></td>
</tr>
<tr>
<td>71 years old or older</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 to 24 years old</td>
<td></td>
<td></td>
</tr>
<tr>
<td>56 to 70 years old</td>
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<td></td>
</tr>
</tbody>
</table>

Do you have any feedback that you would like to give us about this survey?

Please type your answer in the box below:

[Feedback box]
Appendix C

Explanation of the term “Integrated Multi-Trophic Aquaculture” to the respondents in the survey

Integrated aquaculture provides the by-products (e.g. waste from one aquatic species) as input (e.g. fertiliser or food) for another.
Appendix D

Example Choice Card as Presented to Survey Respondents from Irish Sample

I would buy neither, even if salmon is on my shopping list
## Appendix E

### Marginal WTP per latent class, country and pooled

<table>
<thead>
<tr>
<th>Country</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
<th>Weighted</th>
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<td>12% ***</td>
<td>48% ***</td>
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<td>100%</td>
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<tr>
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<td>53% ***</td>
<td>15% ***</td>
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<tr>
<td><strong>Italy</strong></td>
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</tr>
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<td>10% ***</td>
<td>17% ***</td>
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</tr>
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<td>28% ***</td>
<td>18% ***</td>
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<td>€10.26 ***</td>
<td>€1.91 *</td>
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<td>€16.34 ***</td>
<td>€4.11 ***</td>
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</tbody>
</table>

*: P <0.1; **: P <0.05; ***: P <0.01
## Appendix F

### WTP estimates for product attributes for pooled and country-specific data

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<thead>
<tr>
<th></th>
<th>Mixed Logit</th>
<th>Generalised Mixed Logit</th>
<th>Scaled Logit</th>
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<tbody>
<tr>
<td></td>
<td>mean</td>
<td>standard deviation</td>
<td>confidence interval</td>
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<tr>
<td><strong>Pooled data</strong></td>
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<tr>
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<td>€ 3.30</td>
<td>€ 0.77</td>
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<td>-€ 0.78</td>
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<td>-€ 1.53</td>
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<td><strong>Norway</strong></td>
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<tr>
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WTP estimates for product attributes for pooled and country-specific data