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McCallum, C., Cerroni, S., Derbyshire, D., Hutchinson, W. G., & Nayga Jr., R. (2021). Consumers' responses to food fraud risks: an economic experiment. *European Review of Agricultural Economics*. https://doi.org/10.1093/erae/jbab029

Published in:
European Review of Agricultural Economics

Document Version:
Publisher's PDF, also known as Version of record

European Review of Agricultural Economics Vol **00 (00)** (2021) pp. 1–28
doi:https://doi.org/10.1093/erae/jbab029

Consumers' responses to food fraud risks: an economic experiment

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Received December 2020; final version accepted June 2021

Abstract

This artefactual field experiment explores consumers' willingness-to-pay (WTP) price premiums for fish products to avoid the risk and uncertainty of purchasing inauthentic produce. The influence of subjective probabilistic beliefs, risk and ambiguity preferences is investigated. Participants' WTP is elicited using experimental auctions, while behavioural factors are elicited using incentivised and incentive-compatible methods: the quadratic scoring rule and multiple price lists. Results show that consumers are willing to pay a premium to avoid food fraud and purchase an authentic fish product. This premium is higher under uncertainty than risk, likely driven by ambiguity preferences which affect consumers' purchasing under uncertainty.

Keywords: authenticity, food fraud, risk and ambiguity preferences, willingness to pay, experimental auctions

JEL classification: C91, D12, D81, Q13

1. Introduction

Food fraud is an intentional action carried out for financial gain and includes adulteration, counterfeiting, substitution and deliberate mislabelling of food products (Spink and Moyer, 2011). Examples include substituting products with lower-quality alternatives and making false statements about the origin

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of the product (HM Government, 2014). Food fraud can become harmful to human health, for instance when it involves the recycling of products unfit for human consumption back into the food chain or using products past their 'use by' date. When food fraud occurs, buyers and/or consumers receive a food product that is inauthentic, meaning that the nature, substance or quality is not what the purchaser expects based on the food standards (HM Government, 2014).[1]

Food fraud deserves much more attention than it currently receives from agribusinesses and policymakers. One potential reason for this lack of attention is because health effects may be absent or undetected. While most food fraud incidents do not lead to widespread harm, this does not negate the fact that food fraud damages consumers' utility and welfare. Given the prevalence of food fraud, it becomes vital for policymakers and businesses to acquire information on how consumers value authentic food when risk and uncertainties related to food fraud exist and which factors affect consumers' valuations.

To this end, this paper investigates consumers' willingness-to-pay (WTP) a premium to buy authentic food and reduce the risk and uncertainty related to food fraud. Specifically, we focus on fish products because the risk of purchasing inauthentic products is particularly high in this sector (Europol, 2016). We describe a situation as risky when the probability of outcomes is known, while it is described as uncertain when these probabilities are unknown (Knight, 1921). The paper also explores the influence of consumers' probabilistic beliefs as well as their risk and ambiguity preferences on WTP for authentic fish products.

At business level, several measures exist to reduce the risk of food fraud. Most of these rely on improved food traceability, which is defined as the ability to trace and follow a food, feed, food-producing animal or substance to be incorporated into feed, through all stages of production, processing and distribution (European Commission (EC) 178/2002). An example is DNA testing, which allows various characteristics of fish to be identified including species and origin of catch (Martinsohn *et al.*, 2018).

Improving traceability along the supply chain should be an ethical duty for food companies. However, it is important to acknowledge that reducing the risk of food fraud can provide tangible benefits to companies. For example, improved traceability can reduce the risk of legal actions against the food company and/or limit reputational risks that may generate demand shocks and negatively impact profit (Frederiksen *et al.*, 2002; Can-Trace, 2004). It can also provide reputational opportunities via corporate social responsibility reports (Maloni and Brown, 2006; Wei and Huang, 2017). While traceability should not just be perceived as a way to increase consumers' WTP and profits (Loureiro and Umberger, 2007), it undeniably creates marketing opportunities for producers (Poghosyan *et al.*, 2004; Cavaliere, Ricci and Banterle, 2015). An improved traceability system can require additional

1 Food standards relate to the legal standards for labelling and composition of food products (Gov.UK, 2020).

investment and increase production costs. Given the additional costs, measuring the premiums consumers are willing to pay is important for businesses to understand whether improved traceability systems are financially viable. Since actions to improve traceability are often enforced by governments, measuring consumers' surplus associated with authentic food is important for cost–benefit analyses to test the feasibility of policy actions.

In this paper, consumers' WTP premiums for authentic fish products is elicited by conducting an artefactual field experiment (Harrison and List, 2004) with 110 consumers from Northern Ireland. Consumers express their WTP in four different scenarios. In the first scenario, they express their WTP for a portion of pollan fillets (250 grams). This is perceived as a high-quality and high-value fish by Northern Irish consumers and recently obtained a Protected Designation of Origin (PDO), a type of Geographical Indication (GI) from the European Union (EU). A PDO identifies a product produced, processed and prepared in a geographical area with characteristics linked to their origin (European Commission, 2013). In the second scenario, consumers express their WTP for herring fillets (250 grams). Herring is perceived by Northern Irish consumers as an ordinary and lower-quality fish compared to pollan. In these scenarios, there is no possibility of food fraud; pollan and herring fillets transacted are fully authentic.

In the third and fourth scenarios, consumers express their WTP in situations that resemble a food fraud incident. Food fraud creates risk and uncertainty as consumers are purchasing a product, which may or may not be the product they intended to buy. In the third scenario, consumers express their WTP for the pollan fillets, but they are told that there is an unknown probability they could receive the herring fillets instead. Since the probability is unknown, this scenario simulates uncertainty. In the fourth scenario, this probability is disclosed, which resembles a situation of risk. In all scenarios, WTP is elicited using the Becker–DeGroot Mechanism (BDM) (Becker, DeGroot and Marschak, 1964) and second-price Vickrey auction (SPVA) (Vickrey, 1961).

This paper contributes to the literature on WTP for authentic food in several ways. First, previous studies find consumers have a low understanding of food traceability (Lichtenberg, Heidecke and Becker, 2008; Dopico *et al.*, 2016) and premiums for authentic food depend on consumers' preferences/beliefs regarding the method used to ensure authenticity (e.g. Loureiro and Umberger, 2007; Agnoli *et al.*, 2016). Rather than eliciting consumers' WTP for a specific approach signalling authenticity (e.g. DNA testing), we elicit a neutral measure of WTP for fully authentic food products independent of the technology used. This is possible because our experimental design allows us to compare consumers' WTP in situations where the authenticity of the product is certain and where it is subject to risk or uncertainty.

Second, the literature examining WTP for traceability of fish-based products is very scarce and elicits WTP via hypothetical value elicitation approaches (e.g. Wang *et al.*, 2009; Dopico *et al.*, 2016), whereas we use incentivised and incentive-compatible value elicitation mechanisms (i.e. BDM and SPVA). In theory, this allows the elicitation of more truthful

WTP and reduces hypothetical bias (List and Gallet, 2001; Murphy *et al.*, 2005; Penn and Hu, 2018).[2]

Third, this paper explores the influence of important behavioural factors, such as probabilistic beliefs regarding food fraud, risk and ambiguity preferences, on WTP premiums for authentic food. These are elicited using incentivised and incentive-compatible methods: quadratic scoring rule (QSR) (Brier, 1950), Tanaka, Camerer and Nguyen (2010) multi price list format (MPL) and Chakravarty and Roy (2009) MPL format. While such behavioural factors are shown to influence consumers' decision-making under risk and uncertainty, their influence on food purchasing behaviour receives little attention (e.g. Lusk and Coble, 2005; Petrolia, 2016; Cerroni, Notaro and Raffaelli, 2019a).

This paper proceeds as follows: Section 2 provides background literature; Section 3 describes the experimental design; Section 4 describes the elicitation methods; Section 5 outlines the models; results follow in Sections 6 and 7 concludes.

2. Background

2.1. Statistics on food fraud

Figures regarding food fraud are highly uncertain and probably underestimated because food fraud is not easily detected by consumers and does not necessarily cause food safety incidents (Johnson, 2014). Sellers may be unaware that food fraud has occurred with their product; for example, if the business selling to the customer is not the offender but has itself been a victim of fraud earlier in the supply chain and sells the inauthentic product to the consumer unknowingly (Ruth *et al.*, 2020).

The Grocery Manufacturers Association estimates that food fraud affects 10 per cent of commercially sold food products worldwide, costing $10 to $15 billion (Johnson, 2014); other estimates are even higher at $30 to $40 billion (PricewaterhouseCoopers (PwC), 2017). In 2013, the Food Standards Agency (FSA) tested 19,758 samples and found that food fraud had occurred in 12.7 per cent of samples in the UK (Food Standards Agency (FSA), 2015).

In 2015, a Europol's investigation found that fish was the third highest food category at risk for food fraud (Europol, 2016). Warner *et al.* (2016) reviewed 200 studies investigating seafood fraud in 55 countries. They found that 20 per cent of samples were mislabelled worldwide and 14 per cent in the EU between 2004 and 2016. Other investigations provided more conservative figures. The EC found that 6 per cent of white fish portions were mislabelled in a sample of 4,000 portions from 29 countries (European Commission, 2015). A similar result (5 per cent) was found by Mariani *et al.* (2015), who tested 1,563 samples of various fish across six European countries.

The rate of fish fraud in the UK is similar to the EU. The FSA's sampling campaign found a rate of 7.4 per cent in 2013 (Food Standards Agency (FSA),

2 Hypothetical bias is the tendency to overestimate WTP with respect to prices paid in real markets.

2015) and 7.7 per cent in 2017 (BBC News, 2018). Independent studies found lower rates. Helyar *et al.* (2014) found a rate of 6 per cent for white fish in 2012, while Mariani *et al.* (2015) a rate of 3.3 per cent for fish in general in 2014. The level in Northern Ireland seems to be higher than that in the UK. In 2016, 15 per cent of fish samples collected by the FSA were mislabelled (Food Standards Agency (FSA), 2016).

The motivation to commit fraud is primarily economic (Johnson, 2014). Therefore, food fraud related to high-quality and high-value products, such as GI products, is more likely to occur (Loureiro and McCluskey, 2000; Aprile, Caputo and Nayga, 2012; Garavaglia and Mariani, 2017). While many cases of fraud relating to GI products have been reported in the media, there is a lack of overall data available. The EU Intellectual Property Office published a report investigating GI infringements. The average infringement rate was 9 per cent in 2014 (European Union Intellectual Property Office, 2016). Other studies focused on specific GI products. Two out of seven Italian PDO cheese samples failed tests by containing milk types not specified on the label (Di Domenico *et al.*, 2017). A much higher level of fraud was found when testing 80 samples of Italian dairy and meat products with PDO status (Di Pinto *et al.*, 2019). There are no specific estimates for GI fish products.

2.2. Legal aspects related to food authenticity and traceability

As the UK was part of the EU when the study was conducted, its legislation on food fraud followed EU legislation. The Food Information Regulation (Regulation EU 1169/2011, (2011)) requires food labelling information must not be misleading as to the characteristic of food. Seafood products have specific labelling requirements (Regulation EC 2065/2001, (2001)) which requires commercial destination, catch area, scientific name of the species and production method are available throughout the supply chain.

The Food Law Regulation's (Regulation EC 178/2002, (2002)) objective is preventing fraudulent or deceptive practices, the adulteration of food and any practices which mislead the consumer. It has a 'one up, one down' requirement that everyone in the food supply chain can identify businesses who supplied them with food and businesses which they supply food to. Since 2012, it requires the quantity/description of food, batch number and dispatch date are recorded. There are specific traceability requirements for many products including seafood. Article 58 of EC 1224/2009 requires that all fish products are traceable at all stages of production and processing from catch to retail.

A study comparing traceability regulations across 17 countries concludes the EU countries and pan-European countries have the strictest regulations. While most countries have traceability regulations for beef, regulation for other commodities is under development or industry led (Charlebois *et al.*, 2014).

2.3. Premiums for traceable food products

Previous research elicits consumers' WTP for labels indicating the traceability (i.e. from-farm-to-fork). Most focus on meat products due to recent food safety scares related to bovine spongiform encephalopathy.[3] The general conclusion is that consumers are willing to pay a premium to receive information on food traceability, which can provide reassurance regarding food authenticity.

Most studies are conducted in North America (e.g. Dickinson and Bailey, 2002; Ward, Bailey and Jensen, 2005; Loureiro and Umberger, 2007) and more recently in Asia (mostly China) (e.g. Wu *et al.*, 2015; Hou *et al.*, 2019). A smaller number are conducted in Europe (e.g. Dickinson and Bailey, 2005; Angulo and Gil, 2007; Agnoli *et al.*, 2016). Two approaches are mainly used to elicit WTP for traceable meat products: stated preferences (e.g. Loureiro and Umberger, 2007; Agnoli *et al.*, 2016) and economic experiments (e.g. Dickinson and Bailey, 2002, 2005). The former elicits preferences and values in hypothetical settings and could suffer from hypothetical bias, while the latter uses incentivised and incentive-compatible value elicitation techniques which mitigate hypothetical bias. Non-hypothetical discrete choice experiments (e.g. Wu *et al.*, 2016) BDM (e.g. Hou *et al.*, 2019) and SPVA (Hobbs *et al.*, 2005) were used to elicit consumers' preferences for general labels informing about the traceability of the meat product. The only studies exploring preferences for a specific traceability system are Agnoli *et al.* (2016) for DNA testing and Shew *et al.* (2021) for blockchain traceability. In general, these studies find that socio-demographic and attitudinal variables such as age, education, income, beef consumption and food safety concern affect WTP.

Only a few studies investigate traceability for other food products. These are mostly conducted in China. For example, Wu *et al.* (2012) investigates the influence of traceability labels on WTP for vegetables; Zhang, Bai and Wahl (2012) for milk and cooking oil; Liu *et al.* (2019) for apples; and Bai, Zhang and Jiang (2013) and Wu, Hu and Xiong (2020) for milk.

While previous research suggests that most consumers perceive traceability of fish products as necessary (e.g. Rodriguez-Salvador and Dopico, 2020), only two studies examine consumers' WTP for traceable fish products. Both use a simple hypothetical contingent valuation method (CVM)-type question to elicit WTP for traceable fish products (Wang *et al.*, 2009; Dopico *et al.*, 2016).

2.4. Behavioural factors and food choice behaviour

Subjective probabilistic beliefs, risk and ambiguity preferences are important drivers of decision-making under risk and uncertainty. However, their influence on food purchasing behaviour has scarcely been studied. Risk preferences refer to an individual's attitude towards actions that generate different outcomes. Probabilities related to the realisation of the outcomes are known. Probabilities related to the realisation of the states of the world are known. For

3 Bovine spongiform encephalopathy is commonly known as mad cow disease.

example, some individuals are generally averse to taking risky actions, while others gain utility from doing so (i.e. risk lovers). When such probabilities are unknown, ambiguity preferences are measured instead of risk preferences and subjective probabilistic beliefs become another important driver of decision-making. Subjective probabilistic beliefs are the subjective probabilities that an individual attaches to the occurrence of each possible state of the world.

Previous research investigates the role of risk preferences in shaping WTP for genetically modified (GM) food (e.g. Lusk and Coble, 2005; Petrolia, 2016; Weir and Sproul, 2019), but, to the best of our knowledge, no studies explore the influence of probabilistic beliefs, risk and ambiguity preferences on WTP for authentic or traceable food.

Many studies elicit qualitative probability judgements and explore their impact on WTP for safe food products (e.g. Misra, Huang and Ott, 1991; Marette, Roe and Teisl, 2012; Malone and Lusk, 2017). These qualitative probability judgements are generally elicited using Likert scales. Hence, their ability to predict choice behaviour is very limited because such judgements cannot be incorporated in formal models of decision-making under risk and uncertainty, such as the Subjective Expected Utility Theory (Savage, 1954). Only a few studies consider the influence of probabilistic beliefs on consumers' choices (Teisl and Roe, 2010; Lusk, Schroeder and Tonsor, 2014; Cerroni, Notaro and Raffaelli, 2019a). However, beliefs are mostly elicited using non-incentivised and non-incentive-compatible procedures, which do not guarantee truthful belief elicitation. Noticeable exceptions are two studies eliciting consumers' subjective probabilistic beliefs related to food safety outcomes (Cerroni, Notaro and Shaw, 2012, 2013). This paper contributes to this literature by eliciting subjective probabilistic beliefs regarding food authenticity using an incentivised and incentive-compatible elicitation method, the QSR (Brier, 1950), which, in theory, guarantees the elicitation of truthful probabilistic beliefs.[4]

Many studies investigate the role of risk preferences on consumers' WTP for safe food. Most use self-reported measures of risk aversion via Likert scales (e.g. Pennings, Wansink and Meulenberg, 2002; Schroeder *et al.*, 2007). Other studies elicit consumer-specific measures of the coefficient of relative risk aversion using Holt and Laury's MPL format (2002). Some studies use a non-incentivised MPL (e.g. Lee *et al.*, 2015), while others utilise an incentivised version (e.g. Lusk and Coble, 2005; Petrolia, 2016). The MPL may not provide truthful risk preferences if it is not incentivised. In this study, we use an incentivised MPL to elicit risk preferences.

The role of ambiguity preferences in shaping WTP for food products is largely overlooked in the literature. A noticeable exception is the hypothetical CVM survey by Kivi and Shogren (2010), which suggests that ambiguity aversion substantially affects consumers' choices regarding food safety

4 Incentive compatibility only holds if the participant is risk neutral (Winkler and Murphy, 1970; Karni and Safra, 1987; Kadane and Winkler, 1988; Johnstone, 2007). In this paper, we correct for potential biases in elicited subjective probabilistic beliefs, due to deviations from risk neutrality, using the method proposed by Offerman *et al.* (2009).

for a sample of US students. Our paper provides at least two significant contributions to this literature. First, we elicit ambiguity preferences using an incentivised version of Chakravarty and Roy (2009). Second, we elicit preferences for a sample of consumers rather than just students.

3. Sample and experimental design

Our sample consists of 110 consumers recruited from the population living in or near Belfast (Northern Ireland, United Kingdom).[5] Advertising was operationalised using leaflets and posters disseminated in various locations (e.g. campus, charity shops, restaurants and bars) in Belfast, most likely resulting in a non-probabilistic random sampling procedure. The study was advertised as a consumer food choice study for fish products.[6] The experiment was conducted at Queen's University Belfast.[7] The sample was randomly split into two treatment groups: 54 participants were allocated to the BDM treatment and 56 to the SPVA treatment.[8,9] Table 1 shows a comparison of key socio-demographic variables between our sample and the population of reference.

Our sample is representative of household income and gender. However, other variables differ slightly from the population of reference. Our sample is over-representative of 18–29 year olds and under-representative of those aged over 50 years. For employment status, students are overrepresented in our sample and retired individuals are underrepresented.

All participants are exposed to the following tasks in the same order: (i) questionnaire to ascertain how hungry and full consumers felt (ii) probabilistic beliefs, risk and ambiguity preference elicitation tasks (iii) induced value tasks[10] (iv) WTP elicitation tasks (either the BDM or the SPVA) and

5 The original sample consisted of 162 consumers. Data obtained from 52 consumers was not analysed because of multiple switching in the risk and ambiguity preference elicitation tasks presented: 28 and 24 participants were excluded from BDM and SPVA treatments, respectively. The identification of participant-specific coefficients of risk and ambiguity preferences was impossible for multiple switchers in the MPL tasks. Multiple switching was unrelated to treatments. Additionally, summary statistics of socio-demographic characteristics were similar; hence, the sample used is comparable to the original sample. We refer interested readers to online Supplementary Appendix H.

6 We acknowledge that the implementation of a random sampling procedure would have been preferable, but it is often difficult to operationalise in experimental studies involving a non-student sample. Given our recruitment strategy, we cannot exclude that the phenomenon of snowballing has occurred, meaning that friends and family members of some participated to the experiment. This may have consequences on the representativeness of our sample and the external validity (i.e. generalisability) of our results. More information on recruitment can be found in online Supplementary Appendix B.

7 The experiment received ethical approval from the Ethics Board for the Faculty of Medicine, Health and Life Sciences at Queen's University Belfast.

8 The sessions were conducted between 23rd October 2018 and 10th December 2018. Afternoon (1 pm) and evening (6 pm) sessions were conducted to control for the effect of time on WTP. The BDM was used in 6 sessions: 2 sessions with 11 participants, 1 with 13, 1 with 14, 1 with 15 and 1 with 18. The SPVA was used in 8 sessions: 1 session with 4 participants, 3 with 8, 3 with 12 and 1 with 16. All sessions were programmed and run using z-Tree (Fischbacher, 2007).

9 The randomisation of participants was conducted once the recruitment campaign was over and thus involved all 162 consumers, with 82 assigned to BDM and 80 to SPVA treatment.

10 Data from the induced value task are not used in this paper; hence, it is not discussed any further.

Table 1. Comparing sample statistics with population of reference[a]

Variable	Belfast city	Sample N = 110	SPVA N = 56	BDM N = 54
Gender (%)				
Female	52	58	66	50
Male	48	42	34	50
Age categories (%)				
18–29	25	54	53	56
30–39	19	14	15	13
40–49	15	19	24	15
50–59	16	6	4	9
60+	25	6	5	7
Household income (£, median)	(25,228)	(25,000)	(25,000)	(30,000)
Employment status (%)				
Employed	54	52	55	48
Unemployed	3	0	0	0
Retired	19	6	4	7
Other	3	1	0	2
Student	4	38	38	39
Highest level of education (%)				
Secondary	–	17	11	24
College	–	13	14	11
Degree or higher	–	69	75	65

[a]Statistics are for 2017 population (Source: Northern Ireland Statistics and Research Agency).

(v) socio-demographic and shopping habits questionnaire.[11] Participants complete the tasks on a private computer screen. Each participant was assigned their own desktop computer, fully distant to prevent talking and looking at other participants' screens. The experimenter provides instructions on the screen at the front of the room before each task. All participants receive a show-up fee of £20 and can obtain additional earnings (up to £100) depending on their choices in tasks (ii) and (iii). All participants have the possibility to buy only one portion of fish fillets in task (iv). Additional earnings are not disclosed until the end of the experiment to mitigate potential wealth effects on bidding behaviour in task (iv).[12]

After task (i) participants are provided with the definition of authentic food, an explanation of GIs and given examples of both. Additionally, past

11 We acknowledge that given the complexity of the experiment and the positioning of the home-grown value (WTP) elicitation tasks after all other tasks, we do not exclude that participants decisions may have been influenced by fatigue.

12 We acknowledge the potential influence of house money effect. This was minimised by paying participants the show-up fee at the start of the experiment (e.g. Canavari *et al.*, 2019).

statistics for food authenticity in the UK are provided to give a common baseline knowledge to participants and allow them to provide informed subjective probabilistic beliefs (e.g. Viscusi and Zeckhauser, 2006; Cerroni, 2020). Experimental instructions are provided in the online Supplementary Appendix A. The experiment design followed guidelines from Lusk and Shogren (2007).

While participants complete tasks (i), (ii) and (iii) before their WTP is elicited, we do not foresee any priming effects of these tasks apart from the probabilistic belief elicitation. Since the probability of receiving an inauthentic fish product on the UK market is disclosed to participants when they bid for the risky portion, the probabilistic belief task could not be placed after WTP elicitation tasks. Additionally, as premiums are calculated using differences between WTP for each portion, any potential priming effect would be cancelled out.

4. Elicitation methods

4.1. Willingness-to-pay elicitation

In both the BDM and SPVA, participants submit sealed bids in four different bidding scenarios, all involving portions of frozen fish fillets (250 g). In these scenarios, participants are asked to bid for the following:

i. A portion of authentic pollan fillets (i.e. food fraud is not possible by design). They are told that this fish was caught in Lough Neagh and has recently obtained a PDO certification.
ii. A portion of authentic herring fillets. They are told that this fish was caught in the UK.
iii. A portion of pollan fillets once they are informed that there is an unknown probability *p* that you will get a portion of herring instead (i.e. food fraud under uncertainty).
iv. A portion of pollan once they are informed that there is a known probability *p* (8 per cent) that you will get a portion of herring instead (i.e. food fraud under risk).

Participants are informed that only one portion of fish can be purchased during the study, which is determined at the end of the experiment with a random draw. Participants are told that, if the randomly drawn scenario is (i) or (ii), participants who buy the product receive the portion of authentic pollan fillets or herring fillets, respectively. However, if the randomly drawn scenario is (iii), which portion of fish fillets the participants receive is determined at the end of the experiment by randomly drawing a coloured chip from a bag containing 100 blue and purple chips. The proportion of blue and purple chips is unknown. If a blue chip is drawn, they receive pollan, otherwise they receive herring. Participants are informed that the number of purple chips represents the probability of receiving an inauthentic fish product on the UK market in 2018, based on statistics from Food Standards Agency (FSA) (2015) and experts' opinions gathered in a preliminary phase of the project.[13] If the randomly drawn scenario is (iv), participants are told that a coloured chip is drawn from the same bag. Now, they are informed that the proportion of blue chips is 92, while the proportion of purple chips is 8. Hence, there is an 8 in 100 chance they receive herring fillets instead of pollan.

Participants submit bids in two steps. First, they submit bids in purchasing scenarios (i), (ii) and (iii). The order in which participants bid in scenarios (i) and (ii) was randomised across participants to minimise order effects. Second, participants bid in the purchasing scenario (iv). This is to avoid the probability p (i.e. proportion of purple chips) being disclosed before participants bid in the uncertain scenario (iii). Participants can check what they bid in scenarios (i), (ii) and (iii), when bidding in scenario (iv).[14]

Before bidding, participants are invited to examine two showcase portions of frozen fish (pollan and herring). These have a similar appearance and packaging.[15] Participants are given instructions about the procedure used to run the auction and provided with numerous examples. A practice round is not conducted as participants were already exposed to induced value auctions. Hence, they were familiar with the WTP elicitation mechanism.

In the BDM treatment, participants are instructed that they will buy the auctioned good if their bid is higher than the market price which is determined by randomly drawing a price from a uniform distribution with support [£0.05, £8.00] in 0.05 increments. The price they pay is equal to the randomly drawn market price. Participants do not buy the auctioned good if their bid is lower than the market price. Instructions follow Lusk, Feldkamp and Schroeder (2004). In the SPVA treatment, participants are told the highest bidder buys the good at a market price equal to the second highest bid. Participants are informed that they bid against three other bidders (group size = 4 in all SPVA sessions). Instructions follow Lusk and Schroeder (2006) and Cerroni *et al.* (2019b). Figure 1 shows all steps participants face in each treatment.

4.2. Probabilistic beliefs, risk and ambiguity elicitation

Other tasks are used to elicit additional behavioural factors: probabilistic beliefs, risk and ambiguity preferences. Participants' probabilistic beliefs regarding the probability that a fish product is authentic on the UK market in 2018 are elicited using the QSR. Risk preferences are elicited using Tanaka, Camerer and Nguyen (2010) MPL. Ambiguity preferences are elicited using Chakravarty and Roy (2009) MPL. All participants are exposed to these tasks

13 Four food fraud experts, from UK universities and food research organisations, were interviewed in October 2018. Semi-structured interviews took place in which they provided estimates for the probability of food fraud occurring for different products. These interviews took place as there were no recent food fraud statistics available for fish products.

14 We acknowledge that order effects may affect our results. In the pilot experiment, we tested randomising purchasing scenarios (i), (ii) and (iii) but participants were confused, hence we just randomise scenarios (i) and (ii) in the experiment.

15 The portions of fish were stored in a freezer at the location of the experiment (Queen's University Belfast) at temperatures below −18°C. Temperature was constantly checked using a data logger stored in the freezer—Elitech RC-5—with data being downloaded and checked every day.

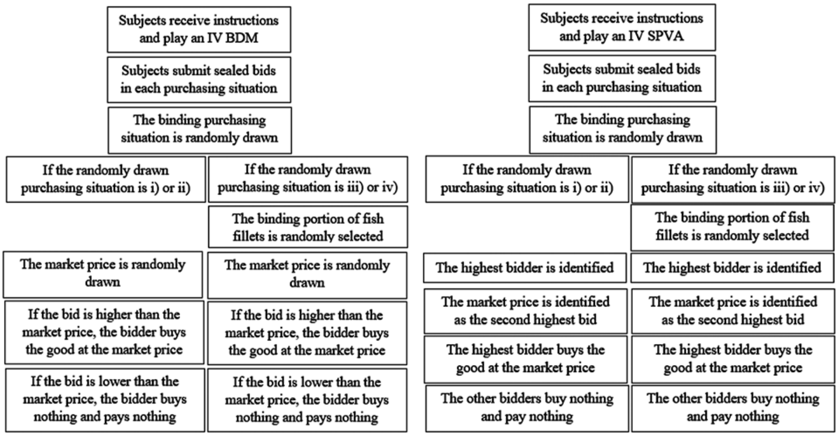

Fig. 1. All steps of the WTP elicitation task in BDM and SPVA treatments.

in the same order.[16] Only one task determines additional earnings for participants in part (ii) of the experiment. This is randomly drawn at the end of the experiment. A description of these elicitation tasks plus a discussion of their strengths and limitations are provided in online Supplementary Appendix C.

5. Model specifications, testable hypotheses and empirical results

5.1. Premium for authentic fish products

In this section, we compare the premium participant i is willing to pay for a portion of authentic pollan fillets with respect to a portion of herring as well as risky and uncertain purchasing situations when outcomes similar to food fraud can occur. Data from the BDM and SPVA are pooled as our analyses show that there are no statistically significant differences in premiums elicited via these methods.[17] Table 2 provides summary statistics of each premium.

Model 1 is estimated to test whether premiums are statistically different across purchasing scenarios:

$$PREMIUM_{i,j} = \alpha + \beta_{HERRING} HERRING_{i,j} + \beta_{RISK} RISK_{i,j} + \beta_{UNCERTAINTY} UNCERTAINTY_{i,j} + \beta_{BDM} BDM + \varepsilon_{i,j} \quad (1)$$

In Equation (1), the dependent variable ($PREMIUM_{i,j}$) is the difference between participant i's bid (i.e. maximum WTP) for a portion of authentic

16 Tasks were not randomised, as tasks 2–4 were kept in order to follow Tanaka, Camerer and Nguyen (2010). Tasks 1 and 5 were not randomised, as Task 5 was complicated so we did not put it as the first task.

17 Differences in premiums across methods were investigated using an econometric approach based on feasible GLS estimation procedure with correction for heteroscedasticity. Results are provided in online Supplementary Appendix D.

Table 2. Mean price premium (in £) for pollan with respect to herring, risky and uncertain portions[a]

Premium over:	Whole sample	SPVA	BDM
Herring	0.890 (1.223)	0.870 (1.152)	0.910 (1.304)
Risky portion	0.143 (0.669)	0.130 (0.531)	0.156 (0.792)
Uncertain portion	0.657 (1.062)	0.548 (0.750)	0.769 (1.308)

[a]Standard deviations are given in brackets.

pollan fillets and his/her bids for fish fillets in the other purchasing scenarios $j = \{$POLLAN, *HERRING, RISK* and *UNCERTAIN*$\}$.[18] This ranges from -£3.00 to £5.50. Specifically, the variable *HERRING* is equal to 1, if we consider the premium that participants are willing to pay to get a portion of pollan instead of herring (otherwise = 0); the variable *RISK* is equal to 1, if we consider the premium that participants are willing to pay to get a portion of pollan instead of the risky portion (otherwise = 0); and finally the variable *UNCERTAIN* is equal to 1 if we consider the premium that participants are willing to pay to get a portion of pollan instead of the uncertain portion (otherwise = 0).

The variable *BDM* is included in the model to control for potential differences in premiums estimated via BDM and SPVA. This variable is equal to 1, if the participants belong to the BDM treatment (otherwise = 0). Model 1 is estimated using a generalised least-square (GLS) estimation procedure with correction for heteroscedasticity accounting for the panel nature of our data set (following Akaichi, Nayga and Nalley (2017) and Cerroni *et al.* (2019b)). To identify the appropriate econometric model, we test for normality and heteroscedasticity of errors.[19,20]

The coefficients $\beta_{HERRING}$, β_{RISK} and $\beta_{UNCERTAINTY}$ measure the premiums that participants are willing to pay, on average, for a portion of authentic pollan fillets compared to other scenarios. Specifically, $\beta_{HERRING}$ is the average premium for a portion of authentic pollan fillets compared to a portion of herring fillets, β_{RISK} is the average premium for a portion of authentic pollan fillets compared to the risky purchasing scenario and $\beta_{UNCERTAINTY}$ is the average premium for a portion of authentic pollan fillets compared to the uncertain purchasing scenario. The coefficient β_{BDM} informs on whether the premiums elicited via the BDM are equal to those elicited via the SPVA. The coefficient α

18 *PREMIUMPOLLAN* will always be £0 but this is to allow an easier interpretation of β*PREMIUMi,j* in the model. If *PREMIUMPOLLAN* was not the reference group, then β*PREMIUMi,j* would be the difference between premiums whereas in our model it is the absolute premium for pollan compared to each portion.

19 Results from these analyses are reported in online Supplementary Appendix E.

20 Participants were informed that the market price for a 250-g portion of frozen fish fillets, similar to pollan and herring, is between £3 and £7 in the market. Model 1 does not control for bids being censored by these market prices because we did not find evidence of bids being concentrated around these market prices. To test the robustness of our results, we also estimated models that account for censoring. Results are provided in online Supplementary Appendix F.

informs about the slope and $\varepsilon_{i,j}$ is the error term. We test whether premiums differ across scenarios *j* by comparing coefficients using a post-estimation Wald test (H_0: $\beta_{HERRING} = \beta_{RISK} = \beta_{UNCERTAINTY}$).

5.2. Factors affecting premiums for authentic fish products

In this section, we test the effect of socio-demographic variables, food shopping habits and behavioural factors on premiums for pollan in different scenarios ($PREMIUM_{i,j}$). Three models are estimated (Models 2a, 2b and 2c). These differ in the dependent variable, but the independent variables are the same. The model specification is similar across models:

$$PREMIUM_{i,j} = \alpha_j + \beta_{BF,j}BF_{i,j} + \beta_{FSH,j}FH_{i.j} + \beta_{SD,j}SD_{i,j} + \varepsilon_{i,j} \qquad (2)$$

In Model 2a, the dependent variable is the premium that participants are willing to pay for a portion of authentic pollan fillets with respect to a portion of herring fillets ($PREMIUM_{i,HERRING}$). This ranges from -£3.00 to £5.50.[21] In Model 2b, the dependent variable is the premium that participants are willing to pay for a portion of authentic pollan fillets with respect to the purchasing situation with a known probability of food fraud ($PREMIUM_{i,RISK}$). This ranges from -£2.50 to £5.00. In Model 2c, the dependent variable is the premium that participants are willing to pay for a portion of authentic pollan fillets with respect to the purchasing situation with an unknown probability of food fraud ($PREMIUM_{i,UNCERTAINTY}$). This ranges from -£3.00 to £5.00.

As the three premiums in Models 2a, 2b and 2c may not be independent, correlation between the three error terms can be expected. Hence, Models 2a, 2b and 2c are jointly estimated using a seemingly unrelated regression (SUR) model (Zellner, 1962). We test for normality and heteroscedasticity; results show that errors are not normally distributed and error variances are not constant.[22] Therefore, standard errors are estimated using bootstrapping.

The vector of variables associated with behavioural factors ($BF_{i,j}$) includes the following variables: *PROB* indicating the participant's subjective probabilistic belief that a fish product is authentic in the UK market in 2018 (elicited via QSR). *RA* and *RN* indicate whether the participant had a risk-averse or neutral choice behaviour in the study by Holt and Laury (2002). *RL* which indicates whether participants had a risk loving choice behaviour is used as reference level; hence, it is not included in the model. *AA* and *AN* indicate whether the participant had an ambiguity-averse or neutral choice behaviour in the study by Chakravarty and Roy (2009). *AL* indicates whether participant had an ambiguity-loving choice behaviour and is used as reference level.

The vector of variables related to food habits ($FH_{i,j}$) includes the following variables: *FISH* indicates if the participant eats fish fillets more than once per

21 Three participants' WTP for herring is higher than their WTP for pollan which is unexpected but 2 of the 3 participants' expected taste of herring is equal to or greater than their expected taste for pollan which partially explains the higher WTP.

22 Results from heteroscedasticity and normality tests plus an OLS and tobit estimation for Models 2a, 2b and 2c are reported in online Supplementary Appendix I.

week. *LN* indicates if the participants have heard of Lough Neagh Fishermen's Cooperative. *FROZEN* indicates if participants usually purchase their fish fillets frozen (or not). *PTRIED* (*HTRIED*) indicates if the participant has tried pollan (herring). *EXPTASTE* indicates participants' expected taste of pollan on a scale from 1 (extremely bad) to 7 (extremely good). *PRICE* indicates the importance of price when food shopping on a scale from 1 (not at all important) to 7 (very important). On the same scale, *AUTH (TASTE)* indicates the importance of authenticity (taste) when food shopping.

The vector of socio-demographic variables ($SD_{i,j}$) includes the following: *FEMALE* indicates if the participant is female, *AGE* is the participant's age in years, *INCOME* is the participant's annual net household income and *CITY* indicates if the participant lives in the city (or not). *COLLEGE* indicates that college diploma is the highest educational attainment achieved by the participant. *UNDERGRAD (POSTGRAD)* indicates that an undergraduate (postgraduate) degree is the highest educational attainment achieved. *SECONDARY* indicates that secondary school diploma is the highest educational attainment achieved and is used as a reference level for all other educational variables.[23]

Summary statistics of behavioural factor, food habits and socio-demographic variables alongside how risk and ambiguity attitudes are categorised can be found in online Supplementary Appendix G.

6. Results

6.1. Premium for authentic fish products

Table 3 reports results from the GLS regression model (Model 1).[24] All coefficients are significant indicating that participants are willing to pay a premium for a portion of authentic pollan fillets with respect to all other scenarios. Participants are willing to pay a premium of £0.79 for a portion of authentic pollan fillets compared to a portion of herring fillets ($p < 0.01$). The premium participants are willing to pay for a portion of authentic pollan fillets compared to a situation of uncertainty regarding a food fraud incident is £0.50 ($p < 0.01$), while the premium they are willing to pay compared to a situation of risk regarding a food fraud incident is £0.14 ($p < 0.01$). Wald tests suggest premiums are statistically different from each other ($p < 0.01$).

On the UK market, 250 g of fish fillets sell for £3.00 to £7.00. Hence, our results suggest a premium of 7.1 per cent to 16.7 per cent for a portion of fish fillets which are definitely authentic compared to an uncertain situation where food fraud may occur. The premium for a portion of fish fillets that

23 We also estimated Models 2a, 2b and 2c considering the panel nature of our data set. We refrain from including this in the manuscript as there is likely an overspecification issue. Results are provided in online Supplementary Appendix J.

24 The results for Model 1 using all 162 participants, not excluding those who were inconsistent in behavioural tasks, can be found in Supplementary Appendix H. The results are the same as in Table 3.

Table 3. GLS estimation of Model 1 with correction for heteroscedasticity[a]

	Model 1
Dep. Var: *PREMIUM*	Coefficient
$\beta_{HERRING}$	0.787***
	(0.050)
β_{RISK}	0.135***
	(0.050)
$\beta_{UNCERTAINTY}$	0.500***
	(0.050)
β_{BDM}	−0.009
	(0.037)
α	0.003
	(0.038)
No. of observations	440
Number of id	110
Time periods (scenarios)	4
H_0: $\beta_{HERRING} = \beta_{RISK}$	169.340***
H_0: $\beta_{HERRING} = \beta_{UNCERTAINITY}$	32.870***
H_0: $\beta_{RISK} = \beta_{UNCERTAINITY}$	52.990***

***$p < 0.01$.
[a]Robust standard errors in parentheses.

are definitely authentic compared to a risky situation, based on our results, is 2.0 per cent to 4.7 per cent.

The order of coefficient magnitudes is reasonable as consumers are getting a low-value product (herring) with certainty in the scenario (ii), while there is only a chance of receiving it in the uncertain and risky scenarios. Results indicate that participants are willing to pay a higher premium for authentic pollan fillets in the uncertain than the risky purchasing scenario. This result can be related to participants' probabilistic beliefs. There is an 8 per cent chance of receiving herring in the risky purchasing scenario, while the majority of participants (102 out of 110) believe the probability of receiving an inauthentic product was above 10 per cent in the uncertain scenario. Another potential explanation is ambiguity aversion. Participants are willing to pay less in the uncertain than the risky purchasing scenario because they prefer to avoid a situation where probabilities are unknown.

6.2. Effect of behavioural factors on WTP for authentic fish products

Table 4 shows the results for the SUR estimation of Models 2a, 2b and 2c. Risk preferences ($\beta_{RA,}$ β_{RN}) and subjective probabilistic beliefs regarding the number of authentic fish products in the UK market in 2018 (β_{PROB}) do not affect the premium in any model.

Table 4. Seemingly unrelated least squares estimation of Model 2[a]

	Model 2a	Model 2b	Model 2c
Dep. Var:	$PREMIUM_{HERRING}$	$PREMIUM_{RISK}$	$PREMIUM_{UNC}$
β_{RA}	0.043	0.283	–0.113
	(0.368)	(0.224)	(0.321)
β_{RN}	–0.188	0.184	–0.162
	(0.578)	(0.249)	(0.467)
β_{AA}	0.772	0.089	0.615*
	(0.509)	(0.218)	(0.325)
β_{AN}	1.028**	0.435*	0.752**
	(0.506)	(0.245)	(0.311)
β_{PROB}	0.152	–0.086	–0.347
	(0.595)	(0.332)	(0.486)
β_{FISH}	–0.059	–0.200	–0.111
	(0.305)	(0.200)	(0.256)
β_{LN}	–0.104	0.017	–0.592
	(0.374)	(0.212)	(0.385)
β_{FROZEN}	–0.329	0.064	–0.009
	(0.253)	(0.137)	(0.233)
β_{PTRIED}	1.164	0.296	0.487
	(0.898)	(0.404)	(0.599)
β_{HTRIED}	–0.138	0.074	0.020
	(0.287)	(0.205)	(0.249)
$\beta_{EXPTASTE}$	0.296***	0.050	0.111
	(0.082)	(0.046)	(0.085)
β_{PRICE}	0.012	0.086	0.110
	(0.101)	(0.074)	(0.084)
β_{AUTH}	0.080	0.023	0.020
	(0.075)	(0.042)	(0.062)
β_{TASTE}	–0.029	0.060	–0.086
	(0.150)	(0.101)	(0.167)
β_{FEMALE}	0.142	–0.131	0.217
	(0.284)	(0.154)	(0.230)
β_{AGE}	0.026*	0.005	0.035***
	(0.015)	(0.009)	(0.012)
β_{INCOME}	–0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
$\beta_{COLLEGE}$	–0.578	0.658*	0.088
	(0.555)	(0.342)	(0.380)
$\beta_{UNDERGRAD}$	–0.224	0.421*	0.463
	(0.468)	(0.232)	(0.348)
$\beta_{POSTGRAD}$	–0.198	0.113	0.661*
	(0.582)	(0.244)	(0.389)
β_{CITY}	0.108	0.119	0.148
	(0.241)	(0.151)	(0.213)
β_{BDM}	0.165	0.125	0.285
	(0.299)	(0.150)	(0.253)

(continued)

Table 4. (Continued)

	Model 2a	Model 2b	Model 2c
Dep. Var:	$PREMIUM_{HERRING}$	$PREMIUM_{RISK}$	$PREMIUM_{UNC}$
α	−2.360	−2.107**	−2.235*
	(1.478)	(0.954)	(1.186)
No. of observations	108	108	108
R-squared	0.295	0.271	0.331

***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.
[a]Bootstrapped standard errors in parentheses.

Ambiguity preferences seem to play a role in explaining participants' WTP a premium, at least in Models 2a and 2c. There is no clear pattern on how ambiguity preferences affect premiums. In Model 2a, the positive and statistically significant coefficient β_{AN} ($p < 0.05$) suggests that ambiguity-neutral participants are willing to pay a higher premium for a portion of authentic pollan fillets with respect to herring than ambiguity-loving participants, even when they are not informed about the possibility of a food fraud incident. While the insignificant coefficient β_{AA} suggests that there is no difference in the premium ambiguity-averse and ambiguity-loving participants are willing to pay. These results indicate that ambiguity-neutral consumers tend to prefer a local fish product with a PDO (i.e. pollan) rather than a non-local and generic product with no GI labels (i.e. herring). These consumers tend to avoid uncertainty related to the quality and the authenticity of the non-GI product. It can be concluded that a PDO label adds value and generates confidence in the high quality and authenticity of the product among ambiguity-neutral consumers.

As expected, these results are replicated in Model 2c, suggesting that ambiguity-neutral consumers are willing to pay a higher premium for a portion of authentic pollan fillets when a food fraud incident may occur and when the probabilities of occurrence are unknown (i.e. uncertainty). This result suggests that ambiguity-neutral consumers are willing to pay to avoid uncertainty related to the occurrence of the food fraud.

While current literature does not account for ambiguity attitudes when investigating WTP for food authenticity, our results suggest that such attitudes substantially affect consumers' valuations and purchasing behaviour. Ambiguity-neutral consumers react to different sources of uncertainty related to food authenticity differently from ambiguity-loving consumers. The former tend to prefer food products whose characteristics (i.e. quality and authenticity) are more certain and are willing to pay a premium to reduce uncertainty related to the occurrence of food fraud incidents than the latter. These results may have very important implications as full information on the traceability of many food products, especially in the fish industry, is very difficult to obtain for consumers. In addition, there is a lack of available data regarding food fraud incidents worldwide. Therefore, consumers make their purchasing decisions in situations characterised by high uncertainty regarding the probability of purchasing a fraudulent food product.

Previous research shows that subjective probabilistic beliefs regarding food safety and healthiness can substantially affect consumers' purchasing decisions and/or support for public policy (e.g. Lusk and Coble, 2005; Teisl and Roe, 2010; Cerroni, Notaro and Raffaelli, 2019a). In this paper, we found no evidence of a possible relationship between beliefs on food authenticity and consumers WTP for authentic food. Several factors may have generated this result. First, previous research focuses mainly on health outcomes related to food safety incidents, while our study does not relate food authenticity to negative externality on human health. Second, it may be that consumers are more familiar with risks related to health outcomes than authenticity outcomes. This implies that our subjects were not able to form well-defined and meaningful subjective probabilistic beliefs.

Similarly, previous research shows risk attitudes substantially affect preferences for safe food and GM food (e.g. Pennings, Wansink and Meulenberg, 2002; Lusk and Coble, 2005; Lee *et al.*, 2015; Petrolia, 2016). Again, we argue that the difference between the negative externalities (unsafe food vs. inauthentic food) may explain why risk attitudes do not influence premiums in our models. In addition, in our risky situation, participants were informed that the probability of receiving a low-quality product is 8 per cent. Such a low probability may have a potential influence on the linkage between consumers' risk preferences and consumers' valuations.

6.3. Effect of habit and socio-demographic on WTP for authentic fish products

Results in Table 4 show that variables related to food consumption habits can partially explain premiums that participants are willing to pay for a portion of authentic pollan fillets compared to herring fillets (Model 2a). The positive coefficient ($\beta_{EXPTASTE}$) ($p < 0.01$) suggests that expected tastiness of pollan influences premiums positively. Previous research shows taste is a strong driver of food purchasing decisions (e.g. Thunström and Nordström, 2015; Macdiarmid *et al.*, 2021). However, food habits have no influence on premiums that consumers are willing to pay for a portion of authentic pollan with respect to a portion when a food fraud incident may occur under risk or uncertainty (Models 2b and 2c, respectively).

Results indicate that socio-demographic characteristics have little influence on the premiums that participants are willing to pay. Household income (*INCOME*), whether participants live in the city (*CITY*) and gender (*FEMALE*) do not affect their premiums in any purchasing scenarios. Our results on income and gender support findings for Canadian consumers' WTP for traceable pork sandwiches (Hobbs *et al.*, 2005). In contrast, other studies find that income positively affects the premium for traceable food (e.g. Ward, Bailey and Jensen, 2005; Haghiri, 2014; Hou *et al.*, 2019).

Participants' level of education does not affect the premium in any purchasing scenario.[25] While recent studies find that more educated consumers are more concerned about food fraud (e.g. Charlebois *et al.*, 2017), evidence on the effect of education on WTP for traceable food is mixed. Some studies find that education positively affects the premium for traceable food (e.g. Haghiri, 2014; Hou *et al.*, 2019), while others suggest that education has no effect (e.g. Ward, Bailey and Jensen, 2005; Hobbs *et al.*, 2005).

Participants' age (*AGE*) influences the premium that they are willing to pay for a portion of authentic pollan fillets with respect to the uncertain situation regarding the food fraud incident (i.e. Model 2c). The positive coefficient (β_{AGE}) ($p < 0.01$) shows premiums increase with age. However, age does not influence premiums in Model 2a or 2b. The positive effect of age is in line with findings for Chinese consumers for pork and Canadian consumers for Salmon (Haghiri, 2014; Hou *et al.*, 2019), but contrasts findings from Ward, Bailey and Jensen (2005) where age has a negative effect for beef for US consumers.

7. Conclusion

Food fraud deserves more attention than it receives from agribusinesses and policymakers. While most food fraud cases do not lead to widespread harm, it is still a form of blatant cheating which can significantly affect people's utility, welfare and possibly health. For example, an inauthentic fish could come from polluted water and if consumed by consumers with health vulnerabilities, affect their health. Therefore, knowledge and understanding of consumers' perceptions of food authenticity and their WTP for authentic food under conditions of risk and uncertainty can be very important for food businesses and policy makers.

In this paper, using an artefactual field experiment, we elicit a general measure of the premium that consumers are willing to pay for authentic food products, net of potentially confounding factors generated by consumers' preferences and perceptions. To this end, we elicited participants' WTP for a high-value and high-quality fish product (i.e. a portion of PDO pollan fillets) and for a low-value and low-quality fish product (i.e. a portion of herring). In addition, we elicited WTP for pollan using lotteries involving different product outcomes and imitate real-world situations where a food fraud incident can occur. In our experimental setting, food fraud involves getting a portion of herring fillets instead of pollan fillets. In the uncertain purchasing scenario, the probability of getting herring fillets instead of pollan fillets is unknown; while in the risky scenario, this probability is communicated to participants. We use pollan and herring because they look and taste similar.

This paper makes two main contributions to the related literature. Firstly, while the use of BDM and SPVA to elicit consumers' WTP for food products is widespread, this is not true for studies exploring WTP for traceable fish-based products. This literature is very scarce and mostly uses hypothetical

25 Alternatively, the influence of education may be non-linear, e.g. an inverted U shape.

value elicitation approaches (e.g. Wang *et al.*, 2009; Dopico *et al.*, 2016). We use incentivised and incentive-compatible value elicitation mechanisms (i.e. BDM and SPVA). In theory, this allows more truthful WTP measures.

Secondly, this paper investigates the role of consumers' behavioural drivers, such as subjective probabilistic beliefs, risk and ambiguity preferences, in shaping consumers' WTP a premium to avoid risk and uncertainty related to food fraud incidents. While previous studies focused on food safety, we are the first to use a wide range of incentivised and incentive-compatible methods: QSR (Brier, 1950), Tanaka, Camerer and Nguyen (2010) MPL and Chakravarty and Roy (2009) MPL.

Our results show that participants are willing to pay a £0.50 premium for an authentic portion of pollan fillets compared to an uncertain scenario where a food fraud may occur. A smaller premium of £0.14 is found for an authentic portion of pollan fillets compared to a risky scenario where a food fraud may occur with known probability. The latter resembles a scenario where a relevant scientific report on food fraud is available to the public. As there is limited information about fish fraud available to consumers, it is likely that consumers usually make choices in a situation of uncertainty. Therefore, if a company invests in measures to ensure full authenticity, it is possible based on our results that they will receive a premium of 7.1 per cent to 16.7 per cent for 250 g of fish fillets.[26]

Additionally, we find evidence that behavioural factors partially affect price premiums. While subjective probabilistic beliefs and risk preferences have no effect on reported WTP, ambiguity preferences play an important role in shaping participants' bidding behaviour. Ambiguity-neutral participants tend to pay more than ambiguity lovers when uncertainty regarding the food fraud incident is simulated. This is an important piece of information for private businesses and policymakers as consumers are likely to make choices in a situation of uncertainty in real-world situations where little information is available about the magnitude and frequency of food fraud incidents. Therefore, while previous research has not explored the influence of ambiguity attitudes on consumers' behaviour, it is important that such attitudes are accounted for when investigating WTP for food authenticity.

Interestingly, our results also suggest that ambiguity-neutral respondents are willing to pay a premium for the portion of PDO pollan fillets than ambiguity lovers even under condition of certainty (with respect to the portion of herring fillets). This may indicate that the PDO label adds value and operates as a signal of quality and authenticity to consumers. Previous research shows WTP for a PDO can depend on indirect factors such as the label acting as a quality indicator or supporting regional products (e.g. Van Ittersum, Candel and Thorelli, 2000; Van der Lans *et al.*, 2001; Garavaglia and Mariani, 2017).

The UK is currently leaving the EU, and how the UK will deal with GI foods is under discussion (see Prescott, Pilato and Bellia (2020)). The latest news is that the UK will create its own GI scheme which mirrors the EU schemes.

26 This premium is based on prices for fish fillet (250 g) in the UK.

Existing UK products registered under EU GI schemes will get UK GI status and remain protected in the UK (DEFRA, 2019).[27] Future studies should examine consumers' WTP price premiums for products that obtain UK GI status, as previous research shows that British consumers' WTP for food labels depends on how much they trust the label and their awareness of the label (e.g. Janssen and Hamm, 2012; Gerrard *et al.*, 2013). Therefore, WTP may depend on how well consumers are informed about the UK GI scheme and their trust in UK food labels compared to EU labels.

Supplementary data

Supplementary data are available at *ERAE* online.

Funding

This research was funded by Invest Northern Ireland, Agri-Food Quest and a Department for the Economy PhD studentship.

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27 It is anticipated that UK products registered under the EU scheme will continue to be recognised post-Brexit; if not they can apply as a third country producer to the scheme (Tillet, 2020).

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