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Using a Discrete Choice Experiment to Elicit Consumers' WTP for Health Risk Reductions Achieved By Nanotechnology in the UK

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Abstract

We present research findings on consumers' willingness to pay (WTP) for reductions in the level of foodborne health risks. The research addresses how such valuations are affected by the means of which the risk reduction is delivered and the methods of risk presentations used in choice tasks. In this case, the research has two treatments. In the first treatment, the comparison is between risk reductions achieved by an improvement in the food system in general (e.g., more stringent regulations and inspection regimes) within the slaughter and meat processing stages of the food chain, as opposed to a risk reduction achieved via innovations in food packaging using nanotechnology, which is the use of nanosensors in packaging. If there is a contamination in packaging, nanosensors reveal a colour change on the packaging material. In the second treatment, the comparison is between valuations of risk reductions in which reductions in risks are presented via absolute values and grids and absolute values together. Both comparisons are achieved via split sample Discrete Choice Experiment surveys. The difference between consumers' valuations of foodborne risk reductions provides an implicit value for nanotechnology (i.e., WTP to avoid) and the effect of risk grids on choices people make. General results show the existence of heterogeneity in British consumers' preferences. The effects of nanosensors and risk grids on consumers' choices are not strong across the models. The valuations of health risk reductions show some variations across the models in both treatment groups.

Keywords: Discrete Choice Experiments; Nanotechnology; Nanosensors; Health Risks; Grids; UK

1 Introduction

There has been an increasing concern over the human health risks posed by recent food issues. The Health Protection Agency (HPA) of the UK estimated that around 1 million people suffer from foodborne illnesses annually. Of these people, around 20,000 are hospitalised, and 500 die. Such foodborne diseases and outbreaks have prompted an increasing concern among public in recent years over food safety.

Associated with the health impacts of food poisonings, there are economic costs. The HPA estimated that each year in the UK foodborne illnesses cost around £1.5 billion[1]. The ineffective and less stringent mitigating strategies in the food supply chain have continued to result in foodborne illnesses and pose risks to public health. This has increased demand for better safety practices and more stringent regulations that ensure the safety of foods in the entire chain as such new technologies and strategies have been developed to provide better and safer foods.

Novel food technologies and their application in food production, however, can be very sensitive issues. They can be beneficial in terms of providing more effective production techniques (e.g. increased yield) producing new tastes, textures, and flavours, or ensuring improved safety during shelf life of foods. Their acceptability and future uses, however, can be affected by how they are perceived. For example, a study by Frewer et al. (1998) showed that people tend to perceive GM foods as harmful, threatening, and risky. This contentious history of GM foods in the UK and EU has shown that there can be strong reaction and opposition to new technologies. The other factors influencing perceptions of novel technologies include media coverage, general underlying attitudes, beliefs and preferences. Among these factors, the level of trust a person has in the food system (producer, processor, and retailer) and in the regulatory process watching over it, is likely to be critical.

This research investigates British consumers' preferences towards the use of a novel food technology, nanotechnology, as a means of reducing foodborne illnesses. Nanotechnology does this by providing new materials and structures at the nano scale (i.e., 1 in a billionth of a scale) which have special properties stemming from their nano structures. The application of nanotechnology in this research is the use of nanosensors which deliver quantifiable reduction on food poisoning risk by showing a change in colour when food is unsafe to eat. The value of the risk reduction delivered in this way is evaluated against

[1] This includes NHS costs, lost earnings, other expenses, and the cost of pain and suffering.

equivalent values achieved in a less controversial manner (e.g., more stringent regulations) in the conventional food chain. This is implemented by conducting split-sample choice experiment surveys investigating people's willingness to pay for health risk reductions attributable to raw whole chicken achieved by (i) an improvement in the food system in general and (ii) nanosensors in packaging that reveal unsafe pathogen levels. In this latter case the credence attributes of raw whole chicken (e.g., safety) turn into search attributes (e.g., appearance).

Given previous research findings on the difficulties of conveying and understanding changes in small probabilities, the research also examines the effects of different risk presentations on willingness-to-pay (WTP) values for the health risk reductions offered. We use two different risk presentations: absolute numbers with and without visual grids, to communicate changes in the level of food poisoning level attributable to chicken.

The remainder of this paper is structured as follows: Section 2 reviews the literature on consumers' perception of food safety and attitudes towards new food technologies. This section focuses on concerns, awareness, and attitudes to nanotechnology. We then review methods used to investigate consumers' valuation of risk reductions. The contributions of the study are also provided in this section. Section 3 explains study design and data collection, and Section 4 introduces the models employed to analyse the data. Section 5 contains the results, and the final section summarises the paper.

2 Literature and Our Contributions

A Novel Technology: Nanotechnology

Nanotechnology is one of the novel technologies currently receiving increasing attention in the UK and elsewhere. It is one the emerging technologies identified by the Food Standards Agency of the UK[2] as requiring greater research on the public's perceptions of it. It is an area of science that creates and manipulates materials in nanoscale (i.e., one in a billionth scale).

The potential application of the nanotechnology to food science and technology is emerging. It is expected to have the biggest impact on agriculture (nanoparticles and nanoemulsions in pesticides), food safety (nanosensors), new product development (formulation, packaging), and food processing

[2] Other novel technologies identified by FSA are cloning, biotechnology, synthetic biology, genetic modification, irradiation, and functional foods.

technologies (nanofilters) (Stampfli et al., 2010; Marette et al., 2009; Augustin and Sanguansri, 2009; Chaudhry et al., 2008, 2009; Lyndhurst, 2009; Illuminato, 2009; Kuzma, 2006; Moraru et al., 2003 and many more).

Nanotechnology in food packaging is one of the potential applications that has brought much attention recently (Stampfli et al., 2010). Some studies showed that nanostructures can be used in smart packages that sense the surrounding environment and allow consumers to know when there is contamination or a pathogen detected (Parr-Vasquez et al., 2003; Yam et al., 2005; Dunn, 2004). Nanosensors are good examples of such innovations in food packaging. They are composed of structures that can detect gases released by food when it is contaminated, and change colour to alert consumers when food is spoiled (Augustin and Sanguansri, 2009). For example, in a lab study, Gfeller et al. (2005) showed that nanosensors can be used to detect active *E.coli.*

Although nanotechnology has promising applications in many sectors, there is concern over its use in the food industry (Stampfli et al., 2010; Marette et al., 2009; Kuzma and ver Hage, 2006). Currently, there is a lack of information on the health and environmental impacts of such technologies. In the UK it has been argued that nanotechnology implementation needs more research on any human toxicological impacts of residue nanomaterials in foods before being used in food production and packaging (House of Lords Science and Technology Committee, 2010). Uncertainty involved in this technology raises concern amongst the public. The public’s experience with previous technologies, such as genetic modification, suggests that caution is required regarding the introduction of nanotechnology. It is therefore very important to assess views and preferences held by public for nanotechnology and for foods produced by this new technology.

A recent FSA report on emergent technologies (Lyndhurst, 2009) showed that people have concerns towards nanotechnologies in general. More specifically, they worry about the technology’s effectiveness, long-term side-effects, and the ability to ensure safety. The public question whether the use of this technology in food systems would be beneficial to them.

The report also shows that people have a low level of awareness of nanotechnologies in general, both in the UK and elsewhere. For example, a UK survey study[3] by the Royal Society and the Royal Academy of Engineering (2004) found that only 29% of participants said they had heard of the term and only 19% of

3 A nationally representative sample of 1005 people aged 15 or over in Great Britain.

them were able to describe what nanotechnologies were. Another recent study by Kahan et al. (2008)[4] from the USA found that 92% had heard either "little" or "nothing at all" about nanotechnologies.

While, in general, awareness towards nanotechnologies appears to be low, some studies show that attitudes towards them are for the most part positive (see the Royal Society and the Royal Academy of Engineering, 2004). The Royal Society and the Royal Academy of Engineering survey showed that, among people who knew what nanotechnologies were, 68% thought nanotechnologies would make life better in the future, while only 4% thought they would make things worse. Some UK and US studies support these findings, e.g., Lee et al., (2005)[5] and Macoubrie (2006)[6]. However, there have still been concerns expressed over nanotechnologies in the UK Nanologue (2006).

Acceptability of nanotechnologies in foods is a more critical issue than in other applications. Some studies showed that people were more willing to accept nanotechnologies in industries other than the food industry (e.g., Nanologue[7], 2006; Lyndhurst, 2009). However, the public's preferences for nanotechnology may also depend on how they will be used in the food industry. For example, Siegrist et al. (2008) found that the use of nanotechnologies in food packaging was viewed more favourably than their use in food production, which may result in nanoparticle residues in foods. Some studies, on the other hand, found that people are willing to buy foods produced using nanotechnologies (e.g., Cook and Fairweather, 2006).

Risk Format Effect on WTP Estimates

All Stated Preference studies involve conveying information to respondents. If the study involves changes in risks then the task is more daunting as communicating information about changes in risk levels is accepted to be a challenging task. Additionally, people may have different familiarity with different risk presentations. The way risks are presented to people can have significant effects on their

[4] A nationally representative online survey that included 1600 respondents.
[5] A nationally representative telephone survey that included 706 respondents.
[6] Study with 177 participants in 3 locations: Spokane, Washington; Dallas, Texas; and Cleveland, Ohio.
[7] Nanalogue is a research consortium composed of 4 institutes: Wuppertal from Germany, EMPA from Switzerland, Forum for the Future from the UK, and triple innova from Germany. More details on them can be accessible at: http://www.nanologue.net/
Nanologue study is an EU funded 6th Framework Programme project looking at the social, ethical and legal implications of nanotechnology. The project consortium of this 21-month old project is composed of the Wuppertal Institute in Germany, Forum of the Future in the UK, EMPA (Swiss Federal Laboratories for Materials Testing and Research), and triple innova of Germany.

understanding of risks and reductions in the level of risks. This may then affect their valuations of risk reductions.

There are various ways of conveying risks to survey respondents. Absolute values (i.e., numbers), relative values (i.e., percentage changes), and visual aids are some of the modes used in survey studies. Among these modes, absolute and relative values are the most commonly used modes in the literature. Absolute values, i.e. numbers, have been used in various studies investigating risks (e.g.,Akgungor et al., 1992; Baker, 1998; Brown et al., 2005; Burton et al., 2001; Crutchfield et al., 1997; Cowan et al., 2000; Hayes et al., 1995; Mourata et al., 2000; Rosen et al., 1998).

For example, in a choice experiment, Baker (1998) used absolute values (i.e. 1 in 10,000) to present cancer risks due to the consumption of pesticides on apples. Similarly, Mourato et al. (2000) used absolute values in their contingent valuation study to present the health impacts of pesticides (e.g., 100 cases of ill health per year).

Alternatively, some studies use probabilities to convey risks to survey respondents (e.g., Huang et al., 2000; Goldberg and Roosen, 2007; Buzby et al., 1995; van Ravenswaay and Hoehn, 1991; Eom, 1992, 1994; Lin and Milon, 1995). For example, Goldberg and Roosen (2007) examined consumers' valuations of foodborne risk reductions in a choice experiment study. They presented the levels of risks in terms of probabilities (i.e., 0%, 40%, 80%).

In addition to absolute and relative risk levels, visual presentations can also be used for conveying risks to respondents. For example, Baker (1998) used photographic representation of different defects on apples when eliciting consumers' WTP for food safety. In a contingent valuation survey study, Krupnick et al. (2000) used risk grids to elicit Canadians' WTP for mortality risk reductions. They showed respondents two risk grids composed of 1000 squares, each square representing the chance of death. They then asked people to indicate which one of the persons shown in two grids was most likely to die in the given time period. Another study investigating people's WTP for risk reductions is Alberini et al. (2004). They used a grid of 1000 squares representing two types of risks: white squares represented survival and red squares represented the death. In a similar study, Adamowicz et al. (2007) used risk grids to indicate the number of people who would get microbial illness and bladder cancer, and people who would die. They represented these three categories of risks (i.e., microbial illness, bladder cancer, and death) with different colours in the grid. In addition to a visual grid, they also used absolute numbers to estimate the value of health risk reductions delivered by a clean water program. In another choice study, Cameron and DeShazo (2002) used risk grids, along with absolute and relative values to show risk reductions achieved by a hypothetical program that would reduce the risk of experiencing specific illnesses over current and future periods of people's life. Unlike others, Loomis et al. (1993) used risk ladders and pie charts in their survey study on Californians' WTP for reductions in exposure to hazardous waste. They also compared WTP estimates from two different surveys in which risks were presented in risk ladders and pie charts. They found that the two different risk communication devices yielded statistically different WTP estimates for risk reductions. The pie charts, particularly, resulted in lower WTP estimates.

Gottlieb et al. (2007) also investigated the effect of different risk presentations on choice behaviour. They found that uncertainty information presented differently (in their surveys presented via five methods: frequencies, absolute numbers, risk grids, one-by-one and simultaneous risk cards) was processed differently by respondents. More specifically, they found that uncertainty information was processed differently when it was presented in a probability (i.e., percentage format) than when it was presented in other formats. They indicated that frequency information (i.e. numbers) was processed more similarly to information extracted from experiences than to probability information (i.e. percentages). They indicated that the reason why percentages differed from frequencies and experienced information was the fact that percentages are unitless and contain no information about the number of times an event occurred. In this regard, Leikas et al (2007) indicated that risk reductions given in terms of probabilities may give a positive signal to consumers regarding the safety of products in question. Whereas, risks given in terms of absolute numbers may be perceived as a negative information and as a result such information may affect consumers' risk valuations. However, Peters et al. (2006) reported in a study that risk estimates do not differ across frequency and percentage formats.

Our Contributions

This research investigates preferences of people in the UK regarding the use of nanotechnology. More specifically, the research examines consumers' valuations of food poisoning risk reductions achieved by nanotechnology, and thus the implicit value of nanotechnology. Due to the novelty of nanotechnology, there are limited studies on the public's views of it in food production and their valuations of foodborne risk reductions that might be achieved. Thus, the research presented here fills this gap in the literature and sheds light on how people view this novel technology and value the benefits it might deliver.

Given previous research findings on the difficulties of conveying and understanding changes in small probabilities, the research investigates the effects of different methods to convey risks to consumers. Findings from various studies in the literature raise the issue of the effect of risk presentations in DCE surveys on people's choices. Thus, this research contributes to the literature by investigating the effect of different risk presentations on people's valuations of health risk reductions. As discussed, the concept of risk and reductions in risk levels are generally provided in terms of probabilities, absolute values, or risk grids. This research utilizes a combination of these formats and investigates the effect of a format change on consumers' valuations.

Additionally, this research investigates heterogeneity in choices for two consumer groups: (1) consumers who usually buy normal standard chickens, and (2) consumers who usually buy niche, better welfare chickens, such as free-range, Freedom-Food, or organic.

3 Study Design and Data Collection

Study Design

The preferences towards nanotechnology are investigated in a specific setting where nanopackaging delivers a quantifiable reduction in food poisoning risk. The value of the risk reduction delivered in this way is measured against equivalent values delivered in a less controversial manner in the conventional food chain (e.g., more stringent regulations). This is implemented by conducting split sample Discrete Choice Experiment (DCE) surveys addressing people's willingness to pay for health risk reductions attributable to raw whole chicken. The samples are split, so for some risk reduction is achieved by (i) an improvement in the food system in general and for some by (ii) nanosensors in packaging that reveal contamination via a colour change.

Given previous research findings on the difficulties of conveying and understanding changes in small probabilities, the effects of different risk presentations on willingness-to-pay (WTP) values for the health risk reductions are also examined. The food risk reductions are delivered by using absolute number with and without risk grids. This is done by using another split sample, so for some respondents risk reductions are presented by (1) absolute numbers (e.g. 10 in 10,000), and for some by (2) risk grids and absolute values together. The effect of the use of risk grids is then the differences between WTP estimates obtained from the data estimations.

Nanotechnology was chosen as a method of providing risk reductions due to current contentious issues regarding its use in food production and packaging in the UK. Whole raw chickens were chosen as a survey good, due to the fact that most foodborne illnesses occurring in the UK are attributed to poultry: "chicken consumption accounted for more disease, deaths, and healthcare usage than any other food type (Adak et al., 2005, p.367)". Approximately 30% of the annual foodborne cases and deaths are attributable to poultry.

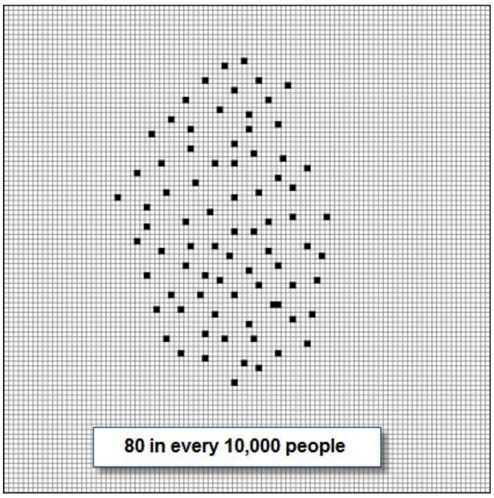
Within the DCE surveys, respondents choose between whole chickens of identical appearance, taste, and texture, but which differ in term of three attributes: level of food risk, level of animal welfare, and price. Table 1 summarises the attributes and their levels of each attribute included in the choice experiment design.

Table 1. Product Attributes and Levels

Attribute	Levels
Level of Food Risk (FP)	10/10,000, 20/10,000, 40/10,000, 80/10000 (baseline)
Level of animal welfare (AW)	40 (baseline), 70, 100
Price (P)	0% (baseline), 5%, 10%, 25%, 50% increase

The level food risks used in the surveys are presented via risk grids with absolute values and absolute values only. Figure 1 shows an example of a risk grid used in the choice tasks. The baseline risk level attributable to chicken is calculated using the estimates from Adak et al. (2005). The level of food risks are 87.5%, 75%, and 50% less than the baseline value.

Figure 1. An Example of Risk Grid Used in the Surveys



Animal welfare is included as one of the chicken attributes due to it increasingly being seen as an important ethical issue among consumers (Bennett, Anderson, and Blaney, 2001; IGD, 2000; Nocella, Hubbard, and Scarpa, 2007; Verbeke and Viaene, 2000; McEachern and Schroeder, 2002). We would like to investigate whether there are any changes in consumers' animal welfare WTP estimates when chickens include nanosensors in packaging.

The level of animal welfare is presented via an indicator which is adopted from a study done by Researchers at the University of Reading[8]. According the researcher, animal welfare can be measured by a system that scores the extent to which the needs and wants of the animal are met and results in an overall welfare score on a scale of 0-100. This system may represent the welfare of the animal in terms of its freedom from hunger, thirst, discomfort, pain, injury, disease, fear and distress, and the extent to which the animal can express natural behaviours and has a happy life. A score of zero would denote extreme suffering, whereas a score of 100 would denote the highest level of welfare that could possibly be achieved. The system applies over the entire life of the animal from birth to slaughter and involves regular independent monitoring of the animal's welfare. In our survey, we consider three levels of animal welfare scores: 40 represents a "legal minimum"[9], score 70 represents a "good life", and score 100

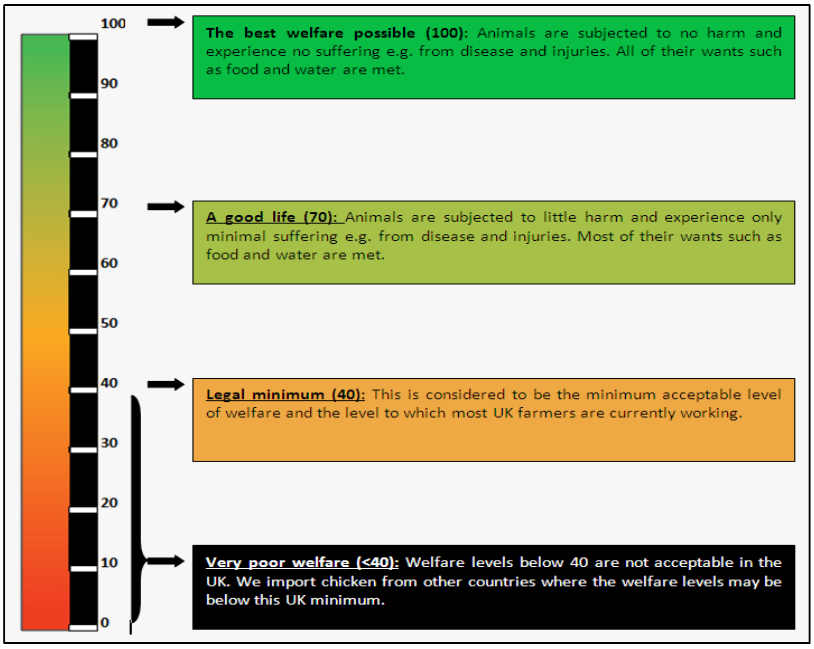
[8] The welfare score used in the study is a hypothetical welfare score. It is based on the Welfare Quality® Index, which is currently being developed by the Welfare Quality® Project to form the basis of a European standard for evaluating the welfare of cattle, pigs and poultry in farms, and during transport and slaughter (for some details on Welfare Quality® Project, see Botreau et al. 2007).

[9] According to this study, welfare levels below 40 are generally not acceptable in the UK.

represents “the best welfare possible”. Figure 2 shows the welfare indicator with descriptions of levels provided to respondents.

The price attribute has five levels ranging from no change in price to 50% increase from respondents’ current price.

Figure 2. Animal Welfare Indicator Used in the Surveys



Survey Design

The study comprises two treatments concerning the means by which the risk reductions are achieved and how food risks are presented. Table 2 presents these treatments, and thus the split samples. The first treatment is composed of a split sample. In the first sample, food safety improvements are delivered via nanotechnology (see Figure 3 for an example of choice task), and in the second sample, the health risk reductions are achieved via less controversial methods, such as more stringent regulations and inspection regimes (see

Figure 4). This is the treatment shown in the first row in Table 2. The levels of risks in these two samples are presented via risk grids and absolute values together. The second treatment explores the effect of different risk presentations on consumers’ choices when food safety improvements are delivered via nanotechnology. This is presented in the first column in Table 2. Risk reductions in this treatment are presented by two modes: (1) by absolute values only (see Figure 5), and (2) by risk grids and absolute values together (see Figure 3).

Table 2. Treatments and Split Samples

	Nano		No-nano
Grid	Nano-sample with risk grid	+	No-nano sample with risk grid
	+		
No grid	Nano-sample without risk grid		

The surveys included eight DCE sets and each set included three chicken options and the respondent's status quo. The status quo option had no nanosensors in its packaging, had the minimum welfare level for standard chickens (i.e., *AW* scored 40). Its price was set at the respondent-specific baseline price derived from a question earlier in the survey. Price changes were common across people in % terms, but the absolute prices would be scaled by this baseline price.

Providing a realistic and accurate choice set and *SQ* option is important. Some people indicated that they bought Free Range, Organic, or Freedom-Food chicken. For these people, their status quo option had to reflect this. In this case, the level of animal welfare is higher than the minimum level. We used a score of 70, representing "a good life", for the nonstandard chickens. The example in Figure 4 shows one of these tasks asked to people who buy high animal welfare chickens (e.g., free-range). Similarly, the example in Figure 3 and Figure 5 address consumers who normally buy standard chicken (not free-range, etc).

For each of the survey treatments an experimental design was created using *NGENE* (Rose et al., 2009). For the pilot surveys, a pivot design minimising D-error was generated using priors of zero for the marginal utility of all attributes. Choice models estimated from the pilot data provided new estimates of the marginal utilities. These point estimates and their standard errors were used as priors in a new Bayesian efficient design (see Rose and Scarpa, 2008) for the main survey. In all cases, the designs comprised 15 blocks. Each block included 8 choice sets, with each set comprising four alternatives, one of which was the status quo. Each respondent was assigned to a block randomly.

Figure 3. Sample DCE Task: Health Risk Reduction via Nanotechnology with Risk Delivered via Grid and Absolute Values

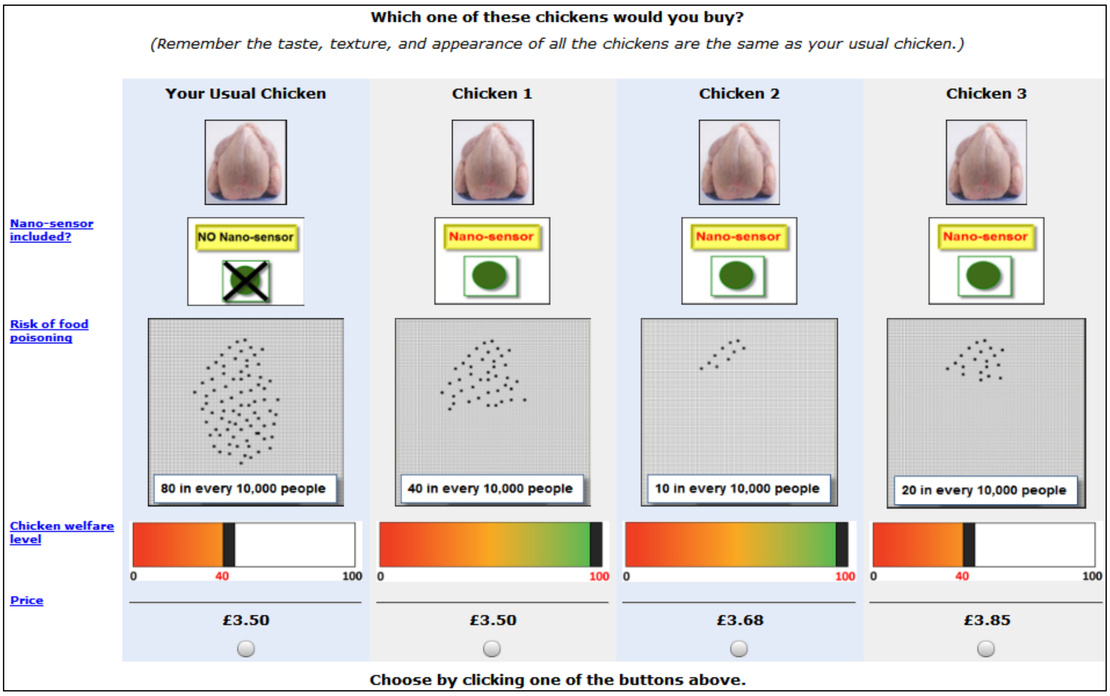


Figure 4. Sample DCE Rask: Health Risk Reductions via Less Controversial Methods with Risk Delivered via Grid and Absolute Values

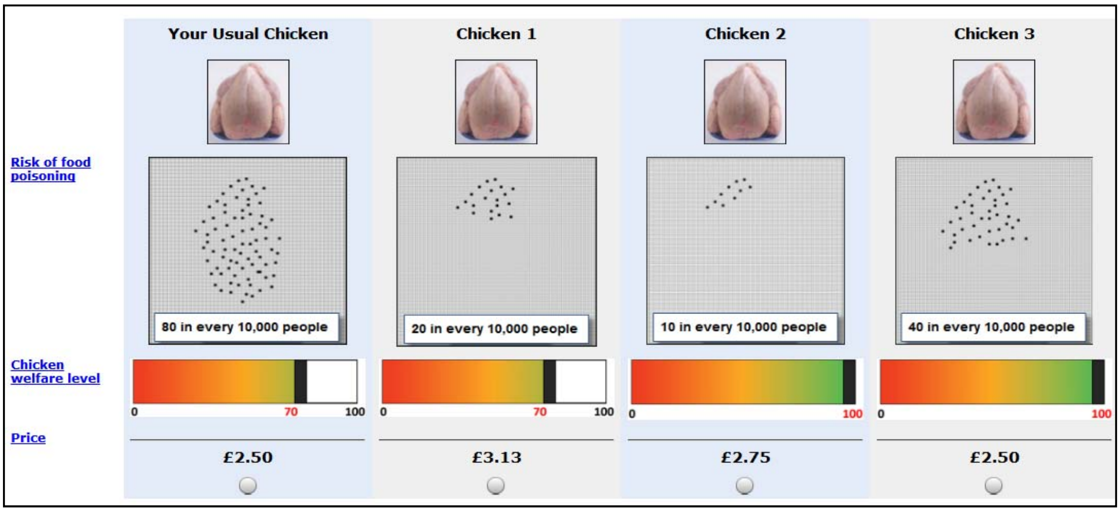
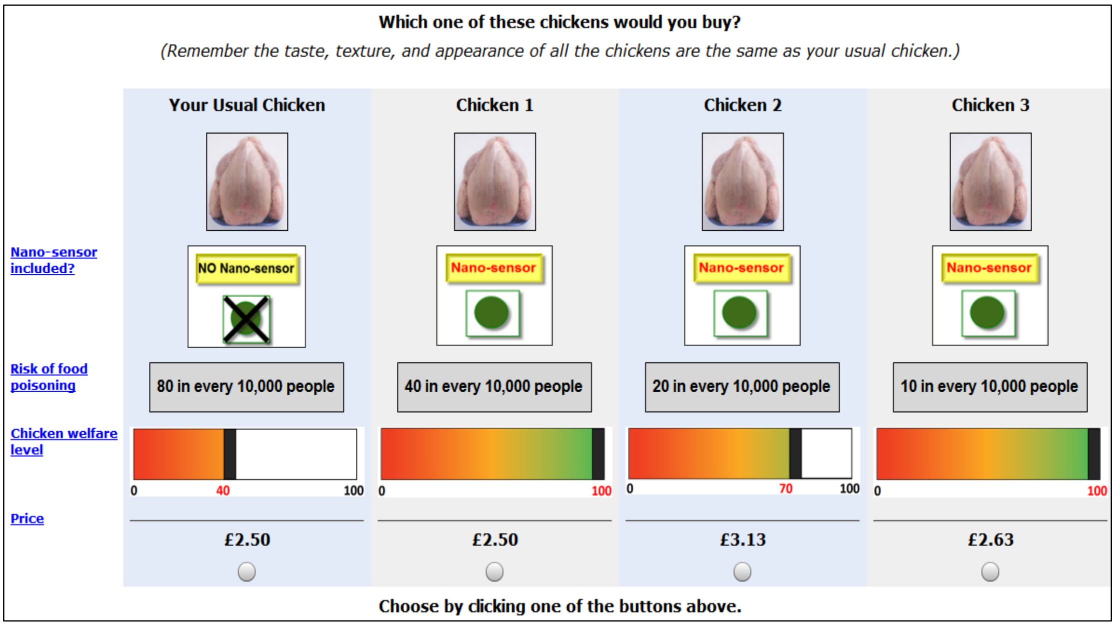


Figure 5. Sample DCE Rask: Health Risk Reductions via Nanotechnology with Risk Reductions Delivered via Absolute Values



Data Collection

Data were collected in late August 2010 through online surveys. Overall, we recruited 449 consumers through a market research company. The majority of the respondents were female (55%), had an A-level education (29%), and fell in 31-45 age group (29%). The average annual household income was about £35,000 (c. $56,000). Forty percent of the respondents were full-time employed, and 21% percent of the respondent had children under 16. A comparison with 2001 UK census data shows that consumers in our sample were not very much different from the UK population (which on average is 30-44 years old (23%), female (51%), and full-time employed (41%).

4 The Models

The conditional logit (CL) has been the basic model used for analyzing stated preference choice data. The shortcoming of this model is that the assumption of homoskedastic error variances, in other words, non-constant error variance or homogenous preferences for all respondents. This has been questioned in various papers, such as Hensher et al. 1999, Louviere, 2001, DeShazo and Fermo, 2002, and Louviere et al., 2002. In this paper, we investigate consumers' preferences for raw whole chickens using a Mixed

Logit Model (MXL), which is a flexible discrete choice model that allows for random parameters and error components that induce correlation over alternatives and choice tasks.

Due to the split-sample nature of the study, we accommodate potential scale effects in our MXL models. The MXL models that accommodate the scale differences (MXL_s) explore the possibility of adding further behavioural information associated with the variance of the distribution of random parameters.

Analysis of the DCE data is based on Random Utility Theory (RUT), which is a theory on human decision-making initiated by Thurstone (1927) and generalized by McFadden (1974). This theory posits that individuals maximise their utilities associated with their choices. The general form for their utilities under MXL specification can be written as:

$$U_{ij} = \beta_i X_{ij} + [\eta_{ij} + \epsilon_{ij}]$$

where β_i is a vector of parameters representing individual's tastes and X_{ij} is a vector of observed explanatory variables related to individual i and alternative j. The error term is decomposed into two additive parts. One part is correlated with alternatives and heteroscedastic over individuals, and another part which is *iid* over alternatives (Hensher and Greene, 2003). Here, η_{ij} is a random term with zero mean and with a distribution that depends in general on underlying parameters and observed data relating to alternative j and individual i; and ϵ_{ij} is a random term with zero mean that is *iid* over alternatives and does not depend on underlying parameters or data, and is normalised to set the scale of utility (Hensher and Greene, 2003).

The conditional choice probability for alternative j over alternative k then takes the following general form:

$$L_{ij}(\beta_i \,|\eta_{ij}) = \frac{\exp[\lambda_s(\beta_i X_{ij} + \eta_{ij})]}{\sum_{k=1}^{K} \exp[\lambda_s(\beta_i X_{ik} + \eta_{ik})]}$$

Where λ_s is a scale parameter for each subset s.

Under the basic MXL model the scale parameter (λ) was specified to be fixed to one for each subset s. In the MXL_s model we acknowledge the fact that this may not necessarily hold. In estimation we achieve this by estimating different values of λ for the different subsets. To facilitate estimation and interpretation, one of which needs to arbitrarily normalised to one.

5 Results

In this part, we will be reporting results from two main analyses: (1) first part investigates consumers' valuation of changes in food poisoning risks (i.e., their WTP) and how this is affected by the presence of nanosensors in food packaging, and (2) second part investigates the effect of different risk presentations on consumers' choices.

If there is no difference between consumers' valuations with or without the presence of nanosensors, then this implies the samples have no disutility associated with nanotechnology. Otherwise, the differences between WTP values represent the implicit WTP to avoid nanotechnology. Similarly, if there is no difference between consumers' valuations with or without the presence of risk grids, then we conclude that risk grids do not have any effect on choices people make.

Overall, there are three models estimated in each part: (1) a model on pooled nano and no nano (or grid no grid), (2) a model for standard chicken consumers, and (3) a model for better-welfare chicken consumers. In model settings, all attributes, except price, are allowed to be random with normal distributions.

The estimation is done via Maximum Simulated Likelihood technique, where 250 Halton draws[10] were used. The variable descriptions for all models are shown in Table **3**.

[10] More information on Halton draws can be found in Train, K. E. (2003).Discrete Choice Methods with Simulation. Cambridge, UK: Cambridge University Press.

Table 3. **Variable Descriptions**

Variables	**Descriptions**
FP	Absolute level of food poisoning *(coded 1, 2, 4, 8)*
AW	Absolute level of animal welfare *(coded 4, 7, 10)*
P	Absolute price *(e.g., £4)*
SQ	Dummy for status quo option
*nano*FP* *nano*AW* *nano*P* *nano*SQ*	Interaction term (where nano=1 in the presence of nanosensors)
*grid*FP* *grid*AW* *grid*P* *grid*SQ*	Interaction terms (where grid=1 when risk grids are used)

The Value of Nanosensor

According to the results from all models in Table 4, on average, consumers prefer raw, whole chicken with a lower risk of food poisoning, better animal welfare, and lower costs. Furthermore, there is significant preference heterogeneity for all attributes in the three models. The results also show that nano interaction terms are not statistically significant at 1%, implying that the inclusion of nanosensors in packaging does not affect their preferences for raw, whole chickens. Having a particular focus on food poisoning, this also implies that both standard and non-standard consumers do not have any disutility associated with nanotechnology (i.e., $WTP_{risk\_reduction\_nano}$ and $WTP_{risk\_reduction\_non\_nano}$ are not statistically different from each other). The insignificant dummy variable for the status quo options of all models (i.e., *SQ*) indicates that there is a tendency within the sample to select alternative options, rather than their status quo option. All attribute parameters in all models are found to be significant at 1% in consumers' choice-making process.

Table 4. Analysis Results

	Model 1 Pooled[a]	Model 2 AW40	Model 3 AW70
Mean			
SQ	-0.31	-0.52	0.41
	(0.27)	(0.36)	(0.44)
FP	-0.71***	-0.82***	-0.82***
	(0.07)	(0.08)	(-0.13)
AW	0.36***	0.25***	0.66***
	(0.04)	(0.04)	(0.11)
P	-2.15***	-2.66***	-1.23***
	(0.22)	(0.25)	(0.29)
*Nano*SQ*	-1.14*	-2.04	-0.69
	(0.64)	(2.11)	(0.88)
*Nano*FP*	-0.36*	-0.62	0.00
	(0.21)	(0.61)	(0.22)
*Nano*AW*	0.21*	0.18	0.50
	(0.13)	(0.21)	(0.62)
*Nano*P*	-0.62	-1.17	-0.36
	(0.69)	(1.70)	(0.85)
St. Deviation			
SQ	1.64***	1.17*	1.05
	(0.35)	(0.71)	(0.71)
FP	0.76***	0.79***	0.53***
	(0.07)	(0.08)	(0.16)
AW	0.38***	0.27***	0.46***
	(0.05)	(0.05)	(0.10)
*Nano*SQ*	2.31**	4.39	1.50
	(1.19)	(3.24)	(1.05)
*Nano*FP*	1.10***	1.51***	1.31***
	(0.32)	(0.52)	(0.47)
*Nano*AW*	0.59***	0.67***	0.57
	(0.22)	(0.28)	(0.67)
Scale Term[b]			
Nano	0.68**	0.16**	0.71
	(0.15)	(0.21)	(0.30)
Number of observations	14112	10400	3712
Number of valid respondents	441	325	116
Rho-2	0.39	0.40	0.42
Log-L	-2995.65	-2179.55	-747.86

[a] Pooled nano and no-nano samples. Figure in parentheses are standard errors. Significant at: * p<.1; **p<.05; *** p<.01

[b] The scale for no-nano sample is fixed at 1. The scale reported here is for nano sample. For example, relative to no-nano case, overall, scale for nano case is 32% less than no-nano case.

The estimation of the Model 1, the pooled model, yields significant standard errors, indicating the existence of heterogeneity in consumers' choices. The results also show that the scales of the subsamples (i.e. nano and non-nano) are not the same. Keeping the scale of the "no-nano" sample fixed at 1, we find that "nano" sample has a scale of 0.68, in other words, 32% less than no-nano sample (i.e., higher error variance in nano sample).

We now split the pooled sample into two to investigate the effect of attribute levels on choices and their likelihood of being chosen by two different types of consumers: (1) consumers who usually buy a normal standard chicken and (2) consumers who usually buy non-standard chickens: free-range, Freedom-Food, or organic. We call these samples the "standard" and "non-standard" samples, respectively. These samples mainly differ in terms of the baseline animal welfare in their status quo option (i.e., *AW*=40 for standard, *AW*=70 for non-standard samples).

Model 2 and Model 3 utilise the pooled data with "nano" interactions. These models are estimated on the choice data for the "standard" and "non-standard" chicken consumers, respectively. The signs of the attribute coefficients in both models are as we expected (i.e., positive for *FP* risk reductions and negative for price). We then test whether nanosensors in the packaging is relevant to consumers. The test result shows that nanosensors have no effect on the choices of standard and non-standard chicken consumers.

Similarly, the analysis of Model 2 shows the existence of a scale difference between nano and no-nano subsamples in this group. However, we do not find a difference in the scales of nano and no-nano subsamples in the Model 3. This may be due to the smaller sample size in this group (116 people) as compared to the sample in Model 2 (325 people).

We now turn to results from WTP estimations. **Error! Not a valid bookmark self-reference.** shows the unconditional distributions of WTP estimates for standard and non-standard consumers from the analysis of Model 1.

Table 5 shows WTP estimates within 95% confidence intervals. Although nanosensors do not have any effect on both consumers' choices (i,e., nano interactions are insignificant thus mean WTPs are the same in both samples), the standard deviations of nano interaction terms on *FP* and *AW* are significant. Thus, we are presenting the upper and lower limits of WTP estimates for both *FP* and *AW* with and without the presence of nanosensors in packaging. Having a particular focus on the valuation of health risk reductions, the WTP estimates for standard chicken consumers in nano sample show more spread distribution. Although, on average, standard consumer are willing to pay the same amount for a unit decrease in food risk in no-nano sample, their overall distribution is more skewed than the distribution in nano case.

An overall comparison of WTPs shows that consumers who buy better welfare chickens are, on average, willing to pay more for better chicken attributes than consumers who buy standard chickens. Having a particular focus on the valuation of health risk reductions, better welfare chicken consumers are willing to pay more to prevent food risks when nano-sensors are used in the surveys (see Table 5). Here, the coefficient *FP* represents the level of food risks. Higher the coefficient, less value consumers assign to the product. Thus, here, negative WTP_{FP} can be thought as the amount person is willing to pay less for an increase in food risk.

As for the WTPs for animal welfare, consumers, who usually buy non-standard chicken with higher level of animal welfare, are willing to pay more for better animal welfare than standard chicken consumers, regardless of the use of nano-sensors. This is intuitive as the use of nano-sensors in packaging does not have any effect on the level of animal welfare. For standard consumers, mean WTPs for an improvement in *AW* are not much different from each other in nano and non-nano samples. The slight difference between the distributions of *AW* mainly comes from the highly significant standard errors.

In summary, overall, all models yield statistically significant product attributes which are all in expected signs. On average, consumers prefer raw, whole chickens with a lower risk of food poisoning, better animal welfare, and lower costs. Generally, the effect of nanosensors on consumers' choices is not strong across the models. The valuations of health risk reductions show some variations across the models.

Figure 6. Unconditional Distributions of WTPs for FP Risk Reductions

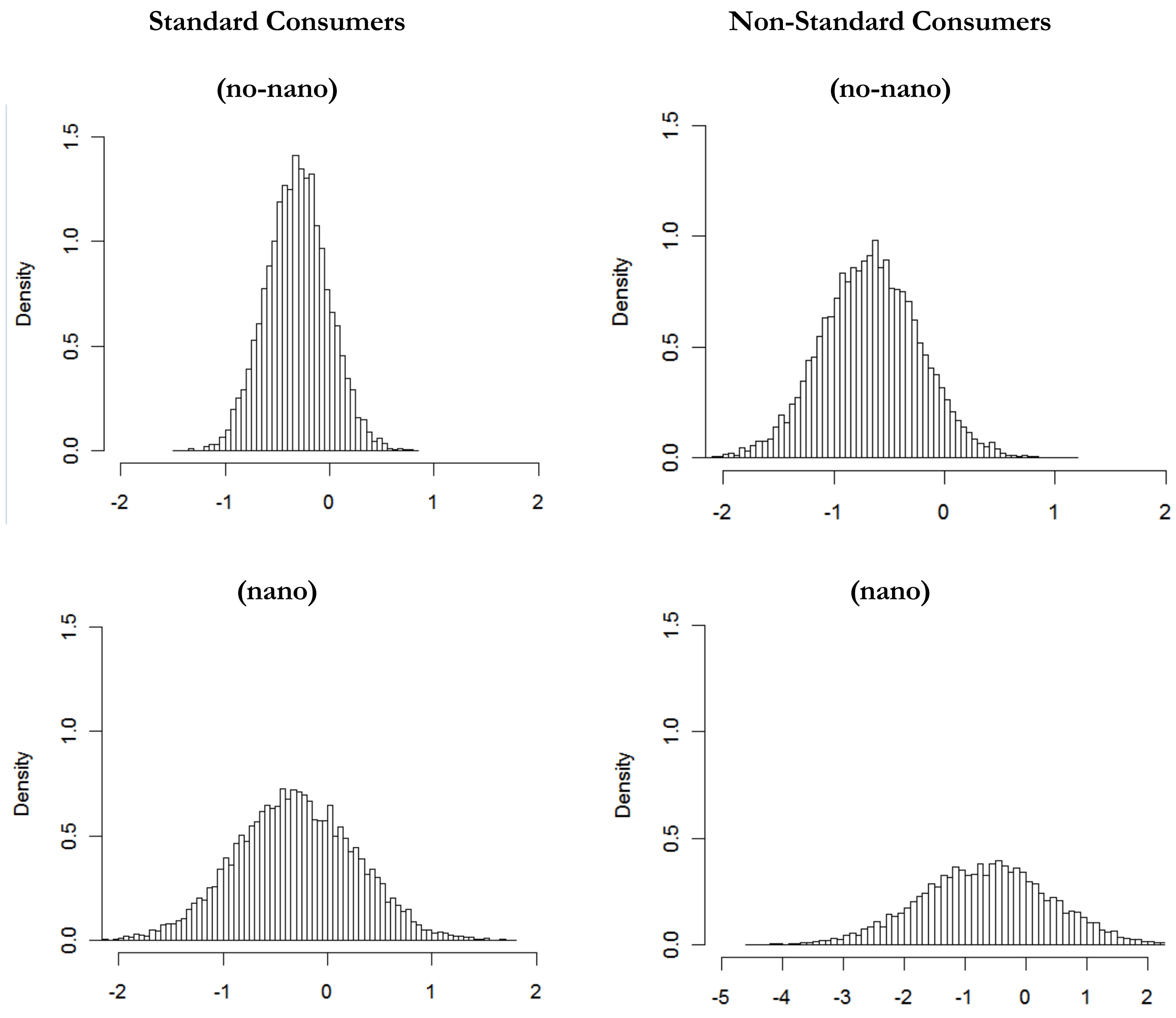


Table 5. Unconditional WTP Estimates (£/chicken)[a]

	Standard chicken consumers			Non-standard chicken consumers		
	Lower	**Mean**	**Upper**	**Lower**	**Mean**	**Upper**
$FP_{no\text{-}nano}$	-0.39	-0.31	-0.22	-0.76	-0.67	-0.66
FP_{nano}	-0.47	-0.31	-0.14	-0.90	-0.67	-0.43
$AW_{no\text{-}nano}$	0.06	0.09	0.12	0.45	0.54	0.62
AW_{nano}	0.02	0.09	0.17	-	0.54	-

[a] WTP estimates for *SQ* is not statistically different from zero at 1% significance level. Thus, we do not report them here.

The Effect Risk Grids

This section reports results from analyses that investigate consumers' valuation of changes in food poisoning risks and how this is affected by different risk presentations, namely risk grids and absolute numbers.

According to the results in Table 6, on average, consumers prefer chicken with a lower risk of food poisoning, better animal welfare, and lower costs. The general results also show that only grid interaction term on *FP* is statistically significant at 1% in Model 1 and Model 2. The grid does not seem having an effect on *SQ, AW*, and *P* in all models.

The estimation of the Model 1, the pooled model, yields positive coefficients for *AW* and negative coefficients for *FP* and *P*. The positive coefficient for *AW* indicates that options with higher levels of animal welfare are more likely to be chosen. Conversely, the negative coefficients on *FP* and *P* variables indicate that increases in these attributes make an option less attractive to consumers. Thus, respondents are less likely to choose this in higher levels. The negative, and significant, dummy variable for the status quo option (i.e., *SQ*) indicates that there is no tendency within the sample to select this option, irrespective of attribute levels. All attribute variables in the model are found to be significant at 1% in consumers' choice-making processes. The analysis results also show that the scales of subsamples (i.e. grid and non-grid) are significantly different from each other. Keeping the scale of the "no-grid" sample fixed at 1, we find that "grid" sample has a scale of 0.77 (i.e., less variance in grid sample).

The marginal utility (MU) derived from an attribute is equal to the summation of the MU in base case, when there is no grid used (MU_{FP}), plus an additional MU when a grid is used (e.g., $MU_{FP*grid}$). When this additional MU, e.g. $MU_{FP*grid}$, is not significant then the MU_{grid} becomes equal to the $MU_{no\text{-}grid}$. The analysis results show that grid interaction terms on *SQ, AW,* and *P* are insignificant at 1% level, indicating that the use of grids does not have any effect on consumers' valuations of these attributes. However, grid has a positive effect on *FP,* indicating that consumers value reductions in food risks more when risk grids are used. They are willing to pay more to prevent food risks when risks were conveyed them via risk grids.

The pooled sample is now split into two to investigate the effect of attributes on choices and their likelihood of being chosen by two different types of consumers: (1) consumers who usually buy a normal standard chicken and (2) consumers who usually buy non-standard chickens: free-range, Freedom-Food, or organic. These samples are called “standard” and “non-standard” samples, respectively. These samples mainly differ in terms of the baseline animal welfare in their status quo option (i.e., *AW*=40 for standard, *AW*=70 for non-standard samples).

The Model 2 is estimated on choices data for “standard chicken” consumers. The signs of the attribute coefficients are as expected (i.e., positive for *FP* risk reductions and *AW*, and negative for price). The grid interaction terms on *SQ, AW,* and *P* are insignificant at 1% level, indicating that the use of grids does not have an effect on standard consumers’ preferences for these attributes. As in Model 1, the use of grid has an effect on consumers’ preferences for the level of food risk reductions.

Similarly, the analysis of Model 2 also shows the existence of a scale difference between grid and no-grid subsamples in this group. However, there is no scale difference observed in the Model 3. This may be due to the smaller sample size in this group (108 people) as compared to the sample in Model 2 (321 people).

The final model, Model 3, is estimated on choices data for consumers who usually buy non-standard chickens. The analysis of the model shows significant coefficients on *FP, AW,* and *P*, all in expected signs. However, the dummy variable for *SQ* is insignificant, indicating that that there is no tendency within the sample to select *SQ* option. The results also show that all interaction terms are insignificant, showing no grid effect on consumers’ choices. Another important result is that consumers in this group tend to value animal welfare more than standard consumers. This is as expected since these consumers normally buy chickens with higher animal welfare (e.g., free-range).

Having a particular focus on the valuation of health risk reductions, standard chicken consumers are willing to pay more to prevent food risks when risk grids are used in the surveys (see Figure 7 and Table 7). Here, the coefficient *FP* represents the level of food risks. Higher the coefficient, less value consumers assign to a product. Thus, here, negative WTP_{FP} can be thought as the amount person is willing to pay less for an increase in food risk.

Table 6. Analysis Results

	Model 1 Pooled[a]	Model 2 AW40	Model 3 AW70
Mean			
SQ	-1.56***	-1.67***	-0.73
	(0.33)	(-4.51)	(0.59)
FP	-0.38***	-0.31***	-0.37**
	(0.08)	(-3.43)	(0.16)
AW	0.38***	0.29***	0.69***
	(0.05)	(6.19)	(0.14)
P	-2.47***	-2.51***	-2.33***
	(0.22)	(-9.91)	(0.41)
*Grid*SQ*	0.30	-0.72	0.66
	(0.57)	(-0.79)	(0.98)
*Grid*FP*	-0.59***	-1.25***	-0.42
	(0.22)	(-3.48)	(0.40)
*Grid*AW*	0.13	0.12	0.20
	(0.09)	(0.91)	(0.28)
*Grid*P*	0.05	-1.75	1.03
	(0.47)	(-1.89)	(0.61)
St. Deviation			
SQ	2.37***	2.17***	1.78***
	(0.33)	(3.98)	(0.45)
FP	0.83***	0.90***	0.82***
	(0.08)	(7.29)	(0.18)
AW	0.48***	0.45***	0.63***
	(0.05)	(8.38)	(0.12)
*Grid*SQ*	1.04	3.42***	3.01***
	(1.08)	(2.76)	(1.00)
*Grid*FP*	0.81***	1.33***	0.77
	(0.20)	(5.72)	(0.49)
*Grid*AW*	0.37***	0.47***	0.26
	(0.09)	(2.51)	(0.34)
Scale Term[b]			
Grid	0.77**	0.57***	0.87
	(0.12)	(0.11)	(0.34)
Number of obs	13,724	10,272	3,452
Number of resp	429	321	108
Rho-2	0.39	0.38	0.44
Log-L	-2899	-2188	-665

[a] Pooled grid and no-grid samples. Figure in parentheses are standard errors. Significant at: * p<.1; **p<.05; *** p<.01
[b] The scale for no-grid sample is fixed at 1. The scale reported here is for grid sample. For example, relative to no-grid case, overall, scale for grid case is 33% less than no-grid case.

As for the WTPs for animal welfare, consumers, who usually buy non-standard chicken with higher level of animal welfare, are willing to pay the same for risk reductions regardless of the use of risk grids. For standard consumers, mean WTPs are the same in grid and no-grid cases. An overall comparison of WTPs for an improvement in the level of animal welfare across these two types of consumers shows that non-standard chicken consumers are willing to pay more for an increase in *AW* than standard chicken consumers. This is an expected result.

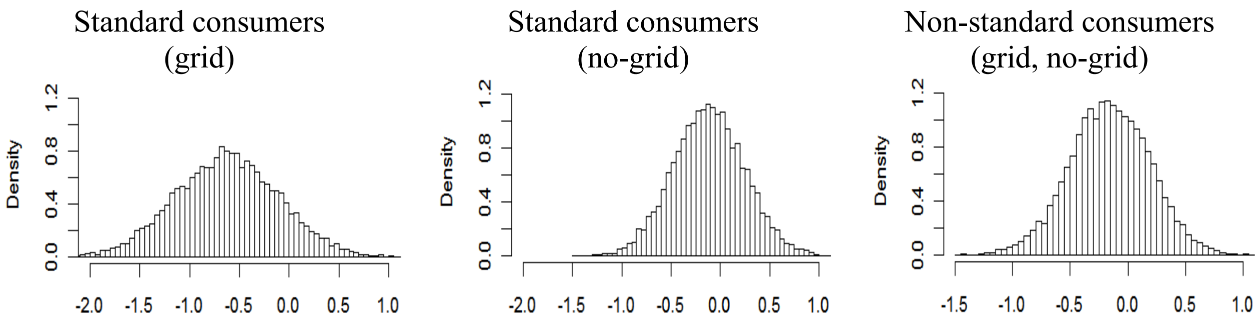
In summary, all models used in this part of the study yield statistically significant product attributes which are all in expected signs. On average, consumers prefer raw, whole chickens with a lower risk of food poisoning, better animal welfare, and lower costs. Generally, the effect of risk grids on consumers' choices is not strong across the models. However, it is found that the use of grids has an effect on standard consumers' valuations of health risk reductions, but not on consumers who buy niche, higher welfare chickens. Non-standard chicken consumers do not seem to have a benefit from the use of grids in surveys, which tended to facilitate the understanding of risks and reductions in risks. Another interesting result of the analysis is that non-standard consumers value increase in the level of animal welfare more than standard consumers.

Table 7. Unconditional WTP Estimates (£/chicken)

	WTP Estimates[a]		
	Lower	**Mean**	**Upper**
Standard chicken consumers			
FP_{grid}	-0.64	-0.50	-0.35
FP_{no_grid}	-0.22	-0.12	-0.02
AW_{grid}	0.06	0.12	0.17
AW_{no_grid}	0.07	0.12	0.17
Non-standard chicken consumers			
$FP_{grid} = FP_{no\_grid}$	-0.31	-0.15	0.00
$AW_{grid} = AW_{no\_grid}$	0.24	0.35	0.47

[a] Confidence intervals are at 95%.

Figure 7. Unconditional Distributions of WTPs for FP Risk Reductions



6 Summary

This research is composed of two main parts. The first part investigates consumers' willingness to pay (WTP) for reductions in the level foodborne health risk. We do this by a specific setting where nanopackaging delivers a quantifiable reduction in food poisoning risk. The value of the risk reduction delivered in this way is measured against equivalent values delivered in a less controversial manner in the conventional food chain, such as more stringent regulations.

The second part of the research examines the effects of different risk presentations on willingness-to-pay (WTP) values for the health risk reductions offered. We use two different risk presentations: absolute numbers with and without visual grids, to communicate changes in the level of food poisoning level attributable to chicken.

We address research questions in these two parts by conducting web-based Discrete Choice Experiment (DCE) surveys with UK consumers. Within the DCE, respondents chose between alternative whole chickens of identical appearance, taste and texture but which differ in term of three attributes: price, level of food risk, and level of animal welfare.

The DCE data was collected in late August, 2010 through online surveys via a market research company. Overall, 449 consumers were recruited. The data was analysed using an extension of the Mixed Logit Models (MXL_s) which account for the heterogeneity in choice preferences and accommodate the differences in scales of the sub-samples (i.e. grid and no-grid & nano and no-nano) that may be observed due to the split-sample nature of the dataset.

Valuations of the risk reductions then allow comparison of the values: (1) $WTP_{risk\_reduction\_nano}$ and $WTP_{risk\_reduction\_non\_nano}$ and (2) $WTP_{risk\_reduction\_grid}$ and $WTP_{risk\_reduction\_non\_grid}$. The differences between these WTP values represent the implicit WTP to avoid nanotechnology and the effect of risk grids on consumers' choices, respectively. If the values are identical then the samples have no disutility associated with the nanotechnology and risk grids do not have any effect on consumers' choices.

Heterogeneity in preferences are further investigated by performing the analyses for two consumer groups: (1) consumers who usually buy normal standard chickens, and (2) consumers who usually buy one of non-standard chickens: free-range, Freedom-Food, or organic.

The general results of all models in both parts of the research showed that, on average, consumers prefer chicken with a lower risk of food poisoning, better animal welfare, and lower costs. The results also showed evidence of heterogeneity in consumers' preferences and scale effects due to the split nature of the datasets.

The analysis results from the first part showed that the inclusion of nanosensors in packaging does not affect consumers' preferences for raw, whole chickens. Having a particular focus on food poisoning, this implies that both standard and non-standard consumers do not have any disutility associated with nanotechnology (i.e., $WTP_{risk\_reduction\_nano}$ and $WTP_{risk\_reduction\_non\_nano}$ are not statistically different from each other). The insignificant dummy variable for the status quo options of all models (i.e., *SQ*) indicated that there is a tendency within the sample to select alternative options, rather than their status quo option. All attribute parameters in all models were found to be significant at 1% in consumers' choice-making process.

An overall comparison of WTPs showed that consumers who buy better welfare chickens were, on average, willing to pay more for better chicken attributes than consumers who buy standard chickens. Having a particular focus on the valuation of health risk reductions, better welfare chicken consumers were willing to pay more to prevent food risks when nano-sensors were used in the surveys.

The analysis results from the second part of the research showed that the use of risk grids did not have a strong effect on consumers' choices. However, it is found that the use of grids has an effect on standard consumers' valuations of health risk reductions, but not on consumers who buy niche, higher welfare chickens. The differences between $WTP_{risk\_reduction\_non\_grid}$ and $WTP_{risk\_reduction\_grid}$ for reductions in *FP* risks were statistically significant for standard consumers at 1% level. This showed that standard consumers value risk reductions differently when risk format changes. They were willing to pay more for safer foods when risk grids were used. In other words, the differences between WTPs for FP risk reduction were positive which implies that there exists a utility associated with the use of risk grids.

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