# *Do consumers really care? An economic analysis of consumer attitudes towards food produced using prohibited production methods*

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# Do Consumers Really Care? An Economic Analysis of Consumer Attitudes Towards Food Produced Using Prohibited Production Methods

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**Abstract**

*Consumer preferences for food produced using currently prohibited production methods matter, especially in relation to potential trade deals. We conduct four discrete choice experiments examining UK consumer attitudes for food produced using several agricultural production methods currently prohibited in the UK, including chlorine washed chicken. Our results reveal negative preferences for these forms of agricultural production methods whereas EU food safety standards are highly valued. Willingness-to-pay estimates indicate that the positive values for food safety are frequently greater than the negative values placed on prohibited food production methods. Similarly, UK country of origin was highly valued but organic production was less valued. We discuss the implications of these results and, more generally, the use of stated preference estimates in economic modelling underpinning trade negotiations.*

**Keywords:** *chlorinated chicken*; *consumer preferences*; *discrete choice experiment*; *hormone implants*; *hormones in feed*; *trade negotiations*.

**JEL classifications:** *Q18, Q17, I18*.

## 1. Introduction

Now that the United Kingdom (UK) has officially left the European Union (EU), there is much discussion surrounding the form and content of future trade agreements with the EU and the rest of the world (Sampson, 2017). Under the new, and currently unknown UK trading arrangements, associated rules and regulations regarding food

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could depart significantly from present EU regimes (Sheldon, 2019). For example, there has been much speculation about a trade agreement with the United States (US) (Office of the United States Trade Representative, 2019; Millstone *et al*., 2019a, 2019b), especially about agricultural and food regulations. Historically, the extent of agricultural trade between the US and the UK has been small, only $1.7 billion in 2015 which is equivalent to 1.3% of total US agricultural exports.[2] There have also been gradual changes to the trading arrangements over time. For example, the EU and US have had a tariff rate quota (TRQ) in place for non-hormone-treated beef for several years. The TRQ means that the US can export up to 45,000 metric tonnes although only 17,500 was exported during 2013–15 via the USDA Non-Hormone Treated Cattle (NHTC) programme, which partly reflects the increased costs associated with programme compliance (Beckman and Arita 2017). However, more recently the US has expressed a strong preference for a trade agreement allowing agricultural production methods common in the US but not currently permitted by the EU or UK – for example, chlorine washed chicken and beef from cattle grown using hormone implants.[3] The continued use of these production methods in the US reflects the increases in productivity for producers (Map les *et al*., 2019).

Clearly, with any change to existing trade arrangements it is necessary to understand the economic consequences, and in this case, the likely reaction of consumers. To date, there has been a lot of public opinion research published about UK consumer attitudes towards agricultural production methods, such as chlorine washed chicken. For example, Which? (2018) reports that 93% of respondents wish to maintain existing food standards after Brexit, 80% opposed the introduction of hormone-treated beef and 72% opposed chlorine washed chicken. Similarly, Savanta ComRes (2020) (2020, in a survey conducted for the RSPCA, reports that 82% of respondents do not support a trade deal with the US that would allow chlorine washed chicken to be imported into the UK. The significance of these findings is underscored by the fact that many UK supermarkets have vowed not to sell chlorine washed chicken (Business Insider, 2020). In contrast, there is currently no economic analysis of UK consumer preferences regarding currently prohibited food products. However, without appropriate economic estimates of relative values, we do not know how much damage such a trade deal would do to consumer welfare.

Evaluation of the potential economic consequences of relaxing trade restrictions such as non-tariff measures (NTMs), allowed by the World Trade Organisation (WTO) (i.e. Sanitary and Phytosanitary (SPS) arrangements or the Agreement on Technical Barriers to Trade (TBT)) requires that economic analysis identify consumer preferences accurately. For example, Arita *et al*. (2017) conducted an analysis of removing the many barriers to trade in food between the US and EU (tariffs and NTMs) using a computable general equilibrium (CGE) model. Their results indicate that gains from trade from removing all barriers would be $11.6 billion, but when they adjust for consumer preferences, the gains fall to $7 billion, though CGE models use highly aggregated, average and simplified consumer responses. Soon and Thompson

[2]Though Poppy *et al*. (2019) note that the international meat trade was worth £74.25 billion in 2015 with the UK accounting for over 5% of this trade, making it the fifth largest market.

[3]In the Office of the United States Trade Representative (2019) the following negotiating objective is explicitly stated: 'Establish a mechanism to remove expeditiously unwarranted barriers that block the export of U.S. food and agricultural products in order to obtain more open, equitable, and reciprocal market access.'

(2019) employ a partial equilibrium model of the international beef market that allows for differentiation between hormone- and non-hormone-treated beef to study the US, Canada and EU beef dispute. Their analysis assumes that EU consumers will buy hormone-treated beef if the price is sufficiently discounted, that is, 15%. Clearly, the results of any such modelling study depend on the assumptions about consumer preferences.[4]

We examine UK consumer preferences for four food products produced using production technologies currently not authorised in the UK but which result from relaxing existing trade restrictions. Our four products are: hormone implants in beef; Ractopamine (a feed additive which promotes leanness and improves feed conversion efficiency) in pig feed; chlorine washed chicken; and Atrazine pesticide in corn production. Revealed preferences, employing actual purchase data, although preferred (e.g. Hussein and Fraser, 2018) are obviously not available in these cases. As a consequence, we use a stated preference discrete choice experiment (DCE) to estimate consumer's willingness-to-pay (WTP) for foods with these attributes.

First, our research adds to the literature examining consumer attitudes and preferences for food produced using new, novel or previously prohibited production methods. The scope of this literature ranges from studies examining genetically modified organisms (GMOs) (e.g. Grebitus *et al.*, 2018), the use of RNA interference (RNAi), a gene editing technology (Britton and Tonsor 2019; Muringai *et al.*, 2020), transgenic rye used to produce bread (Edenbrandt *et al.*, 2018), and the use of nanotechnology in food safety (Erdem, 2015, 2018). It has frequently been found that consumers have concerns regarding new or novel technologies (e.g. Frewer, 2017; Kamrath *et al.*, 2019). These concerns can act as a constraint on acceptance by consumers as well as the potential commercialisation of technology.

Second, our research contributes to the wider discussion surrounding country of origin (CoO) food labelling. The UK introduced mandatory CoO food labels for unprocessed pig, poultry, sheep/goat meat in 2015 via Commission Implementing Regulation (EU) No 1337/2013 (it was already in place for beef). In contrast, voluntary CoO labelling is in place for semi-processed meat and when meat is used as an ingredient in processed food.[5] Mandatory labels generally correct market inefficiencies such as asymmetric information by ensuring that consumers are informed about the origin of food. In contrast, voluntary labels are used to signal differences in product quality and to highlight specific credence attributes. The distinction between mandatory and voluntary labels is important as it has notable cost implications for business – mandatory labelling is more costly (Roe *et al.*, 2014). Economic evidence for consumer use and value attached to CoO suggests that, although CoO is wanted by consumers, it is not as highly valued as other food attributes such as price, taste,

[4]Some trade literature has also examined aspects of NTMs in agriculture, specifically chlorine washed chicken and hormone beef, especially the political economy of trade barriers and protectionism resulting from scientific uncertainty and possibly misguided public preferences (Calzolari and Immordino 2005; Bullock *et al.,* 2019). Many US consumers mistakenly suppose that hormones are used in the production of other types of meat, such as chicken and pork, partly because of food labels which indicate 'no added hormones' (NAH), reflecting a polarisation of views on hormone use in the US (see Norwood *et al.,* 2015).

[5]Commission Implementing Regulation (EU) 2018/775 requires the provenance of the primary ingredient to be indicated where this differs from the advertised provenance of the final product with effect from 1 April 2020.

appearance and duration (Balcombe *et al.*, 2016).[6] However, despite this evidence, there have been calls to extend mandatory CoO labelling post-Brexit. For example, a 2018 UK parliamentary Food and Rural Affairs Committee (House of Commons, 2018) explicitly acknowledged the need to extend mandatory CoO labelling to include more food products such as bacon, sausages and cheese. This position might reflect political pressures to support the UK farming food industry post-Brexit. Benton (2017) indicate that 67% of survey respondents prefer to buy UK food with 27% claiming they would buy more British produce even if imported food prices declined. Given the mixed evidence regarding consumer values attached to CoO, our analysis provides additional evidence, particularly for CoO combined with information about agricultural production methods.

The structure of this paper is as follows. In section 2, we briefly review the relevant DCE literature. Section 3 gives a description of the production methods we examine. Section 4 details the design and implementation of our DCE. Section 5 provides our econometric specification and in section 6 we report our results. Section 7 considers the implications of our findings regarding consumer preferences, new processing technologies and the implications for trade negotiations. Section 8 concludes.

## 2. Literature Review

The provision of information about production methods is an example of a credence attribute, and how it is conveyed matters (Messer *et al.*, 2017; Lusk and McCluskey 2018). Furthermore, the combination of attributes used is important as there is evidence that whether attributes are included or excluded from choice sets affects consumers' valuations.

Most related studies focus on the use of growth hormones in beef. For example, Tonsor et al. (2005) report that UK consumers are prepared to pay to avoid hormone-grown beef. More recently, Lewis *et al.* (2017) conducted a DCE to estimate the value of a hormone-free label for beef (as opposed to no label) with results indicating that respondents valued hormone-free beef very highly.[7] Also respondents who valued the hormone-free label considered food safety as important, a finding previously reported by Miller et al. (2016) who note that the literature indicates that food safety frequently yields very high estimates of WTP and these estimates are higher than those for animal welfare or environmental concerns.

Chlorine washed chicken is typically examined as an aspect of food safety. In particular, the literature considers consumer preferences for chlorine washed chicken to reduce *Campylobacter* (a food borne bacterium that can cause various illnesses, and is a concern for the UK government; MacRitchie *et al.*, 2014). Kawata and Watanabe (2018) examined Japanese consumers' WTP to reduce food related illness using a large set of methods including a chlorine wash. For pork, Ortega *et al.* (2020) examined how consumer preferences for a GM 500 gram pork loin are affected by information provision regarding genetic modification. In particular, preferences for GM change

[6]Using an economic experiment to test information preferences, Beiermann *et al.* (2017) report that a high proportion of respondents (i.e. 80%) use CoO information when free and that demand increases when combined with food safety benefits associated with local production.

[7]No hormone-produced beef enters the UK because of existing trade restrictions. This means that a hormone-free label only has meaning if the DCE informed respondents that the products on offer could be produced using growth hormones.

depending on the specific benefit of the GM technology. Thus GM technology to improve food safety is associated with greater consumer acceptance, although WTP for GM pork remained negative. Finally, there is a body of literature examining pesticide use in food production and consumer attitudes (e.g. Chalak *et al.*, 2008; Peschel *et al.*, 2019). Although there is no literature specifically examining Atrazine, the pesticide we consider, the literature indicates that consumers generally prefer the use of less pesticide and if feasible, agricultural production that is pesticide free, such as organic. A recent example is Peschel *et al.* (2019), who examine a pesticide-free food label for dates.

The relative importance of CoO information differs by product type. For example, Balcombe *et al.* (2016) observe that CoO is highly valued for fresh meat produce but is less so for processed meat in the UK. Asante-Addo and Weible (2020) conclude that Ghanaian consumers value domestic chicken more than imported chicken with a specific preference for antibiotic hormone-free produce. Aboah and Lees (2020), in a review of the literature, note that CoO matters more for beef and lamb than for chicken, for which organic is considered the most important attribute. They attribute this to existing CoO legislation which requires information about geographic origin rather than specific production methods, such as chlorine washed chicken. It is also the case that higher values are attached to CoO for food that originates from a respondent's own country, that is, a home-country bias. However, this bias can be reduced by the provision of other information. For example, Slade *et al.* (2019) report that Canadian consumers positively value imports of dairy products if accompanied by geographical indications (GIs). In contrast, Norris and Cranfield (2019) note that Canadian consumers require a significant price discount to buy imported dairy products as a result of a new trade deal with the EU.[8] Clearly, CoO appears to be valued by consumers but the interaction between CoO and other product attributes affects consumer values.

## 3. The Production Practices

Our DCE examined four food products that are currently unavailable to UK consumers: chlorine washed chicken; beef produced with the use of growth hormones such as hormone implants; pork feed hormone additives (e.g. Ractopamine) during production; and Atrazine pesticide used in corn production. Before we provide detailed information regarding the design and implementation of the DCE, we briefly describe the production practices and treatments examined.

Chlorine is used in certain countries (e.g. the US) to rinse whole chickens to kill microorganisms on the surface of the bird, specifically bacteria like *Salmonella* and *Campylobacter*. Chicken treated this way have been excluded from the EU market since 1997. Importantly, the European Food Safety Authority (EFSA) does not view the use of chlorine in this context as unsafe. The EU operates a 'farm-to-fork' approach to reduce meat-borne bacteria at all points along the meat supply chain, to meet food safety requirements while also delivering higher animal welfare. Chlorine

[8]Canada has moved away from protecting its domestic dairy industry with the introduction of trade agreements such as the Comprehensive Economic and Trade Agreement (CETA) with the EU.

washing, on the other hand, reduces overall costs of production because less effort is made to control bacteria in the supply chain.

The use of additional hormones in animal (e.g. beef) production is common in countries such as the US and Australia. In beef production the hormone is typically released into the animal over time by means of an implant. Hormones allow the animal to grow bigger more rapidly while consuming less feed, which reduces the costs of production. Also, because of the resulting changes in the diet of the animals, they have a leaner carcass that in turn satisfies consumer preferences for less fatty meat and reduces the amount of cholesterol consumed.

Although the dosage levels of hormones are relatively low, the European Commission banned the use of hormones in animal production on potential safety grounds. This precautionary approach is still in operation as there remains uncertainty and insufficient evidence about the types of hormones being used and what doses can be considered safe. To address potential consumer concern in the US, a negative labelling regime is in place, that is, beef produced without the use of hormones can be labelled 'No hormones (beef)'. There are specific sets of farming practice that need to be followed for this statement to be allowed.[9]

Pork producers in the US are allowed to use Ractopamine as a feed additive to increase the rate of animal growth. Ractopamine (a beta agonist growth promotant) increases protein synthesis, making the animal more muscular, reducing the fat content of the meat and increasing the return per animal. Unlike hormone implants, Ractopamine does not affect the hormone status of the animal. The use of Ractopamine is currently not authorised in the EU because the EFSA argues that there is insufficient evidence to declare this product safe. More importantly, it is argued that this type of food additive has a detrimental impact on animal welfare through the way in which it changes animal growth rates and allows production systems to be organised. The EU's position on Ractopamine has recently been followed by Thailand which has banned pork imports grown using this additive.

Finally, turning to pesticides, the EU does not permit the use of Atrazine. However, it is a frequently used herbicide in the US on crops such as maize and sweetcorn, where its use is recommended in combination with other chemicals. In the US herbicides are applied to 97% of corn planted land, with Atrazine accounting for 60% of herbicide active ingredients (USDA, 2017). The EU's main concern with Atrazine is the off-site environmental impact and specifically the contamination of groundwater. As with all chemicals, small (and safe) residue levels are tolerated in food – for example, 0.05 mg/kg.

## 4. DCE Design

We use four food products to examine consumer attitudes. This choice was informed during several one-to-one focus group sessions we ran to consider product type of choice of DCE attributes as well as an examination of product sales data in the UK. The specific products are:

1 500 grams chicken breast

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[9]More details are provided by the USDA: https://www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/food-labeling/meat-and-poultry-labeling-terms

2 250 grams beef sirloin steak
3 1 kg pork loin joint
4 2 pack of corn on the cob

Next, we considered the set of attributes to include within the DCE. Based on one-to-one feedback during the initial stages of the design of the DCE, we determined the attributes and associated levels and these are summarised in Table 1.

The specific text used to describe these attributes is available in Figure A1 (online). We note that when describing CoO, we have explicitly labelled the UK and the EU but we have not for meat from outside the EU, we do this to avoid to conflating origin with production methods.

Given these products and their attributes, several combinations are effectively infeasible: organic production rules out the use of hormone implants in beef, the use of Ractopamine with pig production or Atrazine use for corn on the cob. We also modified the set of quality assurance levels between the products to ensure that respondents did not treat some combinations as unrealistic. Thus, for chicken, we included three quality standards as well as a ‘no standard’ option. We modified the quality assurance standards for the three other products to no standard/Red Tractor because the production methods are inconsistent with the RSPCA and QAI quality standards. The

Table 1
Summary of attributes and levels for all products

| Product | Attribute | Description and levels |
|---|---|---|
| 500 grams chicken breast | Price | 2.00, 3.00, 3.99, 4.75, 6.50, 9.25 |
| | Country of origin | UK, EU, Non-EU |
| | Organic | Yes/No |
| | Food standards | Meet EU and Does not meet EU |
| | Quality assurance | None, RSPCA, QAI, Red Tractor |
| | Chlorinated chicken | Yes/No |
| 250 grams beef sirloin steak | Price | 2.50, 2.95, 3.40, 4.00, 5.00, 6.25 |
| | Country of origin | UK, EU, Non-EU |
| | Organic | Yes/No |
| | Food standards | Meet EU and Does not meet EU |
| | Quality assurance | None, Red Tractor |
| | Hormone implants | Yes/No |
| 1 kg pork loin joint | Price | 4.00, 5.50, 6.99, 8.00, 11.99, 15.50 |
| | Country of origin | UK, EU, Non-EU |
| | Organic | Yes/No |
| | Food standards | Meet EU and Does not meet EU |
| | Quality assurance | None, Red Tractor |
| | Hormone in feed | Yes/No |
| 2 pack of corn on the cob | Price | 0.85, 0.99, 1.24, 1.50, 2.00, 2.50 |
| | Country of origin | UK, EU, Non-EU |
| | Organic | Yes/No |
| | Food standards | Meet EU and Does not meet EU |
| | Quality assurance | None, Red Tractor |
| | Pesticide use (Atrazine) | Yes/No |

Red Tractor assurance standard is not limited to agricultural production only undertaken in the UK.

Given the number of attributes and attribute levels, a balanced design required that we generated multiples of 12. We used 48 cards each with 3 options employing 4 blocks yielding 12 cards per respondent, following an efficient design assuming an MNL utility specification assessed using D-error (Scarpa and Rose 2008), using Ngene version 1.1.2 (ChoiceMetrics. 2012). Given uninformative priors, our design can be considered conservative. The constrained design of 48 cards of 4 blocks of 12 yielded an MNL D Error of 0.081. An example of the final online choice card is presented in Appendix S1: Figure A2. We used the dual-response method (Brazell *et al.*, 2006) to the collection of DCE data, first asking respondents to make a choice from the product options offered and then asking a subsequent question about whether the respondent would actually reject all options offered, and not choose any of the options. This approach generates a full set of conditional choice data, including no choice responses.

Our pilot study was implemented online yielding a total of 35 for the chicken DCE. The pilot data revealed that the survey instrument and associated DCE had worked appropriately. Model results in terms of attributes and associated values all appeared plausible. In addition, the level of respondent engagement was deemed good based on answers to feedback questions.[10]

In total, 1,600 survey responses were collected online between December 2018 and January 2019. A nationally representative sample based on socio-economic characteristics was recruited with the help of a market research company. The full survey form is available in our Appendix S1. Overall, our sample data shows that we recruited slightly more males (51%) than females (49%) for all four DCE. The age composition of each DCE was close to a uniform distribution with slightly more responses collected from those in the over 65 age group. Household size had a mode of two and almost 60% of respondents live in a household with children. In terms of household income, the sample mean was in the range £26,000 up to £31,199, which is consistent with the UK population. In terms of educational attainment, the mode for all DCE is an undergraduate degree. Next, we asked all respondents about their shopping habits and attitudes to food and Brexit. More than 60% of respondents are responsible for all or most of the food and grocery shopping. We also asked respondents if they thought EU exit will have a positive, neutral or negative effect on food (in general) over the next couple of years. The responses indicate that more respondents think that EU exit will have a negative effect on food (36%) than a positive effect (24%). Approximately 40% of respondents for all DCE think the effect will be neutral or do not know. Finally, we asked respondents if they thought that the quality of food can be judged by its price. Four out of five respondents agreed that the quality of food can be judged by price.

[10]A full version of the chicken DCE is provided in Appendix C (online) as an example of the final survey instrument. Note the version provided is slightly different to that employed online in terms of page progression.

## 5. Model Estimation

We employed a Bayesian (random parameter) mixed logit (MXL) specification (also known as the Hierarchical Bayesian Logit) to estimate the preference parameters, for several reasons. Bayesian methods are now well established in the stated preference literature. There are several reasons why we use a Bayesian specification to undertake model estimation. Most importantly, within the literature Bayesian methods are recognised at being better able to deal with difficulties of empirical identification associated with classical approaches to simulation (Balcombe *et al.*, 2016).

This model allows for heterogeneity across respondents so that each respondent has their own preferences. Accordingly, the WTP attributes can be elicited at the individual level. The MXL model also allows for heterogeneity of responses, meaning that differences in respondent characteristics that may lead to differences in WTP are allowed for in the model specification and captured in the estimates.

Our model is as follows. Let $x_{ijs}$ denote a $k \times 1$ vector of attributes from the DCE presented to individual $j$ ($j = 1,\ldots, J$) in the $i$th option ($i = 1,\ldots, I$) of the $s$th choice set ($s = 1,\ldots, S$). Next, let $U_{ijs}$ be the utility that the individual $j$ attains from $x_{ijs}$. Given these definitions, it then follows that individual $j$ receives utility from the $i$th choice in the $s$th choice set:

$$U_{ijs} = x'_{ijs}\left(\beta_j\right) + e_{ijs} \tag{1}$$

where $\beta_j$ is a ($k \times 1$) independently and identically normally distributed vector describing the preferences of individual $j$ with mean α and variance covariance matrix Ω. $t(.)$ is some transformation of the parameters that can take a number of forms. For example, we might employ the log-normal for the price coefficient and the normal distribution for all other parameters. Finally, the error term $e_{ijs}$ in equation (1) is assumed to be extreme value (Gumbel) distributed, independent of $x'_{ijs}$ and uncorrelated across individuals or choices, which leads to a logistic likelihood of an individual choosing a given option in any given task.

We estimate our models in WTP space, with parameters directly interpretable as WTPs. To estimate the MXL in WTP space, we employed a parameterisation of the form:

$$t\left(\beta_j\right) = \exp\left(\beta_{1j}\right)\left(1, \beta_{2j}, \ldots, \beta_{kj}\right)' \tag{2}$$

where the quantities $\beta_{2j}, \ldots, \beta_{kj}$ are the marginal rates of substitution (MRS) with the numeraire being the price attribute within the given DCE. These, therefore, represent estimates of the WTP for each of the specified attributes. By estimating in WTP space the MRS are estimated directly, which can significantly reduce the instability associated with WTP estimates recovered from preference space (Balcombe *et al.*, 2010).

With our MXL we modelled all attributes as random parameters employing the normal distribution. The only exception was for price which was modelled as a log-normal distribution. Given the set of attributes employed our econometric specification is as follows for the chlorinated chicken data:

$$\begin{aligned} U_{ijs} = \exp(\beta_{1,j})[&-Price_{ijs} + \beta_{2,j}Chlorwash_{ijs} + \beta_{3,j}EUFS_{ijs} \\ &+ \beta_{4,j}Organic_{ijs} + \beta_{5,j}CoOEU_{ijs} + \beta_{6,j}CoOUK_{ijs} + \beta_{7,j}QSRedTrac_{ijs} \\ &+ \beta_{8,j}QSRSPCA_{ijs} + \beta_{9,j}QSQAI_{ijs} + \beta_{2,j}OptOut_{ijs}] + e_{ijs} \end{aligned} \tag{3}$$

where the $OptOut_{ijs}$ captures the no choice option. *Chlorwash* is a dummy for whether the chicken has been chlorine washed; *EU FS* is a dummy indicating that the food meets EU food safety standards; *CoO UK* and *CoO EU* are dummy variables relative to the excluded level non-EU; *Organic* is the type of farm production system with the reference level being Conventional; *QS RedTrac*, *QS QAI* and *QS RSPCA* are dummies for the quality standard relative to the excluded level of no quality assurance (for the other products it will only be *QS Red*). For the cases of corn, pork and beef, *Chlorwash* was replaced with *Atrazine* (for Corn), *Hormone in Feed* (for Pork), and *Hormone Implants* (for Beef). For these goods, the quality assurance only contained the Red Tractor versus none option (i.e. no *RSPCA* or *QAI* attribute). Thus, for these three goods:

$$\begin{aligned} U_{ijs} = exp\left(\beta_{1,j}\right)[-Price_{ijs} + \beta_{2,j} ProdMethod_{ijs} + \beta_{3,j} EUFS_{ijs} + \beta_{4,j} Organic_{ijs} \\ + \beta_{5,j} CoOEU_{ijs} + \beta_{6,j} CoOUK_{ijs} + \beta_{7,j} QSRedTrac_{ijs} + \beta_{2,j} OptOut_{ijs} + e_{ijs} \end{aligned} \tag{4}$$

The priors used for all the models were standard normal for the prior mean of $\beta_{k,j}$ along with Gamma(1,1) distributions for the precision parameters. Additionally for the parameters $\beta_{k,j}$ $k>1$ represent willingness to pay truncated so we imposed the condition that its absolute size must be less than or equal to the total difference to maximum and minimum price for the experiment – that is, no one attribute can be worth more than the total price variation in the experiment and to the individual. For the means we imposed the condition that this must be less than 75% of this difference.

Estimation used the Software STAN (https://mc-stan.org/), which employs Hamiltonian Monte Carlo Markov Chain algorithms to simulate the posterior distribution for both the individual parameters and mean and variances of these parameters. For all the models we ran, we employed a 'Warm-up' of 5,000 iterations followed by 2,000 draws from 5 independent chains (10,000 draws in total). Convergence was monitored visually using trace-plots, and using the Rhat (Vehtari *et al.*, 2019) diagnostic. All models converged well according to these criteria, and indicative trace plots are presented in Appendix S1.

## 6. DCE Results

In all of the results tables we show the attributes in descending order of WTP. Our results for chlorine washed chicken are shown in Table 2.

As Table 2 shows, the estimates for chlorine washed chicken are negative. In terms of the magnitude of the WTP estimates, the RSPCA quality assurance attribute is very highly valued along with the Red Tractor label and the EU Food Safety attribute. A high value is also placed on UK production compared to that from the EU or Non-EU. Finally, although positively valued, organic production has the lowest WTP estimate.

The mean estimates can be misleading where they mask considerable variation, as indicated by the proportion of respondents reporting a positive value for the attributes (extreme right-hand column). The actual posterior distributions for individuals confirms these substantial variations in responses. For example, while people on average do not like chlorine washed chicken, with some hating it, around 40% express a positive valuation of it. Thus, as always, we need to be careful simply reporting mean estimates as they can mask heterogeneity of preferences. This is in strong contrast to the other attributes, where there is considerably less heterogeneity in response.

Table 2
WTP estimates, chicken

| | Mean | SE Mean | Stdv | Median | 25% | 75% | Prop> 0 |
|---|---|---|---|---|---|---|---|
| Logged Negative Price * | -0.71 | 0.03 | 0.64 | -0.67 | -1.11 | -0.20 | 0.17 |
| Chlorine Wash | -0.81 | 0.11 | 2.29 | -0.49 | -2.38 | 0.66 | 0.40 |
| EU Food Safety | 2.24 | 0.06 | 1.25 | 2.16 | 1.36 | 2.97 | 0.98 |
| Organic | 0.90 | 0.03 | 0.68 | 0.86 | 0.43 | 1.35 | 0.92 |
| EU COO vs Non EU | 0.74 | 0.01 | 0.28 | 0.71 | 0.55 | 0.91 | 1.00 |
| UK COO vs Non EU | 2.18 | 0.06 | 1.25 | 1.97 | 1.31 | 2.88 | 1.00 |
| Red Tractor | 2.36 | 0.03 | 0.61 | 2.32 | 1.97 | 2.65 | 1.00 |
| RSPCA | 2.27 | 0.02 | 0.35 | 2.23 | 2.03 | 2.47 | 1.00 |
| QAI | 1.69 | 0.01 | 0.2 | 1.68 | 1.56 | 1.79 | 1.00 |
| Opt-out | -1.23 | 0.14 | 2.99 | -2.75 | -3.64 | 1.17 | 0.34 |

*The logged negative price is the mean logged coefficient of the negative of price ($\beta_1$) in equation (3).

Our results for the other products and the respective WTP estimates are reported in Tables 3, 4 and 5.

These results are very similar to those reported in Table 2. There are negative estimates for all of the production methods examined. The magnitude of these estimates is almost as strong as the positive estimates for the other attributes. Interestingly, the proportion of respondents expressing a positive value for the method of production are all less than 20%, significantly lower than for chlorine washed chicken. As already noted, this result might occur because of the potentially high value some consumers place on food safety in terms of possible food poisoning. However, examining this motivation in more detail is beyond the scope of the current research. Chlorine washed chicken has received a considerable amount of attention within the UK media recently as a result of the decision to exit the EU and this might well have coloured attitudes to this specific production practice.

Table 3
WTP estimates, corn

| | Mean | SE Mean | Stdv | Median | 25% | 75% | Prop> 0 |
|---|---|---|---|---|---|---|---|
| Logged Negative Price* | 0.71 | 0.02 | 0.45 | 0.88 | 0.43 | 1.07 | 0.91 |
| Atrazine Pesticide | -0.46 | 0.02 | 0.48 | -0.57 | -0.87 | -0.12 | 0.18 |
| EU Food Safety | 0.45 | 0.01 | 0.28 | 0.42 | 0.22 | 0.65 | 0.97 |
| Organic | 0.38 | 0.01 | 0.27 | 0.36 | 0.17 | 0.53 | 0.95 |
| EU COO vs Non EU | 0.21 | 0.01 | 0.16 | 0.21 | 0.11 | 0.32 | 0.92 |
| UK COO vs Non EU | 0.63 | 0.01 | 0.28 | 0.62 | 0.42 | 0.79 | 1.00 |
| Red Tractor | 0.39 | 0.02 | 0.35 | 0.34 | 0.12 | 0.63 | 0.88 |
| Opt-out | -0.64 | 0.03 | 0.62 | -0.97 | -1.1 | -0.29 | 0.19 |

***Notes:*** SE – Standard Error; Stdv – Standard Deviation; Prop – Proportion.
*The logged negative price is the mean logged coefficient of the negative of price ($\beta_1$) in equation (4).

Table 4
WTP estimates, pork

| | Mean | SE Mean | Stdv | Median | 25% | 75% | Prop> 0 |
|---|---|---|---|---|---|---|---|
| Logged Negative Price* | -0.81 | 0.04 | 0.85 | -0.74 | -1.36 | -0.03 | 0.24 |
| Hormone in Feed | -3.24 | 0.15 | 3.17 | -3.70 | -5.68 | -1.04 | 0.17 |
| EU Food Safety | 3.27 | 0.09 | 1.83 | 3.20 | 1.86 | 4.37 | 0.99 |
| Organic | 2.03 | 0.09 | 1.96 | 1.92 | 0.73 | 2.94 | 0.88 |
| EU COO vs Non EU | 0.58 | 0.02 | 0.47 | 0.54 | 0.29 | 0.86 | 0.91 |
| UK COO vs Non EU | 2.97 | 0.08 | 1.69 | 2.82 | 1.82 | 3.88 | 0.98 |
| Red Tractor | 2.67 | 0.10 | 2.14 | 2.48 | 1.12 | 3.93 | 0.90 |
| Opt-out | -3.48 | 0.20 | 4.11 | -5.20 | -6.79 | -0.37 | 0.23 |

***Notes:*** SE – Standard Error; Stdv – Standard Deviation; Prop – Proportion.
*The logged negative price is the mean logged coefficient of the negative of price ($\beta_1$) in equation (4).

Table 5
WTP estimates, beef

| | Mean | SE Mean | Stdv | Median | 25% | 75% | Prop> 0 |
|---|---|---|---|---|---|---|---|
| Logged Negative Price* | -0.14 | 0.04 | 0.73 | -0.07 | -0.64 | 0.44 | 0.45 |
| Hormone Implants | -1.07 | 0.04 | 0.83 | -1.10 | -1.74 | -0.49 | 0.11 |
| EU Food Safety | 1.30 | 0.03 | 0.65 | 1.27 | 0.81 | 1.72 | 0.99 |
| Organic | 0.83 | 0.03 | 0.62 | 0.80 | 0.41 | 1.15 | 0.93 |
| EU COO vs Non EU | 0.58 | 0.02 | 0.40 | 0.58 | 0.34 | 0.80 | 0.94 |
| UK COO vs Non EU | 1.61 | 0.03 | 0.58 | 1.56 | 1.20 | 1.93 | 1.00 |
| Red Tractor | 1.34 | 0.04 | 0.82 | 1.32 | 0.72 | 1.93 | 0.97 |
| Opt-out | -1.78 | 0.05 | 1.01 | -2.28 | -2.53 | -1.13 | 0.09 |

***Notes:*** SE – Standard Error; Stdv – Standard Deviation; Prop – Proportion.
*The logged negative price is the mean logged coefficient of the negative of price ($\beta_1$) in equation (4).

We also produced WTP results for the three types of meat using a common per unit measure (i.e. per 100 grams) (see Appendix S1). The results indicate that, per 100 grams, the largest negative estimate is for hormone implants in beef, followed by hormone in pork  and finally chlorine washed chicken. It is also the case that the relative magnitude of the WTP estimates is greatest for beef, although the quality assurance attributes for chicken are highly valued. Importantly, the results generated for our four DCEs are generally consistent in terms of the magnitudes and the importance attached to each attribute.

Finally, the size of the negative WTPs are substantial in proportion to price. For chicken the negative WTP suggests a price reduction of approximately 26%, for beef it is 36% and for pork it is nearly 60%. These price reductions are larger than the estimates used in the models examining the economic benefits from removing existing trade restrictions between the US and the EU. Our estimates are also similar to those reported by Lewis *et al*. (2017) who report that UK consumers on average required a discount of 60% on US labelled beef.

## 7. Implications

Several important implications arise from our results.

First, in existing research examining costs and benefits of new trade deals between the EU and US the numbers used to capture consumer preferences matter. For example, Arita *et al*. (2017) observe that stated preference research yields estimates of consumer value considered to be on the high side, which leads researchers to significantly lower values than those reported. Similarly, Soon and Thompson (2019) employed a price discount of 15% for hormone-treated beef if entering the EU and an even bigger discount for a smaller group of consumers. In contrast, our estimates suggest that consumers would be willing to pay substantial amounts to avoid consuming food products produced using production methods currently sanctioned in the US. Although we acknowledge that stated preference research needs to be treated with caution as a result of potential biases (e.g. hypothetical bias), there would appear to be a reasonable case for examining the welfare benefits of any trade deal with a greater range of value estimates. We also note that this somewhat negative attitude to stated preference estimates does not correspond with the use of stated preference estimates for environmental policy evaluation (e.g. HM Treasury, 2018).

Second, there are implications for potential changes in supply chains following new trading arrangements. Economic studies using gravity models confirm that trade declines with distance (Carrère *et al*., 2020).[11] However, if these existing supply chains are disrupted for any reason, Poppy *et al*. (2019) observe that other countries (e.g. US for beef, New Zealand and Australia for lamb) could make up the short fall in supply, perhaps implying that these products are close substitutes for existing supplies. Our results suggest that consumers are likely to treat both different sources and (often associated) different production methods differently. For example, we find that there is a preference for EU over non-EU sourced produce. Putting this aside, in principle, both Brazil and Thailand could provide significant imports of poultry meat. However, these imports are not fresh poultry for which there is considerable retail demand from UK domestic consumers. Also, there are aspects of poultry farming in Brazil that have serious consequences for animal welfare and it is clear from our results that consumers have strong preferences for high welfare standards. There is also the issue of carcass balance and how the EU poultry sector has organised itself to move different cuts of meat to different countries based on consumer preferences (Cowen and Morrin 2018). The importance of understanding carcass balance not only relates to the cuts of meat that the UK would need to import to satisfy consumer preferences but also how the UK poultry sector would deal with exporting the cuts of meat that are not demanded in the UK.

Third, it is unclear if the UK will retain the same CoO regulations once the UK leaves the EU (Fraser and Balcombe 2018; Millstone *et al*., 2019). Consumer welfare is enhanced if consumers can make more informed food choices. Providing information such as CoO could be seen as being fundamental to support informed consumer choice. However, any meat products that enter the UK that are going to be used in processed food do not need to declare CoO. Thus, unless method of production becomes a required piece of information to provide to consumers, they will not be able to make an informed choice regarding specific meat products. However, existing

[11]In addition, not only is the UK heavily reliant on the EU in relation to trade in food, much of this trade passes through the Dover Strait (see Garnett *et al.,* 2020 for details).

WTO rules would appear to rule out the use of labels indicating method of production or process under what is sometimes referred to as the 'consumers' right to know' (Hobbs and Kerr 2006; Smyth *et al.*, 2017). In this context, especially if consumers express a strong dislike of specific production methods, it is unclear how consumers can make an informed choice at the point of purchase.

One potential solution to this dilemma is for an increase in the use of information technology so that consumers can be informed about the food they are consuming. For example, Fraser and Balcombe (2018) discuss the potential benefits from employing blockchain technology and the use of SmartLabels initiatives. With the development of trusted information technology there is less reason for food products to be offered to consumers without full disclosure of the source, method of production and supply chain to final product being made available. Thus, any asymmetric information that has given rise to sub-optimal food choice can be corrected even for processed food that meets the demands of consumers for convenience. However, unless the provision of this is made mandatory there appears to be little reason why importers would adopt this approach to information provision. Moreover, as noted by Hobbs and Kerr (2006), the use of mandatory labelling is restricted by the WTO. Therefore, in a situation in which the existing barriers to trade are removed it is far from clear how UK consumers will be able to identify food products that have been produced using alternative modes of production unless they are allowed to be brought to the attention of consumers in any resulting bilateral trade agreement. Indeed, there may well be benefits to consumers from the UK being able to pursue bilateral trade agreements in part because of the limitation of the WTO in terms of consumer protection as opposed to producers (Hobbs and Kerr 2006). But, even if two countries could agree a bilateral trade agreement and include labels that support consumers' right to know a third country could challenge the agreement and the costs of actual implementing this type of policy will be substantial (Smyth *et al.*, 2017).

## 8. Conclusions

We report the results of a Discrete Choice Experiment designed to examine consumer preferences with regard to food and associated forms of food production, that is: hormone implants in beef; Ractopamine in pig feed; chlorine washed chicken; and Atrazine pesticide used in corn production. Our motivation is the need to understand and to take account of consumer preferences for food produced using prohibited production methods, especially in analysis of potential future trade deals. Our results show that, in each of these cases, production methods have significantly negative mean WTP estimates, whereas all other attributes show significantly positive mean WTP estimates. Interestingly, for all food products examined, the negative mean WTP estimates for production are not absolutely larger than the positive mean WTP estimates reported for the most highly valued attributes.

For one of the production methods examined, chlorine washed chicken, our results also reveal that a minority of consumers view this practice positively, which warrants further detailed research. The importance of food safety is also explicitly identified for the other three food products. In terms of CoO, we find that UK production is highly valued, especially for beef, pork and corn and that non-EU production is not valued even relative to generic EU CoO. Taken together these results indicate the potential balance of requirements that UK trade negotiators should be seeking post-Brexit if they are attempting to produce a trade deal that aligns with UK consumer preferences. Specifically, no matter what trade deals are concluded by the UK government in the future, it is clear that UK consumers display strong preferences for particular food attributes, so the use of clear and transparent food labelling should remove uncertainty with respect to purchase decisions. Almost certainly, it is the ability of consumers to make an informed choice that matters most and the economic costs associated with any food-related trade deals that ignore this could lead to substantial losses of welfare for UK consumers.

## Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

**Appendix S1.** Online appendices.

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