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Consumer attitudes to genetically modified organisms in food in the UK

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Summary

This paper reports a study of UK consumer attitudes to genetically modified organisms (GMOs) in food and the extent to which these attitudes translate into willingness to pay to avoid these products. The results indicate the relative importance of different aspects of the food system in forming food preferences, and that GM food is only one of a number of concerns, albeit a significant one. Attitudes towards organic food are found to be a useful indicator of attitudes towards GM technology, as the preference structure that underlies the former also appears to inform the latter. Significant differences are found between attitudes to GM food in which plants are modified by the introduction of genes from other plants and those in which plants are modified by the introduction of genes from animals and plants.

Keywords: choice modelling, GMOs, food safety, stated preference

JEL classification: C25, D12, Q18

1. Introduction

Consumer concern about food safety has been increasing. Pesticide contamination, pollution, food scares and health concerns are having a major impact on consumer purchasing behaviour. The use of genetically modified organisms (GMOs) in food products appears to be the cause of particular anxiety and mistrust among consumers, especially those in the UK and other parts of Europe (Bredahl, 1999; Senauer, 2001).

Society has recognised that together with the (potential) benefits, there are (potential) risks to humans, other natural organisms and the environment, stemming from the development and application of gene technologies, although the extent of those risks is as yet unknown. Most countries have introduced laws to regulate the use of gene technologies to protect the health and safety of people and to safeguard the environment (Engel *et al.*, 1995b). The regulatory framework in any country is influenced by public opinion and cultural attitudes towards risk, health and the environment and supported by an assessment of risks associated with gene technology. Food safety and quality are key issues in private and public decision-making regarding the types of food products offered in the market and the regulations enforced.

Given consumers' concern about the use of GM technology in food, governments and the food industry have made a number of strategic responses (Engel *et al.*, 1995a). For example, the EU has placed restrictions on imports of US soya produced using these techniques, the UK food and drink manufacturers and retailers voluntarily agreed to the adoption of labelling of foodstuffs containing genetically modified soya or maize protein (IFST, 1998), and some major retailers in the UK have removed all GM products from their shelves. Identifying the strength of consumer attitudes on this issue, and specifically consumers' willingness to pay to avoid these products, one can start to identify the appropriate level of policy response.

This paper reports the results of an analysis of attitudes of a sample of UK consumers to GMOs in food. The research method adopted for this purpose, choice modelling, has the significant advantage of allowing the issue of primary interest (here GMOs) to be presented along with a number of other potential consumer concerns, so allowing an exploration of the trade-offs that are made in real decision-making.

2. Choice modelling and willingness to pay

There has been an extensive range of surveys of consumer attitudes towards GM foods, across many countries (see, e.g. Kelley, 1995; Hoban, 1998; Norton *et al.*, 1998; Smith and Riethmuller, 1999; Yann Campbell Hoare Wheeler, 1999; Mendenhall, 2000; Wirthlin Group, 2000; Wolf and Domegan, 2000). Many of these studies only identify qualitative attitudes, such as a rating of 'concern' about the technology, or whether consumers would be willing to purchase it. Such views, however, will normally be conditional upon the circumstances within which GM food becomes available. Is rejection of GM food independent of the level of price discount that might be available? Are environmental or ethical concerns about GM production techniques non-negotiable, or could they be offset by potential alternative environmental benefits from GM crops? As with all consumer behaviour, the observed outcomes will be the result of constrained choice. Contingent valuation (CV) as applied to environmental goods has long recognised this problem, and has led to an emphasis on alternative uses of resources that may be committed to conservation, and the 'scope' of the good being considered in relation to the wider environment.

Choice modelling is a particularly attractive way of approaching this issue, in that the choices presented explicitly highlight the trade-offs that often have to be made in actual decisions. More specifically, the technique allows a single issue of interest to be broken down into the range of elements that it comprises, allowing the trade-offs between these components to be analysed.

2.1. Choice modelling: theory

The central idea behind choice modelling is that individuals can choose between alternative options that contain a number of attributes with different levels. Respondents are not asked to report how much they prefer alternatives, nor even how much they value individual changes in an attribute; they are merely asked to identify which of a number of options they prefer. Formally, the approach is based within the framework of random utility theory, and there have been extensive applications in marketing and environmental valuation (e.g. Morrison *et al.*, 1996; Adamowicz *et al.*, 1998; Blamey *et al.*, 1998; Bennett, 1999; Hansen and Schmidt, 1999).

Random utility theory proposes that individual consumers choose alternatives that yield the greatest utility and so the probability of selecting an alternative increases as the utility associated with it increases. The individual consumer's utility level associated with the choice of an alternative, j, comprises a deterministic (observable) component (v_j) and an unobservable or stochastic component (e_j):

$$U_j = v_j + e_j \tag{1}$$

where v_j is the indirect utility function and e_j is a random error component. It is important to note that utility is stochastic from the point of view of the researcher, not the consumer.

To motivate the discussion, let us consider a simple case where there are two attributes in each option: the form of technology used to produce food (traditional or GM) and the level of the weekly food bill for the individual. If only two options are provided, the choice set could be as illustrated in Table 1. In selecting between these two, the respondent is asked to compare the reduced food bill with the change in technology. Option 1 is chosen if the welfare from its level of attributes is preferred to that generated by Option 2. At that level, it is tautological: the respondents choose the option they prefer. The model is given empirical content by explicitly modelling the process by which welfare is generated. In its simplest form we can specify

Table 1. A simple choice set

Attributes	Option 1	Option 2
Technology	Traditional	GM technology
Weekly food bill	100% of current	80% of current

that

$$U_j = \beta_1 \mathrm{GM}_j + \beta_2 \mathrm{PAY}_j + e_j \tag{2}$$

where U_j is the utility obtained by an individual from option j; GM is a dummy variable indicating the use of GM technology and PAY is the level of food expenditure; β_1 and β_2 are parameters to be estimated.

Formally, the respondent will choose option j over an alternative k if $U_j > U_k$. The task of the statistical analysis is then to identify estimates of the β parameters so that the predicted choices, made on the basis of a comparison of the utilities predicted for each option using equation (2), match as closely as possible the actual choices revealed in the survey. McFadden (1974) has shown that the random utility model can be estimated by the conditional logit model.[1]

The model is implemented by choosing a particular distribution of disturbances. Typically it is assumed that the disturbances are independently and identically distributed, with a Gumbel distribution (Ben-Akiva and Bierlaire, 1999):

$$F(e) = \exp[-\exp(u)] \tag{3}$$

where $F(e)$ denotes the cumulative distribution function and u is normally distributed. Testing the properties of the error process can lead to significant efficiency gains, and added insight into the choice process (Hausman and McFadden, 1984; Rolfe *et al.*, 1999).

The assumption of identically and independently distributed error terms leads to the variant of the logit model used in discrete choice modelling.[2] Hence the probability of person i choosing option j from N options can be expressed as

$$\mathrm{Prob}(Y_i = j) = \frac{\exp\left[\lambda \sum_{k=1}^{K} \beta_k X_{kj}\right]}{\sum_{j=1}^{N} \exp\left[\lambda \sum_{k=1}^{K} \beta_k X_{kj}\right]} \tag{4}$$

where Y_i is a random variable denoting the choice made and X_k $(k = 1, \ldots, K)$ are the choice attributes. λ is a scale parameter, which is inversely related to the variance of the error term ($\lambda = \pi^2/6\sigma^2$, where σ^2 is the variance of the error term). Adamowicz and Boxall note that the scale parameter 'is confounded with the parameter vector and cannot be identified. Normally, … [the scale parameter] is set equal to 1.0…' (Adamowicz and

1 In the choice modelling literature, this version of the logit model is sometimes referred to as the multinomial logit model, although, as Greene (1997) points out, the two logit specifications differ slightly.

2 If it is assumed that the disturbances are not independent nor identically distributed normal random variates, the more complex binary or multinomial probit model would be used (Louviere, 2001).

Boxall, 2001: 10). However, in this paper we examine two forms of heterogeneity: heterogeneity in tastes (i.e. the β parameters) and heterogeneity in scale (i.e. the λ parameter).

It is important to note that individual-specific characteristics can be incorporated to explain choices, but they have to do so in a particular way. Let us consider the following formulation, which allows the utility gained from an option to vary across individuals:

$$U_{ij} = \sum_k \beta_k X_{kj} + \sum_m \alpha_m Z_{mi} + e_{ij} \tag{5}$$

where i identifies the individual, and Z_{mi} is characteristic m of respondent i (for example, age or education), which may affect utility values. The probability that individual i will select option j is then

$$\begin{aligned} \text{Prob}(Y_i = j) &= \frac{\exp\left[\lambda\left(\sum_k \beta_k X_{kj} + \sum_m \alpha_m Z_{mi}\right)\right]}{\sum_j \exp\left[\lambda\left(\sum_k \beta_k X_{kj} + \sum_m \alpha_m Z_{mi}\right)\right]} \\ &= \frac{\exp\left[\lambda \sum_k \beta_k X_{kj}\right] \exp\left[\lambda \sum_m \alpha_m Z_{mi}\right]}{\sum_j \exp\left[\lambda \sum_k \beta_k X_{kj}\right] \exp\left[\lambda \sum_m \alpha_m Z_{mi}\right]} \end{aligned} \tag{6}$$

and hence the terms in Z cancel. Because the personal characteristics are constant for all choices open to individual i they have no impact on the choices made, if they enter the utility function linearly. However, personal characteristics can be included in the analysis, if they affect the way that attributes contribute to utility, as follows:

$$U_{ij} = \sum_k \beta_k X_{kj} + \sum_k \sum_m \alpha_{km} X_{kj} Z_{mi} + e_{ij}. \tag{7}$$

Not all of the interaction terms need to be included, and one may have some prior beliefs as to which attributes will be affected by which characteristics, but this can, to some extent, be determined empirically.

2.2. The role of the scale parameter

As noted above, it is usually the case that the variance of the error term is assumed to be constant within the sample, and hence the scale parameter cannot be identified. However, the role of the scale parameter is important when conducting tests of equivalence of parameters across sub-populations within the sample. Thus, on the basis of a statistical test one may reject the hypothesis that the parameters are the same for two sub-populations (and hence the utility functions differ), when in fact it may be that the utility functions are equivalent but the variance differs across the populations.

2.3. Partworths

An important aspect of the interpretation of the outcomes from choice models is the notion of a 'partworth'. The individual parameters generated by the model do not have a direct interpretation, other than in their signs or statistical significance. However, the parameters can be combined to identify monetary values associated with changes in each attribute level.

Let us consider again the initial example of equation (2). A shift from traditional to GM technology, *ceteris paribus,* will change utility by an amount β_1. The question can then be posed: how much would the consumer be willing to pay to attain the subsequent level of utility, while retaining the traditional technology? This willingness to pay to avoid GM technology, expressed as the change in the food bill (x), can be derived from

$$\beta_1 \times 1 + \beta_2(\mathrm{PAY}_1) + e_1 = \beta_2(\mathrm{PAY}_1 + x) + e_0 \qquad (8)$$

where, in terms of equation (2), $j = 0$ denotes the choice of no GM technology and $j = 1$ denotes the choice with GM technology.[3]

This can be solved to give an expected value of x:[4]

$$E(x) = \beta_1/\beta_2. \qquad (9)$$

x is the partworth associated with a unit increase in the attribute, and can be interpreted here as the maximum that the respondent would be willing to pay in the form of an increased food bill to avoid consuming GM food. In this example one might expect β_1 to be negative (i.e. the presence of GM will reduce the probability that the option will be chosen), and β_2 also to be negative (i.e. options with higher payment levels will be less likely to be chosen). Hence, there would be a positive willingness to pay to avoid GM food.

3. The application

The survey was administered over the summer of 2000, in Manchester, UK. A 'drop-off and collect' approach was undertaken, with approximately 2,000 surveys delivered to randomly selected streets across Manchester, and then collected again approximately 3 days later. The person who did the household's food shopping was asked to complete the questionnaire. Some respondents elected to return their surveys by post. A total of 228 complete surveys were obtained over a 6 week period (Table 2 presents some summary statistics.) This was not a stratified sample and hence it cannot claimed to be wholly representative of the population. For example, it may be that a higher non-response rate occurred amongst low-income households. Although, as commented elsewhere (Gordon *et al.*, 2001), this is not a problem unique to

3 An alternative approach would be to ask what level of compensation (in the form of a reduced food bill) would the consumer require to accept GM technology. Because of the linearity of the utility function, these welfare measures would be equal in magnitude but opposite in sign.

4 It is assumed that $E(e_0) = E(e_1) = 0$.

Table 2a. Descriptive information for sample

Employment status	Home-maker	Employee	Self-employed	Student	Retired	Seeking work	
%	11.5	45.9	11.5	4.4	23.0	3.8	
Household pre-tax income (£)	0–10000	10001–20000	20001–30000	30001–40000	40001–50000	50001+	
%	13.45	19.30	23.4	20.47	9.94	13.45	
Gender	Male	Female					
%	29.6	70.3					
Age (years)	11–20	21–30	31–40	41–50	51–60	61–70	71+
%	1.1	16.4	28.4	15.9	15.9	12.6	9.8
Education	Stopped at 16	Stopped at 18	College/ univ. degree	Other			
%	21.31	9.84	52.46	16.39			
Household size	1	2	3	4	5	6	8
%	21.4	34.1	18.7	18.1	6.6	0.6	0.6
Children under 16	0	1	2	3	4		
%	68.9	11.5	14.2	4.9	0.6		
Organic purchasing	Infrequent	Occasional	Committed				
%	37.2	37.2	25.7				

All values indicate the percentage of the sample within each category.

Table 2b. Food expenditure levels for sample

Weekly food bill[a] (£)	Mean	SD	Min	Max
	75.6	43.7	10.0	250.0

[a] Including eating out.

choice modelling studies of this type, the results should be interpreted with a degree of caution in this respect.

One issue with surveys of consumer attitudes, and in particular with a topic as contentious as GM foods, is that the survey process itself may give the topic an unwarranted prominence. Thus, if consumers believe that the survey is about GM foods, they may discount other aspects of the food system. To minimise this effect, the information given to respondents concerned the food system as a whole, and a number of attributes of the food system were presented to them, with GM technology given no greater weight than any other. In part, this places GM food in a context, and, also, it allows us to compare the values placed upon GM avoidance with other issues that may be of concern.

Each option (or 'food future', as it was termed in the questionnaire) presented to the respondent consisted of five attributes, with each attribute taking a number of values. All attributes were described in detail in the preamble to the survey questionnaire. The attributes and potential levels are reported in Table 3. The full survey is available on request from the authors.

Table 3. Attributes and their levels

Attribute	Level
Level of weekly food bill (% change from current)	−50, −40, −30, −20, −10, 0, +10, +20, +30, +40
Form of production technology used	Traditional, GM (plants), GM (plants and animals)
Level of on-farm chemical use	−30%, no change, +10%
Structure of food system (food miles)	−30%, no change, +10%
Food health risk	1/15,000, 1/10,000, 1/5,000

The inclusion of the food bill (expressed as a percentage of the current level) is self-evident: it takes the role of the 'payment vehicle'.

The production technology was identified as having three possible levels: 'traditional', which represented the current system;[5] GM technology where plants were modified only by the use of plant genes; GM technology where plants were modified by the use of both plant and animal genes. The last

5 In the UK at present there is no commercial GM food production.

was included to explore the common result from attitudinal surveys, that consumers are much more concerned about GM technology that involves animal genes.

The level of on-farm chemical use is represented as a proxy for the intensity and potential environmental impact of agriculture.

The 'structure of the food system' was included purely to emphasise that the survey was about the way that food was produced and delivered to consumers as a whole, and provided an issue that was not farm- or technology-focused. Specifically, the notion of a 'local' as opposed to 'global' food system was introduced and this attribute was represented by the measure of 'food miles' (the distance travelled by the food product from producer to consumer).

The risk of food-related illness[6] was also introduced as another aspect of the food system, and one that has been addressed previously within the context of contingent valuation studies (Henson, 1996).

Given these attributes, and attribute levels, it is then necessary to construct an experimental design, so that their impacts can be identified. A 'main effects' design (Green, 1974) was chosen, giving a total of 28 choice sets, each of which contained three 'food futures' (see Appendix). Such a design is consistent with a linear utility function (i.e. the marginal utility of an attribute is independent of the level of the other attributes). Each choice set included what was described as the status quo, defined as no change in food bills, chemical use and food miles, traditional technology, and a food risk of 1/10,000.

Of the 28 choice sets, one was omitted as it was dominated by the status quo in that all attribute levels, including the food bill, were perceived to be 'worse'. To keep the survey manageable by the respondent, the remaining 27 choice sets were split into three subsets of nine, and each respondent was randomly allocated one of the sets of nine choices to complete.

The final section of the survey collected standard socio-economic data on the respondent, and included a debriefing question on the survey itself.

3.1. Results

A total of 2,030 choice sets were completed and available for analysis. However, some respondents selected the status quo for all nine choice sets presented to them. One interpretation is that these respondents are registering a form of protest vote: because of strong objections to some aspect of the choice sets, they consistently select the current position, without any consideration of the attribute levels being presented. If this is correct, an explicit assumption of the choice modelling approach, i.e. that observed choices are conditioned by attribute levels, is violated. To include such choices in the analysis, and attempt to explain them on the basis of attribute levels, would lead to biased estimates. It was therefore decided that these observations

6 Food risk was described in the questionnaire in terms of the probability of food-borne, severe illness, which could include 'stomach pains, fever and sickness which require you to go to hospital. A return to normal health would be expected in 15–30 days.'

Table 4. Alternative model specifications[a]

Model 1	Model 2
Different variances over I, O, C	Constant variance over I, O, C
Parameters varying over I, O, C	Parameters varying over I, O, C
LLF = −1176.21	LLF = −1179.14
Parameters = 23	Parameters = 21
Model 3	**Model 4**
Different variances over I, O, C	Constant variance over I, O, C
Constant parameters over I, O, C	Constant parameters over I, O, C
LLF = −1218.94	LLF = −1226.16
Parameters = 11	Parameters = 9

[a]I, O, C denote the Infrequent, Occasional and Committed organic food purchasers, respectively.

should be excluded.[7] These exclusions, combined with some missing responses for some questions, generated a final dataset of 1,626 observations (covering 183 households), which was used in the subsequent analysis.

As noted above, personal characteristics of respondents can be included in the analysis, interacting with attribute levels to explain choices. It was found that gender was a significant determinant of attitudes towards the GM technology, but not the other attributes. No other individual-specific characteristics could be found that were significant. However, during the exploratory phase of the analysis, it was noted that current rates of organic food purchase seemed to be linked to choices made about food futures. Survey respondents were asked to indicate how often they purchased organic foods and so it was possible to generate three consumer groups: (i) Infrequent purchasers of organic foods (i.e. those who 'Never' or 'Rarely' purchase); (ii) Occasional purchasers of organic foods (i.e. those who purchase 'Sometimes'); (iii) Committed purchasers of organic foods (i.e. those who purchase 'Often' or 'Always'). Defining dummy variables for these three consumer groups (see Table 2 for the relative frequencies in the sample) and interacting them with the choice attribute variables allowed this purchase behaviour to be introduced as an individual-specific characteristic.

As discussed in Section 2.1, the scale parameter, λ, of such choice models is confounded with the parameter vector and the former is, typically, simply set equal to one. To test for heterogeneity in tastes (i.e. the β parameters) and heterogeneity in scale (i.e. the λ parameter) a series of nested models, described in Table 4, were estimated. For reasons of space, only the preferred

7 A Hausman test of the difference in coefficients for the full dataset against the restricted dataset generated a Hausman statistic (χ^2_{21}) of 218.13, and hence the hypothesis that there is no systematic difference in coefficients is resoundingly rejected.

Table 5. Preferred model (Model 2)

	Coeff.	Std. error	z	$P > \|z\|$
bill	−0.0312	0.0034	−9.05	0.000
bill × O	0.0198	0.0045	4.41	0.000
bill × C	0.0251	0.0053	4.73	0.000
GM(P)	0.3661	0.2402	1.52	0.127
GM(P) × O	−0.1911	0.2843	−0.67	0.501
GM(P) × C	−1.1341	0.3441	−3.30	0.001
GM(P) × fem	−0.4244	0.1802	−2.36	0.018
GM(P + A)	−0.8183	0.2554	−3.20	0.001
GM(P + A) × O	0.0617	0.3001	0.21	0.837
GM(P + A) × C	−1.2944	0.3885	−3.33	0.001
GM(P + A) × fem	−0.7190	0.2148	−3.35	0.001
chem	−0.0405	0.0048	−8.40	0.000
chem × O	−0.0077	0.0065	−1.18	0.237
chem × C	−0.0219	0.0082	−2.66	0.008
fm	−0.0164	0.0031	−5.27	0.000
risk	0.1497	0.0215	6.97	0.000
risk × O	−0.1012	0.0285	−3.55	0.000
risk × C	−0.0994	0.0353	−2.82	0.005
sq	1.7662	0.1805	9.78	0.000
sq × O	−0.5597	0.2392	−2.34	0.019
sq × C	−0.6573	0.2678	−2.46	0.014

Number of obs = 1626. LR $\chi^2(21) = 1214.41$. Log likelihood = −1179.1407. Pseudo $R^2 = 0.3399$.

model is presented here (Table 5). Specifically, the estimated models were as follows.

Model 1

This denotes the most general specification, which allows both the variance and the parameters of the utility function to vary across the three consumer groups (Infrequent, Occasional, and Committed purchasers of organic food). Following Swait and Louviere (1993), the model is estimated using a grid search over the scale parameters (λ_O and λ_C) for the Occasional and Committed groups simultaneously, while using the Infrequent group as the baseline.

Model 2

This specification allows only the parameters of the utility function to vary across the three consumer groups, while assuming that the variances are the same. Significant effects are identified for all attributes of the choice set apart from the issue of food miles, about which the three groups appear to be in agreement. A Likelihood Ratio test of Model 1 against Model 2 fails to reject the latter, more restrictive, specification (LR = 5.86; $\chi^2_{0.05,2} = 5.99$).

Model 3

This version relaxes the assumption that the variances of the three consumer groups are equal but assumes constant utility function parameter values across groups. Again, a grid search over the scale parameters (λ_O and λ_C) is used. This yields estimates of the scale parameters λ_O and λ_C of 0.9 and 1.13, respectively, implying that the variance for the Occasional (Committed) groups is greater (smaller) than for the Infrequent group. A comparison of Models 1 and 3 provides a test of the stability of parameters across the consumer groups. The LR test statistic is 85.46, which, against a critical $\chi^2_{0.05,12}$ value of 21.03, implies that the parameters are significantly different.

Model 4

This is the most restrictive version of the model, in which parameters and variance are not differentiated across the three 'organic' consumer groups. It does, however, permit the interaction of gender with attitude towards GM technology. The restrictions implied by this model are rejected, when this specification is compared with Model 1 (LR = 99.9, $\chi^2_{0.05,14} = 23.69$), with Model 2 (LR = 94.04, $\chi^2_{0.05,12} = 21.03$) and Model 3 (LR = 14.44, $\chi^2_{0.05,2} = 5.99$).

The preferred model (Model 2) is reported in Table 5. In this model, the baseline is the group of male, infrequent purchasers of organic food and traditional (non-GM) production technology. O and C denote dummy variables that indicate if the respondent is a member of the Occasional or Committed organic food purchasing group, respectively. The coefficient on bill is expected to be negative and is interpreted as the (negative) of the marginal utility of a percentage change in the consumer's food bill. Using the respondent's current level of food bill, the marginal utility of income could be generated. In the subsequent analysis it is assumed that the relative, rather than the absolute, marginal utility of income is constant across the sample.

Technology is represented by two dummy variables: GM(P) for genetic modification involving plant material alone and GM(P + A) where it involves animal genes also. fem is a dummy variable, taking a value of one if the respondent is female. Thus, the insignificant coefficient on the GM(P) variables implies that moving from traditional to a GM technology using plant genes alone does not reduce the utility for men, but the coefficient on GM(P) $\times$ fem suggests it does have an impact on women. Both genders react adversely to the use of animal and plant technologies, but for women the response is greater.

The remaining variables are introduced as cardinal variables. chem denotes the percentage change in chemical use, and the negative coefficient implies that increased use of agrochemicals on-farm reduces utility for the base group; fm denotes the level of food miles, and the negative coefficient suggests that respondents prefer more 'local' food systems; risk is the level of food risk (coded as 5, 10 or 15, with larger numbers implying lower risks), and the results indicate that respondents prefer lower food risk.

A common aspect of choice modelling applications is determining whether there are impacts on utility that are associated with an option as a whole, rather than the individual attribute levels that make up the option. This is relevant only when there is an obvious interpretation of the option in question. There is such an interpretation of the status quo option included in every choice set in the survey. It is therefore possible to test whether respondents may have a tendency to simply select the current position, irrespective of the attribute levels of the other options used. The other two food futures, which, along with the status quo, make up each choice set, have no equivalent interpretation. A dummy variable, sq, is defined, taking a value of one if the option is the status quo, and zero otherwise. The estimated coefficient is positive and highly significant, implying that there is a tendency within the sample to select this option, irrespective of the attribute levels. It should be noted that those who always selected the status quo have been excluded from this analysis, and so this effect cannot be attributed to a 'protest vote'.

Interpretation of the differences between the consumer groups is best undertaken using the implied partworths. However, these partworths are heavily dependent on the estimate of the marginal utility of a percentage change in food bill, that is, the (negative) coefficient on the bill variable. It should be noted that the model implies that this marginal utility varies across the three groups, and falls as the consumption of organic food rises. The estimates of these marginal utilities, and their associated standard errors, are given in Table 6.

The marginal utility for the Committed group is close to zero, and is significantly different from zero only at the 15 per cent level. The implication is that the members of this group are placing little emphasis on the level of food bills when making their choices. A zero marginal utility of a percentage change in food bill could be a realistic approximation if the expenditure changes being considered are small, but the change in food bills ranges from −50 per cent to +40 per cent. Although the Committed group have a slightly higher mean income than the other two groups, they also have higher food bills, and it is unlikely that changes in food bills of this magnitude could be considered as negligible.

Table 6. Estimated marginal utility of a 1 per cent increase in food bill, by group

Group	Marginal utility	Standard error	Marginal utility as % of utility at status quo
Infrequent	−0.0312	0.0034	−2.1
Occasional	−0.0114	0.0029	−2.3
Committed	−0.0060	0.0040	−1.2

Table 7. Composite parameter estimates, by groups

Attribute	Notation	Infrequent	Occasional	Committed
GM (plant)	GM(P)			
Male		0.366	0.175	−0.768**
Female		−0.058	−0.249	−1.192**
GM (plant + animal)	GM(P + A)			
Male		−0.818	−0.757**	−2.113**
Female		−1.537**	−1.476**	−2.832**
Chemical use	chem	−0.041**	−0.048**	−0.062**
Food miles	fm	−0.016**	−0.016**	−0.016**
Risk	risk	0.150**	0.049**	0.050*
Status quo	sq	1.766**	1.207**	1.109**

* (**) significant at the 5% (1%) level.

3.2. Estimates of partworths

As noted above, monetary values can be given to unit changes in attribute levels by taking the ratio of the attribute coefficient to the coefficient on the monetary variable. Because for many of the attributes the relevant coefficient is a linear combination of two (or more) estimated parameters, composite coefficients[8] have to be calculated; these are presented in Table 7.

GM technology involving plants appears to be a significant determinant of choice only for the Committed group, with women being more concerned than men. The Infrequent and Occasional groups appear to be indifferent between traditional production methods and this form of GM technology. For GM technology involving animal genes, the picture is a little different: all groups except men within the Infrequent group are significantly affected by the presence of this technology, and as the respondent becomes more committed to organic food, the effect seems to be greater. A similar pattern emerges for chemical use, although the reverse occurs for food risk, with the Committed organic group placing less weight on changes in health risks.

Using the estimates of the marginal utility of food bill changes (from Table 6) and the composite parameter estimates in Table 7, partworths for unit changes in attributes can be calculated.[9] To make the results more readily interpretable, these partworths are presented for specific changes in attribute

8 For example, to obtain the composite GM(P) parameter for females one needs to sum the parameter for males (0.3661) and the coefficient on GM(P) × fem (−0.4244), hence a composite parameter on GM(P) for females of −0.058.

9 For the record, partworths based on the estimated coefficients of the more general Model 4 were very similar for the Infrequent and Occasional consumer groups. Those for the Committed group were higher than those presented in Table 8.

Table 8. Willingness to pay (in terms of per cent change in food bills)

	Infrequent	Occasional	Committed
A GM-free diet			
Male	26.25***	66.50***	352.12*
Female	49.31***	129.70***	471.95**
A reduction of 10% in chemical use	13.00***	42.30***	103.20*
A reduction of 10% in food miles	5.20***	14.40***	27.10*
A reduction in food risk from 1/10,000 to 1/15,000	24.00***	21.35***	41.60

* (**) (***) partworth significant at the 15% (10%) (5%) level.

levels in Table 8.[10] As the food bill enters the choice sets as a percentage change from current level (see Table 3), these valuations are in terms of the percentage change in the household's food bill. As none of the partworths for GM technology involving only plants genes were significant,[11] the 'GM-free diet' referred to in Table 8 concerns a food bill without GM technology involving animal and plant gene transfer.

A notable feature of these results is the statistical insignificance of the willingness to pay estimates for the Committed group of consumers. In fact, the significance levels presented here do not imply that the attribute is unimportant in respondents' choices—on the contrary, as the results in Table 7 attest, the coefficients on the individual attributes are statistically significant. Rather they indicate the precision with which a monetary valuation can be identified. The latter depends on the marginal utility of food bill changes, which, as already noted, is small and only statistically significant at the 15 per cent level for the Committed consumer group. Whether the precision of these estimates would be improved by respecifying the way in which the payment vehicle is defined, or by changing some other aspect of the design of the consumer experiment, will be explored in future research in the area.

Infrequent consumers of organic food would be willing to increase their food bill to avoid animal and plant GM technology. These changes are substantial (26 per cent for males and 49 per cent for females) but feasible. For the Occasional group, the implied increases in the food bill for a GM-free diet are of sufficient size to suggest that this group would never choose

10 In this table, the asterisks indicate whether the estimated partworths are significantly different from zero. It is also interesting to ask whether they are significantly different across the consumer groups. When the Occasional WTP is compared with that of the Infrequent group we find a significant difference with respect to a GM-free diet, chemical use and food miles but not food risk. Comparisons with the Committed group are again confounded by the small, marginally significant marginal utility of food bill changes for that group. To save space, the detailed results are not reported here but are available from the authors on request

11 As the partworth is derived as a non-linear function of the estimated parameters, the significance of the partworth itself is estimated using the Wald test formula (Greene, 1997: 163).

to purchase GM food, as is the case also for the Committed group. That consumers of organic products have a high willingness to pay for a GM-free diet may not be very surprising but it should be stressed that the data do not suggest that there is an unequivocal aversion to GM technology. Even the Committed group of organic consumers selected a food future that included either plant or animal and plant GM technology in 15 per cent of their choice sets. The average characteristics of these GM choice sets selected by the Committed organic group included the weekly food bill reduced by 12 per cent and the level of agrochemical use down by 23 per cent.

The valuation of changes in chemical use also mirror what one might expect across the consumer groups. The Infrequent group would be prepared to pay 13 per cent more on food bills to achieve a 10 per cent reduction in chemical use. The value for the Occasional group is some three times larger, and again, that of the Committed group is inflated by the low estimate for the marginal utility of changes in the food bill. All consumer groups are willing to pay for more locally supplied food: the Infrequent group would be willing to increase their food bills by 5 per cent for a 10 per cent reduction in food miles, and again the Occasional group's valuation is about three times larger. These groups would also be prepared to pay substantially more for safer food:[12] on average, an extra 20–25 per cent in food bills to achieve a reduction in risk of severe food poisoning from 1/10,000 to 1/15,000.

An issue that needs to be addressed is whether the results seem reasonable in the context of other valuation studies and other information available on attitudes to such food issues. The food issues dealt with here are commonly identified by large sections of the population. For example, Henson (2001) reports that, when not prompted, over 35 per cent of consumers in the UK indicated that GMOs were of concern to them when buying food, a figure of nearly 30 per cent is reported for pesticides and over 40 per cent identified concern regarding food poisoning (the figures when consumers are prompted on a range of food safety issues are even higher). Although the organic sector accounts for a relatively small proportion of retail sales, its rapid growth in the UK and many other countries in recent years may be taken as further evidence of consumers' willingness to pay for what they view as safer, more 'environmentally friendly' food.

Information on the scale of changes in actual and potential purchasing behaviour associated with these concerns is more scarce (particularly with respect to GMOs). Henson (1996) reports the results of a CV study in which 'the implied 'willingness to pay' of UK consumers to avoid a case of food poisoning in 1996 was £2,554 for eggs and £5,446 for chicken' (Henson, 2001: 11). Although these specific estimates may be deemed excessively large, the notion that consumers are prepared to pay significantly

12 The risk variable was coded 5, 10 and 15, corresponding to a 1/5,000, 1/10,000 and 1/15,000 risk of food poisoning. Thus a change in the attribute from 10 to 15 implies a reduction in risk from 1/10,000 to 1/15,000.

higher amounts for food they regard as safer seems well established. Henson and Azam (2001) report a conjoint analysis, in which various food characteristics are evaluated, which showed that the 'method of production was of greatest importance to respondents, accounting for around 48 percent of variation in the utility of respondents across each characteristic' whereas the equivalent figure cited for price was around 20 per cent. This suggests that consumer concerns about production methods will translate into relatively high willingness to pay to avoid food produced in what is considered to be an inappropriate manner.

The results cited in Table 8 seem therefore broadly acceptable, although the caveats noted above regarding the possibility of sample bias and the difficulties associated with accurate identification of WTP for the Committed organic purchasers should be borne in mind. We would also argue that the nature of the choice modelling framework, with the difficulties it poses to respondents employing strategic behaviour and its explicit treatment of the trade-offs involved in consumer choice (Bennett and Blamey, 2001), generates greater confidence in estimates produced.

4. Conclusions

This paper has provided an overview of an approach to identifying the values consumers may have with regard to GM foods. It represents the first attempt in the literature to identify WTP to avoid consumption of GM food and illustrates the fact that choice modelling brings with it a number of advantages in this area of study. One of the most significant of these advantages is the possibility of embedding the issue of interest within a broader context and hence exploring the trade-offs. In this case the specific concern regarding GMOs has been located and examined within the broader framework of consumer attitudes to the organisation of the food production system. It also allows an investigation of the impacts of individual-specific attributes on preferences.

However, the fact that respondents are not explicitly asked to value GM foods, but instead these values are inferred, leads to the possibility, reported here, that it may not be possible to precisely calculate WTP to avoid GMOs in food, even though there are strong preferences regarding such genetic modification. In the current context this result may be due to the survey design, the fact that some respondents did not fully consider the monetary aspects of their choices in the way that they would have in a real market, or the way that the preference structure has been modelled.

The results indicate the relative strengths of different aspects of the food system in forming preferences; GM food is only one element amongst a number of concerns, albeit an important one. Moreover, attitudes differ significantly between GM technology in which plants are modified by the introduction of genes from other plants and that in which they are modified by the introduction of genes from animals and plants. The results also indicate that attitudes towards organic food may be taken as a useful indicator of attitudes towards GM technology: the value sets that underlie the former appear to inform the latter also. This is an important result if one wants to gauge the extent of concern about GMOs in a heterogeneous consumer population.

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References

Adamowicz, W. and Boxall, P. (2001). Future directions of stated choice methods for environmental valuation. Paper presented at the AES One-Day Conference on 'Choice Experiments: A New Approach to Environmental Valuation', Imperial College, London, 9 April 2001.

Adamowicz, W., Boxall, P., Williams, M. and Louviere, J. J. (1998). Stated preference approaches for measuring passive use values: choice experiments and contingent valuation. *American Journal of Agricultural Economics* 80: 64–75.

Ben-Akiva, M. and Bierlaire, M. (1999). Discrete choice methods and their applications to short-term travel decisions. In R. Hall (ed.), *Handbook of Transportation Science*. International Series in Operations Research and Management Science, Vol. 23. Dordrecht: Kluwer Academic. http://dmawww.epfl.ch/roso.mosaic/mbi/handbook-final.htm (accessed 1 February 2001).

Bennett, J. (1999). Some fundamentals of environmental choice modelling. Choice Modelling Research Report 11. Canberra, A.C.T.: University College, The University of New South Wales.

Bennett, J. and Blamey, R. (2001). The strengths and weaknesses of environmental choice modelling. In J. Bennett and R. Blamey (eds), *The Choice Modelling Approach to Environmental Valuation*. Cheltenham: Edward Elgar, 228–241.

Blamey, R. K., Bennett, J. W., Morrison, M. D., Louviere, J. J. and Rolfe, J. C. (1998). Attribute selection in environmental choice modelling studies: the effect of causally prior attributes. Choice Modelling Research Report 7. Canberra, A.C.T.: University College, The University of New South Wales.

Bredahl, L. (1999). Consumers' cognitions with regard to genetically modified foods. Results of a qualitative study in four countries. *Appetite* 33: 343–360.

Engel, K.-H., Schauzu, M., Klein, G. and Somogyi, A. (1995a). Regulatory oversight and safety assessment of genetically modified foods in the EU. In K.-H. Engel, G. Takeoka and R. Teranishi (eds), *Genetically Modified Foods: Safety Aspects*. Washington, DC: ACS.

Engel, K.-H., Takeoka, G. and Teranishi, R. (eds) (1995b). *Genetically Modified Foods: Safety Aspects*. Washington, DC: ACS.

Gordon, J., Chapman, R. and Blamey, R. (2001). Assessing the options for the Canberra water supply: an application of choice modelling. In J. Bennett and R. Blamey (eds), *The Choice Modelling Approach to Environmental Valuation*. Cheltenham: Edward Elgar, 73–92.

Green, P. E. (1974). On the design of choice experiments involving multifactor alternatives. *Journal of Consumer Research* 1: 61–68.

Greene, W. H. (1997). *Econometric Analysis*. Englewood Cliffs, NJ: Prentice Hall.

Hansen, L. and Schmidt, M. (1999). Revisiting Conjoint: how Danish pig producers found the future road to environmentally concerned Danish consumers (mimeo).

Hausman, J. and McFadden, D. (1984). Specification tests for the multinomial logit model. *Econometrica* 52(5): 1219–1239.

Henson, S. J. (1996). Consumer willingness to pay for safer food. *Journal of Agricultural Economics* 47(3): 403–420.

Henson, S. J. (2001). Food safety and the European consumer. Paper presented at the 71st EAAE Seminar: The Food Consumer in the 21st Century, 18–20 April 2001, Zaragoza, Spain.

Henson, S. J. and Azam, M. (2001). Trade-off between food safety and other product attributes in food choices: the case of pesticide use in tomato production. Reading: Department of Agricultural and Food Economics, University of Reading.

Hoban, T. (1998). Trends in consumer attitudes about agricultural biotechnology. *AgBio-Forum* 1(1): 3–7. http://www.agbioforum.org (accessed 1 June 2000).

Institute of Food Science and Technology (IFST) (1998). Genetic modification and food. Position statement. IFST. London, UK.

Kelley, J. (1995). Public perceptions of genetic engineering: Australia 1994. Final report to the Department of Industry, Science and Technology. Canberra: International Social Science Survey, Australia.

Louviere, J. J. (2001). Choice experiments: an overview of concepts and issues. In J. Bennett and R. Blamey (eds), *The Choice Modelling Approach to Environmental Valuation*. Cheltenham: Edward Elgar, 13–36.

McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. In P. Zarembka (ed.), *Frontiers in Econometrics*. New York: Academic Press, 105–142.

Mendenhall, C. (2000). Estimates of WTP premium for non-GMO foods—a survey. Paper presented to the 4th International Conference on the Economics of Agricultural Biotechnology, Ravello, Italy, 24–28 August, International Consortium on Agricultural Biotechnology Research.

Morrison, M. D., Blamey, R. K., Bennett, J. W. and Louviere, J. J. (1996). A comparison of stated preference techniques for estimating environmental values. Choice Modelling Research Reports. Canberra, A.C.T.: The University of New South Wales.

Norton, J., Lawrence, G. and Wood, G. (1998). The Australian public's perception of genetically-engineered foods. *Australasian Biotechnology* 8(3): 172–181.

Rolfe, J., Bennett, J. and Louviere, J. J. (1999). What information do the error terms hide in choice modelling environmental valuation studies? Contributed paper, 43rd AARES Conference, Christchurch, New Zealand.

Senauer, B. (2001). The food consumer in the 21st century: new research perspectives. Paper presented at the 71st EAAE Seminar: The Food Consumer in the 21st Century, 18–20 April 2001, Zaragoza, Spain.

Smith, D. and Riethmuller, P. (1999). Consumer concerns about food safety in Australia and Japan. *International Journal of Social Economics* 26(6): 724–741.

Swait, J. and Louviere, J. (1993). The role of the scale parameter in the estimation and comparison of multinomial logit models. *Journal of Marketing Research* 30(3): 305–314.

Wirthlin Group (2000). U.S. consumer attitudes toward food biotechnology. Report on Wirthlin Group Quorum Surveys. http://ificinfo.health.org/foodbiotech/survey.htm (accessed 1 June 2000).

Wolf, M. M. and Domegan, C. (2000). A comparison of consumer attitudes toward genetically modified food in Europe and the United States: a case study over time. Paper presented to the 4th International Conference on the Economics of Agricultural Biotechnology, Ravello, Italy, 24–28 August, International Consortium on Agricultural Biotechnology Research.

Yann Campbell Hoare Wheeler (1999). Public attitudes towards biotechnology. Report commissioned by Biotechnology Australia, July, mimeo.

Appendix: Experimental design

If one has four attributes (A, B, C, D), each with three levels, one can generate a main effects design using a græco-latin square, which involves only nine options (O_1–O_9):

	B1	B2	B3
A1	C1,D1	C2,D3	C3,D2
A2	C3,D3	C1,D2	C2,D1
A3	C2,D2	C3,D1	C1,D3

Thus, each attribute level appears in an option with every level of the other attributes. Taking one option (O_1) as the status quo, which has to be included in every choice set, and assuming a total of three options per choice set, there are 28 possible choice sets (S_1–S_{28}) that can be constructed:

(S_1) O_1, O_2, O_3
(S_2) O_1, O_2, O_4
. . .
(S_8) O_1, O_3, O_4
(S_9) O1, O_3, O_5
. . .
(S_{28}) O_1, O_8, O_9

The change in the level of food bill is as yet unassigned. The status quo value (for O_1) is set at 'no change', leaving 56 values of food bill to be assigned (i.e. for each of the 28 choice sets above, two values of food bill change are yet to be assigned). These remaining 56 values are assigned at random, drawn with repetition from the 10 possible values of changes in food bill shown in Table 3.

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