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# Effect of information about benefits of biotechnology on consumer acceptance of genetically modified food: evidence from experimental auctions in the United States, England, and France

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## Summary

This study investigates the effect of information about potential benefits of biotechnology on consumer acceptance of genetically modified (GM) foods. Consumer willingness to accept compensation to consume a GM food was elicited using an incentive compatible auction mechanism in three US states (California, Florida, and Texas) and in two European countries (England and France). Results indicate that information on environmental benefits, health benefits and benefits to the third world significantly decreased the amount of money consumers demanded to consume GM food; however, the effect of information varied by type of information and location. Consistent with prior research, we find that initial attitudes toward biotechnology have a significant effect on how individuals responded to new information.

**Keywords:** genetically modified food, biotechnology, product information, incentive-compatible auction, consumer attitudes

**JEL classification:** L15, D12, D44

## 1. Introduction

The debate over genetically modified (GM) foods is a contentious one. On one side of the debate are environmental and consumer activist groups, who tout the risks associated with GM food consumption and production. These views are countered by some agribusinesses such as chemical producers and seed manufacturers who contend that benefits of GM food production outweigh risks. Despite the intensity of the debate in the agricultural sector, most consumers are generally unfamiliar with issues associated with GM foods. For example, a large-scale poll of European consumers in 2000 found that over half the respondents had never talked about biotechnology with anyone and that over 70 per cent wanted to know more about the advantages and disadvantages of biotechnology (Eurobarometer, 2000). Similarly, a large-scale poll of US consumers in 2001 found that over half the sample had heard 'nothing' or 'not much' about GM foods or biotechnology (Pew Initiative on Food and Biotechnology, 2001). The Pew Initiative on Food and Biotechnology concluded that US public opinion about genetically modified foods is 'up for grabs' and Gaskell *et al*. (2003) indicated that (p. 1) 'for some Europeans the jury is still out on biotechnology'.

Government food regulatory agencies are interested in the effects of educational efforts aimed at disseminating information to the public primarily because educational efforts have the potential of improving social welfare by reducing information asymmetries. Although it is often argued that consumer education will improve acceptance of biotechnology, whether and to what extent information dissemination might affect consumers' attitudes toward GM food is largely unknown.

In addition to the issue of education, which involves the presentation of balanced information on benefits and risks of biotechnology, various groups on both sides of the debate are interested in the effects of one-sided information dissemination (e.g. advertisement) on public acceptance of the technology. In fact, several biotechnology companies jointly formed the Council for Biotechnology Information (CBI) with the primary aim of disseminating information on the benefits of biotechnology. This organisation, and its counterparts, have publicised the benefits of biotechnology through a variety of media outlets including television, magazines and newspapers. Understanding the effects of such information dissemination is important on several fronts. First, agribusinesses are interested in the returns to advertising and how such advertisements might be made more effective. Second, analysing the effects of such advertisements can help policy makers and anti-biotechnology activist groups to understand consumer acceptance of biotechnology and how consumers react to new information.

This paper seeks to determine whether and how different types of information on the benefits of biotechnology affect consumer acceptance of GM foods. Our primary objectives are (i) to determine whether introducing information on the benefits of biotechnology influences the economic value consumers place on a GM food, (ii) to investigate the relative effect of information about the benefits of biotechnology to the environment, personal health and the developing world on consumer acceptance of a GM food, and (iii) to identify whether consumers in selected US and European locations react differently to information on benefits of biotechnology. Existing evidence suggests that European consumers are less accepting of GM foods than consumers in the USA (e.g. Gaskell *et al.*, 1999; Lusk *et al.*, 2003). Differences in culture and trust in food regulatory agencies appear to be at least partially responsible for this divergence. It is unknown, however, whether consumers on both sides of the Atlantic react similarly to information statements about GM food. Knowledge of the relative responsiveness of consumers to information on benefits of GM food production across the Atlantic could provide insight into the degree to which divergent views on biotechnology can be reconciled by advertising or educational efforts.

In this paper, we focus solely on the effect of information on benefits of GM food production. Clearly, anti-biotechnology organisations are more interested in the effect of information on potential risks of biotechnology, such as possible degradation of biodiversity, the potential for consumers developing allergic reactions to altered foods, and possible development of herbicide-resistant weeds or pesticide-resistant insects. Given our restricted research budget, we chose to focus on investigating effects of information on benefits of biotechnology primarily because of the large investments made by agribusinesses in advertising such benefits; however, we believe it is equally important to investigate the effect of information on the risks of biotechnology on consumer acceptance of GM food. This is an issue we leave to future research.

To investigate the effects of information on benefits of biotechnology on consumer acceptance of GM food, experimental auctions were conducted in three US and two European locations, where we elicited the minimum compensation demanded (willingness-to-accept) to consume a GM versus a non-GM food in a non-hypothetical incentive compatible auction involving real food and real money. Data were collected using a within-subject design where willingness-to-accept was elicited before and after an information shock was introduced.[1]

## 2. Background

A number of studies have examined consumer acceptance of GM foods in the USA and Europe in an economic framework (e.g. Baker and Burnham, 2001; Burton *et al*., 2001; Lusk *et al*., 2001, 2002, 2003; Noussair *et al*., 2002; Lusk, 2003a; see Lusk *et al*. (2004) for a review). Results generally suggest that when no direct benefit is provided to consumers, fear or concern over biotechnology dominates purchasing behaviour, as most consumers are willing to pay premiums for 'GM-free' products over foods with GM ingredients. However, Lusk *et al*. (2002) and Lusk (2003a) have found that when specific benefits are provided by biotechnology, some US consumers might actually be willing to pay premiums for GM foods.

Although several studies have analysed consumer acceptance of GM foods, much less is known about the effect of information on valuations of GM food. To our knowledge, Rousu *et al*. (2002) is the only study to extensively explore the effect of information on consumer willingness-to-pay (WTP) for non-GM foods. Using experimental auctions in the USA, they found that consumers who received positive information about GM food actually placed a greater value on GM labelled food than on non-GM labelled food for two of the three goods analysed. However, individuals who received negative information about GM foods discounted the GM labelled foods by about 35 per cent relative to the non-GM food. Consumers who received both positive and negative information about GM foods discounted the GM labelled foods anywhere from 17 to 29 per cent. Rousu *et al*. (2002) also found that verifiable third party information had an influence on consumer acceptance of GM foods. For example, when consumers received positive information, negative information and third party information, GM labelled foods were discounted by only 0–11 per cent depending on the product analysed. Of direct relevance to this study, Rousu *et al*. (2002: 31) concluded that their results 'explain why biotechnology companies have invested heavily to advertise the positive aspects of biotechnology', and that 'Although these [agribusiness] companies are interested parties and provide biased information, their information has increased the demand for GM-foods—even in the presence of negative information.'

The Rousu *et al*. study defined positive information to include general information, scientific information, and information on human, financial and environmental impacts. So although its results are useful for identifying

1 Some proponents of biotechnology argue that consumers should be engaged in a dialogue on biotechnology rather than simply given information as was the case in this study. Because of the inherent unpredictability of dialogue sessions, this paper focuses on the effect of controlled, informational statements on consumers' valuations of GM food without making any judgements about the relative merits of dialogue in altering perceptions of GM food.

the relative impacts of positive versus negative information, it gives little insight into which specific type of information has the largest influence on consumer acceptance. For example, one cannot discern whether information about environmental rather than human impacts drove behaviour. This study investigates whether information on benefits of biotechnology to the environment, health or the world has a larger effect on acceptance. This study also goes beyond Rousu *et al.* by analysing the determinants of informational effectiveness and by comparing the effects of information across several diverse locations.

Although few economic studies have investigated the effect of information on GM food acceptance, several social psychology studies have done so. Frewer *et al.* (1998) found that the credibility of the information source significantly influenced individuals' reactions to information about food biotechnology; however, source credibility was strongly influenced by individuals' prior attitudes toward biotechnology. As discussed in Frewer (2003), individuals who hold extreme views toward biotechnology might choose to distrust an information source rather than change their attitudes when presented with information that runs counter to their initial attitude. Scholderer and Frewer (2003) investigated whether information on benefits of biotechnology affected attitudes toward biotechnology among a sample of European consumers. They found that none of a variety of different information strategies were effective in changing individuals' attitudes toward food biotechnology. They also found that, although attitudes were unchanged, information did affect consumer choice, but in a negative direction: individuals were less likely to choose GM foods when presented with information on benefits of food biotechnology. The authors attribute the latter effect to the fact that individuals' attitudes were predominantly negative prior to information dissemination.

## 3. Conceptual model

Following Hayes *et al.* (1995) and Rousu *et al.* (2002), we investigate the value of an exchange of a non-GM food for a GM food by analysing a consumer's state-dependent, von Neumann–Morgenstern utility function. Consumer $i$ receives utility $U_G$ if a good state occurs or utility $U_B$ if a bad state occurs from consuming a food, where $U_G > U_B$. Both utility states are a function of monetary wealth, $U_j(W)$ ($j = G, B$), where the standard assumptions apply: $U_j' > 0$ and $U_j'' < 0$. In our experiment, consumers are endowed with a non-GM food. For simplicity, we assume that the consumer perceives the non-GM food to yield $U_G(W)$ with certainty. That is, they believe that consuming the non-GM food will yield a good outcome with 100 per cent probability. However, consuming the GM food has an uncertain outcome as shown below:

$$E\mathrm{U} = p(I)U_G(W) + (1 - p(I))U_B(W) \tag{1}$$

where $p(I)$ is the consumer's perceived (prior) probability that consuming the GM food will result in a good state and $I$ represents the type and level of information the consumer possesses about GM foods, where $I \in [-\infty, \infty]$. Positive $I$ indicates the individual has, on balance, favourable information about GM foods, whereas negative $I$ indicates the individual has overall unfavourable information about GM foods. The perceived probability of a good outcome from GM food consumption is a function of the level of information a subject has when he begins the experiment. Given this definition, we assume $p' > 0$, e.g. consumers with more positive information perceive a greater probability that a good outcome will occur from consuming GM food than consumers with more negative information.

The minimum compensation an individual would be willing to accept ($WTA$) to consume the GM food rather than the non-GM food is defined as

$$U_G(W) = p(I)U_G(W + WTA) + (1 - p(I))U_B(W + WTA). \tag{2}$$

Thus, $WTA$ is the amount of money that a consumer must be given to make him indifferent between consuming the non-GM food with wealth $W$ and a certain outcome or going through with the gamble of consuming the GM food with wealth $W + WTA$.

The primary objective of this paper is to determine how consumers' valuations change when positive information is provided. In the first stage of our experiment, subjects use only whatever information they bring into the experiment to determine the probability of a good outcome occurring from GM food consumption. After a few bidding rounds, we then provide subjects with additional, positive information about GM foods. After a subject receives new positive information from the experimental monitor, individuals weigh the new information against their belief in prior information to arrive at a new information level $\hat{I}$. Following Viscusi (1989) and Liu *et al.* (1998), we assume the new positive information is incorporated following a Bayesian updating rule with a gamma distribution as follows:

$$\hat{I} = \frac{\alpha I + \beta \tilde{I}}{\alpha + \beta} \tag{3}$$

where $\tilde{I}$ is the new, posterior information on GM foods, $\beta$ is the weight an individual assigns to the new positive information, and $\alpha$ is the weight an individual assigns to their prior information, $I$.[2]

The required compensation an individual must be provided to give up his non-GM food and consume the GM food is now given by

2 Whether the consumer actually perceives the new information as positive or negative is obviously subjective and will depend on respondent interpretation.

$$U_G(W) = p\left(\frac{\alpha I + \beta \tilde{I}}{\alpha + \beta}\right) U_G(W + WTA) + \left(1 - p\left(\frac{\alpha I + \beta \tilde{I}}{\alpha + \beta}\right)\right) U_B(W + WTA). \quad (4)$$

To determine the effect of new positive information on a consumer's valuation, we totally differentiate equation (4) with respect to $WTA$ and $\tilde{I}$. The result is given by equation (5):

$$\frac{\mathrm{d}WTA}{\mathrm{d}\tilde{I}} = \left(\frac{\beta}{\alpha + \beta}\right)\left(\frac{p'(U_B - U_G)}{U'_G p + U'_B(1 - p)}\right) \leq 0. \quad (5)$$

A consumer's $WTA$ declines as more favourable information is provided. That is, once a subject receives information he perceives to be favourable about GM foods, he now demands less compensation to consume the GM food. The converse is also true: if a subject perceives the new information to be negative, $WTA$ will increase. The extent to which the new information affects $WTA$, however, depends on the weight the consumer places on the new positive information versus his prior beliefs. If a subject totally distrusts the new positive information $\beta = 0$ and $\mathrm{d}WTA/\mathrm{d}\tilde{I} = 0$. In this case, the new positive information has no impact on the subject's valuation. The more weight an individual places on the new positive information, the greater the impact on the change in $WTA$.

In the analysis that follows, we seek to determine the effect of subjects' prior knowledge and attitudes about GM foods on $\mathrm{d}WTA/\mathrm{d}\tilde{I}$. Individuals who perceive themselves to be more knowledgeable about GM foods are likely to place more weight on their prior information than subjects who believe they have little knowledge of GM foods. If so, it is clear from equation (5) that more knowledgeable individuals will be less influenced by new information than consumers with little knowledge of GM foods.

In addition, individuals holding initial negative attitudes toward GM foods are likely to place less weight on new positive information about benefits of GM foods (Frewer *et al*., 1998). So, by measuring a consumer's knowledge level and initial attitudes toward GM foods prior to the information shock, we can obtain proxies for $\alpha$ and $\beta$. Social psychology literature suggests that individuals tend to reject external information on subjects that they feel knowledgeable and strongly about (Vertzberger, 1990; Frewer, 2003).

## 4. Methods

We conducted experimental auctions in three US locations and two European locations. Experimental auctions have the advantage of putting subjects in a setting that uses real goods and real money where subjects are held accountable for their choices. As a result, experiments reduce problems associated with hypothetical bias (e.g. Fox *et al.*, 1998).[3] Furthermore, an experiment can place subjects in a context where consumption is required. This requirement forces individuals to put cognitive effort into their bidding decisions (Fox, 1995), isolates the effect of interest, and can help mitigate problems with 'outside of the lab' or field opportunities. As a result, a consumption requirement permits greater control over the experiment than when individuals have free disposal and must speculate at prices and availability of field substitutes.[4]

## 4.1. Valuation measure

Experimental auctions to value novel goods or improvements in food safety usually elicit consumer willingness-to-pay (WTP) (e.g. Fox, 1995; Fox *et al.*, 1998; Roosen *et al.*, 1998; Lusk *et al.*, 2001). Instead, we estimate consumer willingness-to-accept (WTA) compensation to give up a non-GM food and consume a food containing GM ingredients.[5] We measure WTA instead of WTP for a number of reasons. First, the WTA value measure more closely resembles what is occurring in the marketplace. Historically, consumers have been 'endowed' with non-GM foods. With the advent of biotechnology, consumers are now asked what it will take to 'accept' GM foods, i.e. how much compensation a consumer must be given (through lower food prices) before he is willing to purchase GM food. The WTP value measure might be more applicable if one were interested in determining the premium to be charged for a non-GM food in a particular niche market.[6] Second, we wished to impose a 'consumption requirement' in our experiment. With a WTP experiment, we would have had to endow subjects with a GM food and elicit values for an upgrade to a non-GM food, with the requirement that all losing bidders eat the GM food. We were

3 Although the non-hypothetical nature of the experiment probably increased the validity of the elicitation approach, some literature suggests that individuals behave in a more rational manner when dealing with high-valued versus low-valued goods (e.g. List and Lucking-Reiley). Unfortunately, the value of virtually all foods is quite low relative to income. Although individuals might have behaved less rationally in our experiment than if a higher-valued good were used, given the constraint of having to use a food product, we believe our approach is superior to any other available approach such as hypothetical contingent valuation, for which there is *no* incentive to respond truthfully.

4 Although the consumption requirement permits greater experimental control, the WTA values elicited in this one-time purchase scenario are likely to be greater than if individuals were allowed multiple purchases, substitution opportunities or private risk reduction (see discussion in Hayes *et al*. (1995)).

5 McClusky *et al*. (2003) also elicited WTA in a GM food setting; however, they used a contingent valuation technique with Japanese consumers. Hayes *et al*. (1995) also elicited WTA in an experiment valuing improvements in food safety.

6 Neoclassical economic theory suggests WTP = WTA, but most empirical evidence suggests the value measures diverge with WTA > WTP. Hanemann (1991), Tversky and Kahneman (1991), Kolstad and Guzman (1999) and Zhao and Kling (2001) offer theoretical explanations for the divergence. Although WTA > WTP, this paper is interested in the *change* in WTA after an information shock, and, as such, it does not necessarily follow that *changes* in WTA would be any different from changes in WTP after an information shock.

concerned that individuals, especially in the EU, might object to consuming a GM food and withdraw from the experiment. Reversing the endowment avoids this problem, but now the WTA measure is needed to elicit values rather than WTP. Third, when eliciting WTP, there is often a large frequency of zero bids (e.g. Lusk, 2001; Fox, 1995). When a subject bids zero in a WTP setting, one must question whether the bid actually reflects a subject's value for the good or whether a subject is simply uninterested in the experiment. Subjects with valuations far away from the market price may decide to bid zero in a WTP auction once they find out they have no chance of winning (Shogren *et al.*, 2001b). In a WTA setting, zero bidding is less problematic from a behavioural standpoint as a subject would not bid zero unless they truly placed no value on the traded good. That said, zero bidding can and does occur in WTA auctions, which can create difficulties in econometric estimation; however, these difficulties are no greater than those arising from zero bidding in WTP auctions.

## 4.2. Auction mechanism

In our experiments, each subject was given a chocolate chip cookie containing no GM ingredients. Subjects then participated in a fifth-price auction to obtain an otherwise identical chocolate chip cookie that was made with GM ingredients. The four lowest bidders won the auction and were paid the fifth lowest bid amount to consume the GM cookie. All other participants consumed their non-GM cookie.

The fifth-price auction was used for a number of reasons. Most important, we sought to use an auction mechanism that was incentive compatible and the fifth-price auction satisfied this requirement. Thus, from a theoretical standpoint we expect this auction to generate equivalent results to second-price, random *n*th-price and English auctions. Because theory provides little guidance in selecting between incentive compatible auctions, we turn to pragmatic and behavioural considerations (see Lusk, 2003b). We wanted to use an auction where the market price was endogenously determined and where subjects could incorporate feedback from the market.[7] The fifth-price auction represents an attempt to combine the behavioural advantages of the second-price and random *n*th-price auctions. Although the second-price auction is theoretically incentive compatible and perhaps the most popular elicitation mechanism in the

7 When subjects are allowed market feedback through posted prices, there is the potential for bidder's values to become affiliated (Milgrom and Webber, 1982). Bidder affiliation can degrade the incentive compatibility of the fifth-price auction. However, List and Shogren (1999) found that bidder affiliation had only a very small impact on bids in an auction similar to that employed here. Although the practice of posting prices in repeated-trial auctions may lead to bidder affiliation, it has the advantage of allowing subjects to participate in an active market with information feedback. Several studies emphasise the importance of an active market environment in generating rational behaviour consistent with economic theory (e.g. Shogren *et al.*, 2001a; Cherry *et al.*, 2003).

literature, several studies have shown that subjects ‘over bid’ in second-price auctions (e.g. Kagel *et al*., 1987; Rutström, 1998). Shogren *et al*. (2001b) found that the random *n*th-price auction worked well for off-margin bidders (those with values relatively far away from the market price), but did not work as well as the second-price auction for on-margin bidders. Shogren *et al*. (2001b: 420) concluded, ‘This combination suggests that there might be an effective mix between the number of subjects ($k$) and the number of units of an auctioned good ($n$) that would engage both on-margin and off-margin bidders.’ Our fifth-price auction represents an attempt to reach this effective mix that engages bidders with values on both tails of the value distribution.

The choice of chocolate chip cookies, referred to as biscuits in the EU, as the unit of analysis was also advantageous for a number of reasons. The good is consumed in both the US and Europe. Moreover, forcing consumption of this product was feasible in a lab setting, which is not possible with many other goods (e.g. vegetable oil or raw potatoes). The ready availability of both GM and non-GM cookies in the US marketplace also increased the appeal of using cookies.

### 4.3. Participant recruitment

Marketing research firms were contacted in Long Beach (CA, USA), Jacksonville (FL, USA), Lubbock (TX, USA), Reading (England) and Grenoble (France). The US locations were selected to provide geographic diversity within the USA, which should increase the generalisability of the findings. Lubbock has a population of about 250,000 and is located in a predominantly agricultural area in the Panhandle of Texas. In contrast, Long Beach is definitively urban as it is located in Los Angeles County, which has a population of over 9.6 million. In terms of size, Jacksonville lies between Lubbock and Long Beach with a population of about 790,000. Lubbock, Reading and Grenoble are roughly similar in terms of population and all have sizeable universities. Reading is about 60 km west of London and has a population of about 250,000. Grenoble is located in SE France and has a population of about 400,000.

The marketing firms randomly recruited subjects from the general population of each city, with the only stipulations being that the recruited participants were females between the ages of 25 and 65 and had household incomes above $25,000. In 2001, women were the primary grocery shoppers in almost 70 per cent of US households (Progressive Grocer, 2002). We limited the age range to prevent participation of a disproportionate number of students or retirees (groups with a relatively low opportunity cost of time). The gender, age and income restrictions were also intended to create more homogeneous samples across the geographic locations, allowing for a stronger test of the ‘location effect’.

Subjects were originally contacted by phone and offered $50 to participate in a 'food preference study'. Those agreeing to participate signed up for a particular time and date that was convenient for them. In each city, several experimental sessions were conducted. About 25 participants were recruited for each session, with the expectation that 20 would actually attend. In fact, the numbers attending were nearer 15 per session.

## 4.4. Auction procedures

Subjects arriving at an experimental session were given a packet and were assigned an ID number. They first had to complete a questionnaire about their knowledge, opinions and attitudes toward GM foods. The survey also contained questions about the individual's values and lifestyles, and basic socio-demographic information. As some consumers might be completely unaware of biotechnology or genetic modification, subjects received an objective information statement prior to administering the survey. The statement was adapted from introductory objective information provided by a number of studies as described in Shanahan *et al*. (2001). The statement read as follows:

> The purpose of this study is to better understand consumers' thoughts about genetic modification in food production. Genetic modification involves new methods that make it possible for scientists to create new plants and animals by taking parts of genes of one plant or animal and inserting them into the cells of another plant or animal. This is sometimes referred to as biotechnology or genetic engineering.
>
> In food production, genetic modification can be used to make fruits and vegetables taste better, last longer, or be resistant to certain pesticides. Genetic modification can also be used to alter plants in a manner that results in increased crop yields. Animals can also be genetically modified to make them grow faster and be resistant to certain diseases.

Other than this statement, no other information about GM foods was provided.

Procedures for the experimental auction were then explained. Prior to participating in the GM food auction, subjects first participated in a non-hypothetical auction with chocolate candy to familiarise them with the procedures. In addition, subjects were given several examples of how the auction worked and we explained why the best strategy was to bid truthfully.[8] The experimental auction proceeded as follows:

Step 1. Participants were given a free chocolate chip cookie. The cookie was in a transparent package containing a label that clearly indicated the cookie contained no GM ingredients.

8 Complete instructions are available from the authors upon request.

Step 2. Participants were shown an otherwise identical cookie labelled as containing GM ingredients.

Step 3. Subjects wrote on distributed bid sheets the minimum amount of money they were willing to accept to exchange their cookie for the cookie containing GM ingredients.

Step 4. Once all bids were recorded, the monitor collected the bid sheets and ranked the bids from lowest to highest in the front of the room.

Step 5. The ID numbers of the four lowest bidders were posted in front of the room along with the fifth lowest bid amount (the market price).

Step 6. Steps 3–5 were repeated for nine additional rounds with information being introduced after the fifth round.

Step 7. At the completion of the 10th round, a random number was drawn (1–10) to determine the binding round. The four winning bidders were then paid the fifth lowest bid amount to exchange their cookie for the cookie made with GM ingredients. All other participants kept their cookie made without GM ingredients.

In the auction instructions, subjects were told that all rounds had an equal chance of being binding and that consumption of the cookie was expected at the end of the auction. Participants were also informed that it was acceptable to bid $0.00 in any round, which would mean they were willing to accept the cookie made with GM ingredients for no compensation.

## 4.5. Information treatments

After the fifth round of bidding, subjects were given an 'information shock', that is, each subject received a sheet with a written statement, which was also read aloud by the monitor. Each experimental session was randomly assigned a particular information treatment, i.e. all subjects within a particular session received the same information shock. The information treatments used in this study are shown in Table 1. Each treatment provided one of three types of information on the benefits of GM food production: an environmental benefit, a health benefit or a world benefit. We provided information shocks to address each of these benefits.

The first two treatments listed in Table 1 are associated with benefits derived from farmers' ability to reduce pesticide usage when using GM crops. According to the US Department of Agriculture, adopters of GM crops used about 4.4 per cent less pesticides than non-adopters in 1998 (Heimlich *et al.*, 2000). Lower pesticide use can have both environmental and health benefits as noted in information treatments 1 and 2. The third information shock focused on world benefits; subjects were informed that use of genetic modification in food production could be used to increase world food supply, which could benefit consumers in third world countries. The information treatments we chose are factually accurate, and represent

**Table 1.** Information treatments

*Treatment 1—environmental benefit*

Recently, biotechnology has been used to develop new types of crops. The cookie that you are bidding on was made from vegetable oil that was derived from crops that were genetically modified to contain a special protein. This protein allows the plant to be resistant to certain insects, potentially allowing farmers to reduce pesticide usage.

Environmental groups claim that pesticide use damages the environment and threatens the survival of many birds, fish, and insects. These groups contend that pesticides reduce species diversity in the animal kingdom and contribute to population declines in animals and plants by destroying habitat, reducing food supplies, and impairing reproduction.

So, the cookie you have been given was made with **NO** genetically modified ingredients. The cookie you are bidding on was made **with** genetically modified seeds that potentially allowed farmers to reduce pesticide usage.

*Treatment 2—health benefit*

Recently, biotechnology has been used to develop new types of crops. The cookie that you are bidding on was made from vegetable oil that was derived from crops that were genetically modified to contain a special protein. This protein allows the plant to be resistant to certain insects, potentially allowing farmers to reduce pesticide usage.

Pesticides may be harmful to human health. Residues from several chemical pesticides have been linked to cancer and other human health problems such as Parkinson's disease.

So, the cookie you have been given was made with **NO** genetically modified ingredients. The cookie you are bidding on was made **with** genetically modified seeds that potentially allowed farmers to reduce pesticide usage.

*Treatment 3—world benefit*

Recently, biotechnology has been used to develop new types of crops. The cookie that you are bidding on was made from vegetable oil that was derived from crops that were genetically modified to contain a special protein. Suppose this protein allows the plant to grow at faster rates and be resistant to drought.

As a result: (a) farmers can produce a greater quantity of crops which should result in a decline in food prices and (b) consumers in third world countries would benefit because of the increased abundance of the food supply. Corn, soybean, rice, and wheat can all be modified in a similar manner to increase world food supply.

So, the cookie you have been given was made with **NO** genetically modified ingredients. The cookie you are bidding on was made **with** genetically modified ingredients that potentially allowed farmers to increase the amount of food they produce.

*Treatment 4—no information*

actual benefits that may occur from current GM crop production. The first two information treatments were used in all five cities. Monetary constraints prohibited using treatment 3 in Long Beach, CA and Jacksonville, FL.

Lastly, we conducted one session in Lubbock and one session in Grenoble where no information was provided after the fifth bidding round. These treatments serve as controls. By conducting a treatment with no information, we can determine the extent to which bids might decline over time simply as a result of the dynamics of the auction where there are no confounding effects of an information shock.

## 5. Results

### 5.1. Samples and data

The experimental auctions analysed in this study were conducted in the late summer and early autumn of 2002. Table 2 reports summary statistics of selected variables separated by information treatment.

Differences in our recruited samples reflect differences in average income and education levels across locations. For example, a greater percentage of participants in California made more than $50,000/year than in Texas or Florida. These data are consistent with US Census Bureau data, which indicate that median US household income was $40,860 in 2001 with median California household income about $7,000/year greater than that in Texas and $10,000/year greater than that in Florida (US Census Bureau, 2003). Our data also conform well to differences in income across countries. World Bank (2003) data indicate that per capita gross national income was $35,060, $25,250, and $22,010 in the USA, United Kingdom, and France, respectively, in 2002. Comparable data on educational attainment across countries are difficult to locate. However, INSEE (2003) reports that 51 per cent of French individuals born between 1968 and 1972 have college degrees, whereas in the US only 25 per cent of individuals 25 and older have a college degree (US Census Bureau, 2003). In the analysis, we control for any differences in demographics across location before drawing conclusions.

Table 2 also reports summary statistics regarding prior knowledge and acceptance of GM foods, which suggest that our sample of participants considered themselves relatively unknowledgeable, with an average response of about three on a scale of one (not at all knowledgeable) to nine (extremely knowledgeable). Regarding initial attitudes, individuals in Texas and Florida were initially more accepting of genetic modification in food production than consumers in California, England, and especially France.

**Table 2.** Summary statistics and definitions of selected variables

| Variable | Definition | Location | | | | |
|---|---|---|---|---|---|---|
| | | Texas | California | Florida | England | France |
| Age | Age in years | 42.719[a] (10.772)[b] | 41.267 (10.437) | 44.385 (10.931) | 47.119 (10.096) | 41.240 (11.235) |
| Education | 1 if obtained university undergraduate degree or higher; 0 otherwise | 0.517 (0.504) | 0.533 (0.505) | 0.474 (0.506) | 0.176 (0.384) | 0.680 (0.470) |
| Income | 1 if household income was greater than $50,000/year; 0 otherwise | 0.534 (0.503) | 0.727 (0.451) | 0.564 (0.502) | 0.545 (0.502) | 0.080 (0.273) |
| Subjective knowledge | Knowledge of facts and issues concerning genetic modification in food production (1 = not at all knowledgeable; 9 = extremely knowledgeable) | 3.155 (1.689) | 3.022 (1.500) | 2.885 (1.826) | 3.162 (1.389) | 4.533 (1.256) |
| Initial acceptance | Response to statement: In general, I believe the use of genetic modification in food production is (1 = unacceptable; 9 = acceptable acceptable) | 5.598 (2.250) | 4.600 (2.240) | 5.330 (1.802) | 4.453 (1.921) | 3.596 (1.945) |
| Number of observations | | 58 | 45 | 38 | 68 | 75 |

[a]Mean values.
[b]Numbers in parentheses are standard deviations.

## 5.2. Unconditional tests of the effect of positive information

First, we tested the hypothesis that WTA prior to the information shock is equal to WTA after the information shock. Table 3 reports results of this unconditional hypothesis test for each location and treatment.[9]

The average of bids in rounds 4 and 5 represents WTA prior to the information shock and the average of bids in rounds 6 and 7 represents WTA after the information shock.[10] WTA bids were originally elicited in local currency, but for this analysis, bids were converted to US dollars using exchange rates at the time of the experiments. The tests are within-subject tests, and as such, individuals' characteristics and tastes are eliminated (i.e. individuals' like or dislike for chocolate chip cookies, etc.). Both parametric paired *t*-tests and non-parametric Wilcoxon signed-rank tests were used to test the hypothesis that WTA did not change after the information shock was introduced for each location and treatment.

Results indicate that information about environmental benefits of GM crop production had a significant influence on WTA bids in all five locations. Specifically, compensation demanded to consume the GM cookie declined by $0.31 in Texas, $0.20 in California, $0.02 in Florida, and $0.03 in England after the environmental information was provided. Surprisingly, compensation demanded to consume the GM cookie increased by $0.51 in France after information about the benefits of biotechnology to the environment were described. The latter result is consistent with the findings of Scholderer and Frewer (2003) in that the French consumers initially held negative attitudes toward GM foods and reacted in a manner opposite to that implied by the one-sided information statement.

Results also suggest that information on health benefits of GM food production had a significant influence on bids in California, Florida and Reading. The effect of health information in Texas was inconclusive, with the non-parametric test suggesting the change in WTA was significant, but the parametric test indicating insignificance. Because the non-parametric test is a less restrictive test, we conclude that health information also had a significant effect on WTA in Texas. The health information did not have a significant affect on bids in Grenoble.

The impact of information on the potential of GM crops to increase world food supply significantly influenced bids in Texas and Reading

9 Extreme bids were removed from the analysis. Specifically, two observations were deleted from California, two observations from Reading, and five observations from Grenoble. These bids were in excess of $20 and ranged as high as $1,000,000. It is very unlikely that these bids represent true preferences for the cookies, but instead are 'protest' bids. The removal of such bids is commonplace in contingent valuation and experimental studies.

10 We excluded the first few rounds from the analysis to allow the market to stabilise and permit subjects to incorporate information from the market through posted prices. The last few rounds of the auction are excluded to eliminate 'end-period' effects. When the analysis was redone comparing only fifth round bids to sixth round bids, and fifth round bids to tenth round bids, similar results were obtained. The procedure of comparing bids immediately before and after the information shock is consistent with Roosen *et al*. (1998).

**Table 3.** Effect of information on bids by information treatment and location

| Information treatment | $WTA^{pre}$ [a] | $WTA^{post}$ [a] | Difference | Test |
|---|---|---|---|---|
| *Reduced pesticide (environmental benefit)* | | | | |
| Lubbock, TX, USA ($n = 13$) | 0.728 (0.377)[b] | 0.422 (0.227) | –0.306 (0.182) | 0.119[c] {0.004}[d] |
| Long Beach, CA, USA ($n = 22$) | 0.605 (0.226) | 0.407 (0.202) | –0.199 (0.075) | 0.015 {0.001} |
| Jacksonville, FL, USA ($n = 19$) | 0.173 (0.104) | 0.148 (0.104) | –0.024 (0.060) | 0.080 {0.013} |
| Reading, England ($n = 20$) | 1.333 (0.557) | 1.305 (0.560) | –0.027 (0.012) | 0.034 {0.012} |
| Grenoble, France ($n = 14$) | 2.205 (0.368) | 2.710 (0.256) | 0.506 (0.310) | 0.127 {0.034} |
| *Reduced pesticide (health benefit)* | | | | |
| Lubbock, TX, USA ($n = 17$) | 0.160 (0.068) | 0.103 (0.063) | –0.057 (0.048) | 0.251 {0.034} |
| Long Beach, CA, USA ($n = 23$) | 0.830 (0.314) | 0.668 (0.303) | –0.162 (0.078) | 0.050 {0.003} |
| Jacksonville, FL, USA ($n = 19$) | 0.219 (0.079) | 0.155 (0.061) | –0.064 (0.039) | 0.117 {0.013} |
| Reading, England ($n = 22$) | 1.439 (0.381) | 0.909 (0.129) | –0.530 (0.306) | 0.098 {0.058} |
| Grenoble, France ($n = 21$) | 2.503 (0.944) | 2.446 (0.975) | –0.057 (0.513) | 0.912 {0.860} |
| *Increase food supply (world benefit)* | | | | |
| Lubbock, TX, USA ($n = 17$) | 2.063 (1.261) | 1.984 (1.266) | –0.078 (0.151) | 0.247 {0.045} |
| Reading, England ($n = 26$) | 0.848 (0.373) | 0.632 (0.326) | –0.216 (0.159) | 0.186 {0.001} |
| Grenoble, France ($n = 23$) | 3.331 (1.179) | 3.032 (1.161) | –0.299 (0.159) | 0.073 {0.240} |
| *No extra information* | | | | |
| Lubbock, TX, USA ($n = 11$) | 0.137 (0.051) | 0.122 (0.046) | –0.015 (0.013) | 0.263 {0.414} |
| Grenoble, France ($n = 17$) | 3.881 (0.997) | 3.698 (1.078) | –0.183 (0.262) | 0.495 {0.278} |

[a] $WTA^{pre}$, mean bid for trials 4 and 5; $WTA^{post}$, mean bid for trials 6 and 7. Values are in US dollars/cookie.
[b] Numbers in parentheses are standard errors of the mean.
[c] *p*-values for the two-tailed *t*-test of $H_0$: $WTA^{pre} = WTA^{post}$.
[d] Numbers in curly brackets are *p*-values for the two-tailed Wilcoxon signed-rank test of $H_0$: $WTA^{pre} = WTA^{post}$.

according to the non-parametric test. Specifically, WTA declined by about $0.08 in Texas when consumers were told that GM food production could benefit third world consumers. Although French consumers decreased their bids, on average, after receiving this information, the result is not statistically significant according to the non-parametric test. In fact, results indicate that over half the subjects in Grenoble either left their bid unchanged or increased their bid after receiving this information.

WTA bids did not significantly change when no information was provided to subjects after the fifth bidding round. This result is confirmed by parametric and non-parametric tests in both Texas and Grenoble. This finding confirms that the reductions in WTA in the first four treatments are actually due to the information shock and are not simply a result of market dynamics.

In summary, results of the non-parametric tests indicate that all three information treatments significantly changed bids in the US locations and in Reading; French consumers, however, were generally unaffected by the information, and in the one case where French consumers significantly changed their bids, they increased the level of compensation demanded to eat the GM food after receiving information about the benefit of GM food production.

## 5.3. Conditional tests of effect of positive information

As shown in Table 2, there are significant differences in demographic characteristics across location. To control for these differences, we estimated censored multivariate regressions to investigate the effects of all exogenous variables on changes in bids[11] after the information shock. In the regressions, three demographic variables, age, education and income, were included to hold constant any differences in subject-specific effects across information treatment. Based on the discussion in Section 3, subjective knowledge and initial attitudes were also included in the regressions. Another measure of prior acceptance, $WTA^{pre}$, was also included as a regressor, both linearly and in interaction with prior acceptance.

Because individuals were not permitted to bid below zero, the dependent variable ($WTA^{post} - WTA^{pre}$) may be censored. That is, any individual who may have been willing to pay (rather than accept) money to eat the GM cookie was prevented by the auction rules from doing so. In such cases, the calculated value of the dependent variable does not reflect the true difference in valuation between bidding rounds. To handle this problem, we estimate a variant of the tobit model. In a traditional tobit model, any observation taking the value of zero is deemed censored. However, in this case, ($WTA^{post} - WTA^{pre}$) $= 0$ does not imply censoring if both $WTA^{post}$ and $WTA^{pre}$ are greater than zero. We denoted all uncensored observations as $D_1$. We define an observation as censored if an individual's bid was zero either before or after the information shock. If an individual's bid was positive prior to the information shock, but zero after the information shock, then the calculated bid difference may be less negative than the true difference. For these censored observations (denoted $D_2$), the true value difference falls in the range of $(-\infty, WTA^{post} - WTA^{pre}]$. If an individual's bid was zero in the round prior to the information shock, but positive afterwards, then the calculated bid difference may be less positive than the true difference. For these observations (denoted $D_3$), the true bid difference falls in the range of $[WTA^{post} - WTA^{pre}, \infty)$. Lastly, if an individual bid zero before and after the information shock, then their true bid difference falls in the range $(-\infty, \infty)$; we denote these observations $D_4$. Given these four types of observations, the likelihood function is

$$\log L = \sum_{D_1} \log\left(\frac{1}{\sigma}\phi(w_i)\right) + \sum_{D_2} \log(\Phi(w_i)) + \sum_{D_3} \log(1 - \Phi(w_i)) \quad (6)$$

where $w_i = 1/\sigma((WTA^{post} - WTA^{pre}) - \delta Z)$ and $\delta Z$ represents the product of the vector of coefficients and the vector of independent variables, $\phi$ is the standard normal density function, $\Phi$ is the standard normal cumulative distribution function, and $\sigma^2$ is the error variance. It is

11 That is, ($WTA^{post} - WTA^{pre}$), where $WTA^{post}$ and $WTA^{pre}$ have the same definitions as in Table 3.

straightforward to show that observations in group $D_4$ drop out of the likelihood function.[12]

We first estimated the most general form of the model, where the effect of each independent variable (age, education, income, subjective knowledge, initial acceptance, $WTA^{pre}$) was allowed to vary by location and treatment in addition to allowing the error variance to vary by location and treatment. From equation (6), we recall that $\delta Z$ represents the product of the vector of coefficients and the vector of independent variables. In the most general model, $\delta Z = \sum_{t=1}^{T} \sum_{k=1}^{K} \delta_{tk} Z_{tk}$, where $t$ represents the information treatment (where $T = 4$) and $k$ represents the location (where $K = 5$). The most general error variance structure is similarly given by $\sigma = \sum_{t=1}^{T} \sum_{k=1}^{K} \sigma_{tk}$.

This model can be used to address the final two objectives of the study, which are to determine the relative impact of different types of information (i.e. environment, health, world and no information) and to determine whether information had a uniform impact across location. Table 4 reports tests of the joint hypotheses that the estimated coefficients are equivalent across location and/or treatment. First, the hypothesis that $\delta_{tTexas} = \delta_{tCalifornia} = \delta_{tFlorida} = \delta_{tEngland} = \delta_{tFrance}$ was tested for each information treatment $t$ (i.e. a given type of information had the same effect in all locations). The hypothesis was strongly rejected for the environmental information treatment in the five locations. The most pronounced effect was in Texas, where individuals reduced their bid on average \$0.31 after the environmental information. In contrast, in France, individuals 'protested' by actually increasing their bids on average by \$0.51 after the environmental information. Results in Table 4 also indicate that health information and world information had a significantly different effect across location. Thus, the effects of environmental, health and world information were location-specific.

The second section of Table 4 reports on the hypothesis that $\delta_{environment\ k} = \delta_{health\ k} = \delta_{world\ k} = \delta_{noinfo\ k}$ for each location $k$ (i.e. all information types had the same effect in a given location). The hypothesis was strongly rejected in Texas. This result stems from the large effect of environmental information in Texas and the very small bid change in the no information treatment in Texas. Health and environmental information had significantly different impacts on bid changes in California and in Florida. In California, environmental information had a larger impact, but in Florida health information had a larger impact. Results also indicate that health, environmental, and world information treatments had significantly different effects in both England and France. Thus, we find the effect of positive information on bid changes depends on the type of information disseminated. In summary, there appear to be strong location and

12 No individual in our sample bid zero before the information shock and then positive thereafter; as such, there are no individuals in group $D_3$ in our regressions.

**Table 4.** Tests for differences in information effect across information treatment and location

| Hypothesis tested[a] | $\chi^2$ value | *p*-value | Degrees of freedom |
|---|---|---|---|
| *Tests for the equality of effect of a given information treatment across locations* | | | |
| Environmental information had the same effect in all locations | 2327.58 | 0.000 | 31 |
| Health information had the same effect in all locations | 176.97 | 0.000 | 31 |
| World information had the same effect in Texas, England, and France | 60.78 | 0.000 | 16 |
| No information had the same effect in Texas and France | 64.38 | 0.000 | 8 |
| *Tests for the equality of effect of information treatments within a given location* | | | |
| All information treatments had the same effect in Texas | 1837.64 | 0.000 | 24 |
| Environmental and health information had the same effect in California | 16.61 | 0.034 | 8 |
| Environmental and health information had the same effect in Florida | 35.34 | 0.000 | 8 |
| Environmental, health, and world information had the same effect in England | 449.75 | 0.000 | 16 |
| All information treatments had the same effect in France | 64.57 | 0.000 | 22 |

[a]Hypotheses are that the estimated coefficients in Table 5 are the same across location or treatment.

treatment effects with regard to the manner in which consumers respond to new information on the benefits of biotechnology.

We now discuss the signs and statistical significance of the parameters for the model given by equation (6) and reported in Table 5.[13] Consistent with the findings of Frewer *et al.* (1998), we found that prior acceptance significantly influenced bids; however, the effect varied by location and treatment. To interpret the effect of prior acceptance on bid changes, it is important to consider the interaction affect between $WTA^{pre}$ and *Prior Acceptance* ($PA$). The marginal effect of $WTA^{pre}$ on bid change, ($WTA^{post} - WTA^{pre}$), is given by $\phi_{WTA^{pre}} + \phi_{WTA^{pre} \times PA} \times PA$, where $\phi$ are the estimated coefficients for the variables denoted by the subscripts. For each location/treatment, we calculated the marginal effect of $WTA^{pre}$ on bid

13 Because the dependent variable in this regression is the difference in WTA, statistical insignificance of a model parameter could be either because the variable affects WTA neither before nor after the information shock, or because the effect of the variable on WTA remains unchanged after the information shock.

**Table 5.** Effect of demographics and prior attitudes on bid changes by information treatment and location: censored regression estimates

| Variable | Texas | | | | California | | Florida | |
|---|---|---|---|---|---|---|---|---|
| | Environmental information | Health information | World information | No information | Environmental information | Health information | Environmental information | Health information |
| Intercept | 0.382** (0.000)[a] | ¯0.028 (0.899) | –1.548** (0.003) | 0.024** (0.001) | –0.103 (0.676) | –0.381 (0.468) | 0.010 (0.850) | –0.032 (0.709) |
| Age | –0.003 (0.350) | –0.003 (0.405) | 0.035** (0.003) | –0.001** (0.001) | –0.003 (0.488) | 0.012 (0.129) | –0.001 (0.528) | 0.001 (0.623) |
| Education | 0.145 (0.128) | 0.228** (0.010) | –0.124 (0.721) | –0.057** (0.000) | –0.111 (0.317) | 0.135 (0.475) | 0.003 (0.894) | –0.061 (0.063) |
| Income | 0.013 (0.798) | –0.088 (0.303) | 0.205 (0.590) | 0.076** (0.000) | –0.113 (0.282) | –0.167 (0.362) | 0.008 (0.686) | 0.034 (0.252) |
| Subjective knowledge | 0.048** (0.000) | 0.008 (0.838) | –0.001 (0.990) | 0.005** (0.001) | 0.050 (0.105) | –0.028 (0.593) | –0.001 (0.982) | –0.020* (0.031) |
| Prior acceptance | –0.087** (0.000) | 0.018 (0.457) | –0.046 (0.6886) | 0.003* (0.035) | 0.072** (0.008) | –0.016 (0.802) | 0.008 (0.316) | 0.019 (0.061) |
| $WTA^{pre}$ | –1.474** (0.000) | 0.306 (0.181) | 0.081 (0.185) | 0.410** (0.000) | 0.555** (0.000) | 0.104 (0.272) | 0.135** (0.000) | 0.888** (0.000) |
| Prior acceptance × $WTA^{pre}$ | 0.191** (0.000) | –0.175** (0.001) | –0.025 (0.424) | –0.088** (0.000) | –0.317** (0.000) | –0.090** (0.005) | –0.129** (0.000) | –0.273** (0.000) |
| Scale | 0.042** (0.000) | 0.120** (0.000) | 0.208** (0.000) | 0.004** (0.000) | 0.190** (0.000) | 0.295** (0.000) | 0.035** (0.000) | 0.052** (0.000) |

| Variable | England | | | | France | | |
|---|---|---|---|---|---|---|---|
| | Environmental information | Health information | World information | Environmental information | Health information | World information | No information |
| Intercept | –0.017 (0.800) | 2.245** (0.001) | –0.726 (0.434) | 4.829* (0.026) | –0.638 (0.871) | –1.013 (0.344) | 1.565 (0.205) |
| Age | –0.001 (0.212) | –0.030** (0.007) | 0.027 (0.069) | –0.007 (0.727) | –0.044 (0.456) | –0.009 (0.629) | –0.043 (0.079) |
| Education | –0.092* (0.026) | –0.055 (0.784) | –0.290 (0.337) | 0.075 (0.902) | 0.942 (0.568) | 0.125 (0.775) | –0.085 (0.841) |
| Income | –0.030 (0.198) | –0.043 (0.791) | 0.178 (0.446) | n.a.[b] | n.a.[b] | 0.142 (0.673) | –1.654 * (0.016) |
| Subjective knowledge | 0.032** (0.000) | 0.023 (0.730) | –0.070 (0.510) | –0.261 (0.204) | 0.564 (0.444) | 0.395** (0.002) | 0.159 (0.192) |
| Prior acceptance | –0.008 (0.223) | –0.100 (0.130) | –0.144 (0.123) | –0.429 (0.151) | 0.053 (0.860) | –0.137 (0.323) | –0.155 (0.230) |
| $WTA^{pre}$ | –0.017 (0.204) | –0.684** (0.000) | –1.464** (0.000) | –1.197 (0.090) | –0.068 (0.309) | –0.108 (0.147) | 0.281** (0.003) |
| Prior acceptance × $WTA^{pre}$ | 0.005 (0.175) | –0.037 (0.353) | 0.459** (0.001) | 0.166 (0.375) | –0.085 (0.088) | 0.028 (0.381) | –0.158** (0.001) |
| Scale | 0.038** (0.000) | 0.334** (0.000) | 0.551** (0.000) | 0.693** (0.000) | 2.242** (0.000) | 0.572** (0.000) | 0.563** (0.000) |

Dependent variable is $WTA^{post} – WTA^{pre}$; log-likelihood function = 29.42; number of uncensored observations = 241; number of left-censored observations = 22; number of left- and right-censored observations = 22; $p$-value of likelihood ratio test of significance of entire model = 0.001.

[a]Numbers in parentheses are $p$-values. *Statistically significant at 0.05 level. **Statistically significant at 0.01 level.

[b]There was insufficient variation in income to estimate this coefficient.

change at the location-specific mean of *Prior Acceptance*.[14] In nine cases, the net marginal effect is negative. This result implies that individuals with higher initial auction bids (i.e. higher initial concern for GM food) reduced their bids by more than individuals with lower initial bids after the positive information shock. This somewhat counterintuitive finding is probably because individuals who initially had higher bids had more room to decrease their bids. In only one case (world information in Reading) was this marginal effect positive. A result more consistent with that of Frewer *et al*. (1998) was obtained by analysing the marginal effect of *Prior Acceptance* on ($WTA^{post}$ – $WTA^{pre}$). The marginal effect of *Prior Acceptance* on bid change, taking into account the interaction term, was calculated at location-specific means as explained above. In seven cases, the net marginal effect was negative. This result indicates that individuals with higher initial acceptance of GM food, as expressed through the survey scale question, reduced their bids by a greater amount after the positive information shock than individuals with lower initial acceptance. Stated differently, individuals with a self-declared lower initial acceptance of biotechnology did not respond as favourably to new positive information as individuals who were initially more accepting. In two treatment/locations (environment/Texas and world/Reading), the opposite result was obtained.

As hypothesised, subjective knowledge significantly affected bid changes in five location/treatments. In four of these cases, higher subjective knowledge was associated with smaller bid changes. This finding is probably a result of the fact that individuals with higher levels of subjective knowledge placed more weight on their prior information and did not react as severely to new information as individuals who had low subjective knowledge.

## 6. Conclusions

In this study, we conducted experimental auctions in three US locations and in two European locations. In each location we elicited the minimum amount of compensation consumers demanded to consume a chocolate chip cookie containing GM ingredients in an incentive-compatible fifth-price auction. Bids for the GM cookie were elicited over 10 rounds, with information about a particular benefit of GM food production being introduced after the fifth round.

Information on environmental benefits, health benefits and world benefits significantly decreased the amount of money consumers demanded to consume a GM cookie versus a cookie with no GM ingredients in all locations except France. Overall, these results suggest that the value consumers place on GM foods can be changed. This is consistent with the results of Rousu *et al*. (2002) showing that positive information significantly affected valuations of GM foods relative to negative or third-party

14 In these calculations, we treated statistically non-significant coefficients as zero.

information. By contrast, French consumers' bids were generally unaffected by positive information, and French consumers actually demanded more compensation to consume the GM cookie after receiving information on the benefits of GM food production to the environment, an effect consistent with the findings of Scholderer and Frewer (2003).

After controlling for differences in personal characteristics, we strongly reject the hypothesis that environmental information had the same effect in all locations. Environmental information lowered bids in the three US locations more than in the two European locations. By contrast, health information lowered bids in England more than in the US locations. Results also indicate that within a given location, there are significant differences in the effect of information treatments. For example, in Texas, environmental information decreased the average bid by $0.31, but the world information decreased the average bid by only $0.08.

We also found consumers' reactions to information were affected by their prior acceptance of GM foods. In general, consumers who were initially more accepting of genetic modification in food production, as expressed through survey questions, reduced their bids by more after receiving positive information than individuals with lower initial acceptance levels. This suggests that individuals with initial negative attitudes toward GM food production are likely to place less weight on new information that is inconsistent with their initial viewpoint than individuals with more favourable initial attitudes. We also found that individuals with more subjective knowledge were less influenced by new positive information, again probably because they placed greater weight on their prior information than the information provided in the experiment. Results suggest that advertising efforts by agribusinesses will be most effective when aimed at audiences with relatively positive attitudes toward the technology or at audiences with little knowledge of biotechnology. Despite these generalisations, it is important to note that the effects of demographics and prior attitudes on reaction to information in different information treatments and locations were quite heterogeneous. Our results also suggest that certain types of information may have a larger impact in some regions of the USA or Europe than in others, implying that one uniform message may not be appealing to all audiences.

This research leaves a number of issues unresolved. Future research might explore how consumers react when both positive and negative information is provided, as would be the case in reality where individuals are exposed to a variety of messages. Fox *et al*. (2002) found, in the context of food irradiation, that when both positive and negative information were provided, negative information tended to have a more pronounced effect than positive. Rousu *et al*. (2002) also found a similar effect with GM foods, although the finding was less dramatic, especially when verifiable third party information was also provided. Despite the limitations of the current study, the results have a number of important implications for public and private educators and agribusinesses.

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