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DO CONSUMERS REALLY REFUSE TO BUY GENETICALLY MODIFIED FOOD?*

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We elicit willingness-to-pay information for similar food products that differ only in their content of genetically modified organisms (GMOs). Participants in the experiment are a demographically representative sample of French consumers. 35% of participants are unwilling to purchase products made with GMOs, 23% are indifferent or value the presence of GMOs, and 42% are willing to purchase them if they are sufficiently inexpensive. The results contrast with surveys that indicate overwhelming opposition to GM foods. There is a surplus to be gained from the segregation of the market for food products into a GMO-free segment and a segment allowing GMOs.

The introduction of genetically modified organisms (GMOs) into food products has ignited a passionate debate, particularly in Europe. On the basis of recommendations from the scientific community, regulatory authorities such as the FSA in the UK, the FDA in the US and the DGAL in France, have recognised that the GMO products currently available are safe for the consumer and the environment. Moreover, there is a consensus among scientists that biotechnology has the potential to create products that will enhance nutrition, increase crop yields, and reduce the use of toxic pesticides and herbicides. Nevertheless, polling of European consumers consistently indicates a high degree of hostility[1] to the presence of GMOs in the food supply. The aversion to GMOs is based on both private considerations, such as potential health risk and a preference for natural foods, as well as social dimensions, such as environmental effects and ethical concerns. It appears that the unfavourable view has been aggravated by the spread of the 'mad cow' epidemic, the lack of benefit that the first generation of GMOs provides to the consumer and the initial introduction of GMOs without the public's knowledge. The tension between scientific recommendations and public opinion has complicated the formulation of government policy with respect to GMOs,[2] because

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[1] For example, Noussair *et al.* (2001) report that 79% of French respondents either agreed or mostly agreed with the statement 'GMOs should simply be banned'. 89% were opposed to the presence of GMOs in food products, 89% in livestock feed, 86% in medicine, 46% in food packaging and 46% in fuels. In the UK, surveys show a similar pattern (Moon and Balasubrimanian, 2001).

[2] Any food product sold in the European Union for human consumption that contains an ingredient that consists of more than 1% GMOs must be labelled 'contains GMOs'. There is no GM produce currently sold in Europe and the only GM products for sale appear as ingredients in processed foods. Currently three types of corn are authorised for cultivation in France. One type of corn and one type of soybean are authorised for importation. In the UK, in addition to corn and soybeans, one type of GM tomato is authorised for importation and use in tomato puree. No GM crops are grown commercially in the UK. In the US, as of early 2002, about two-dozen different GM fruits, vegetables, and grains were being cultivated. In the US, there are no specific regulations for biotech products, which are subject to the same regulations as other products. See Caswell (1998, 2000) for a discussion of policy issues relating to the labelling of GM products.

in a democratic system public opinion must be taken into account in addition to the scientific merits of the policy and the market pressures in the economy.

However, there is reason to question whether the anti-GMO sentiment expressed in surveys would be reflected in actual purchase behaviour. It is known that individuals' decisions can differ drastically between when they are hypothetical, as in a contingent valuation study or other survey, and when they involve a real commitment to purchase; see for example Neill *et al.* (1994); Cummings *et al.* (1995); Brookshire and Coursey (1987); List and Shogren (1998); or List and Gallet (2001). Furthermore, most surveys do not inquire about actual purchase decisions at specific prices and, as Ajzen *et al.* (1996) note, subtle contextual cues or small changes in information provided to survey respondents may change results dramatically. More specific criticisms apply to surveys about preferences over public goods, such as the preservation of GMO-free crops. Sagoff (1988), Blamey *et al.* (1995) and Nyborg (2000) argue that survey and hypothetical contingent valuation measurement techniques for public goods do not reveal participants' willingness-to-pay. Surveys place respondents in the role of citizens, who make judgements from society's point of view, rather than consumers, who make actual purchase decisions. Thus the two instruments, surveys and purchase decisions, measure different variables. In addition, even if provision or preservation of a public good is valuable to an individual, it may not be reflected in his willingness-to-pay because of the free rider problem (Stevens *et al.*, 1991; Krutilla, 1967).[3]

The focus of this paper is to consider, using experimental methods, the extent that actual decisions to purchase food products are affected by the presence of GMOs. We study purchasing behaviour of consumers with a laboratory experiment designed to elicit and compare the willingness to pay for products that are traditional in content and labelling, that are explicitly guaranteed to be GMO-free and that contain GMOs. We also consider buyer behaviour with respect to different thresholds of maximum GMO content. The participants in our study are a demographically representative sample of residents of the Grenoble, France area.

We use an experimental approach because of the absence of field data. The current policy of most major European retailers not to carry GM foods, which has resulted from pressure of activists and the media, means that it is very difficult to estimate product demand for foods containing GMOs using field data from European countries. For the few GM products that are available, there is experimental evidence that consumers are unaware of the labelling of GM content; see Noussair *et al.* (2002). Furthermore, in the US, where the vast majority of GM food is sold, demand for GMOs cannot be inferred from market data since GM content is not indicated on the labelling. We are unaware of any previous estimates of consumer demand for the GMO-free characteristic in food products. However, previous work suggests that experiments provide a good alternative method to

[3] A well-documented example of a dichotomy between surveys and consumer behaviour was observed during the introduction of recombinant bovine somatropin (rbST), a bovine growth hormone, into milk production in the US in 1993. Surveys indicated that a majority of consumers had a negative opinion of the technique, primarily on ethical grounds. On the basis of the survey data, analysts predicted a 20% decline in total milk consumption. However, there was no decrease in actual milk consumption after the introduction of the technique; see Aldrich and Blisard (1998).

study product demand in general, and that the artificial setting of the lab does not drastically alter consumer behaviour.[4]

1. Policy Issues: Segregation and Thresholds

In response to the tension between scientific and public opinion on the issue of GM foods, the policy adopted by most European governments has been to declare a moratorium on approval of new GM products for cultivation and sale. For the few products that have already been approved, their policy has been to segregate GM and GMO-free products at all stages of production, to require labelling of products containing GMOs, and to allow the market to determine how much of each type of product is sold. However, banning new GMOs may be inefficient if there are welfare gains from the adoption of biotechnology that are foregone. In addition, although segregation and mandatory labelling is free-market-oriented[5] in that it offers consumers a choice, some economists might view it also as an inefficient policy.[6] Segregating the entire process of production is costly to farmers and firms throughout the production chain, especially in the upstream part of the chain, which consists of the seed producers, farmers and primary processors.[7] Since there is no evidence that the GMOs that regulatory authorities have approved are harmful either to health or to the environment, it can be argued that the expenditure represents a deadweight loss.

On the other hand, if the production tracks are not segregated or labelling of GMO content is interdicted, as it is in the US, a 'lemons' scenario may result (Akerlof, 1970). The GMOs currently on the market were introduced for agronomic reasons and the foods containing them are indistinguishable from conventional foods to the consumer in the absence of labelling information. Since GMOs lower production costs, producers have an incentive to insert them into the food supply. If consumers value foods containing GMOs less than foods that do not contain GMOs, they will be unwilling to pay more for an unlabelled product than an amount that reflects the presence of GMOs. This would cause the market for non-GMO varieties to disappear, reducing social welfare by eliminating potential gains from trade. Furthermore, it could potentially cause a market collapse for entire products. If a firm cannot disclose that its product uses no ingredients that contain GMOs, it might replace ingredients that consumers

[4] See for example Shogren *et al.* (1999).

[5] Romer (2001) notes that the institutions of science and the market are the main engines of globalisation. However, in some cases, the consensus of the scientific community and market pressures can clash with each other and with public opinion. The case of the first generation of GMOs in food products appears to constitute a prominent example of a situation where science, public opinion and the market each exert pressure toward different outcomes. More generally, the current anti-globalisation movement might be interpreted as a backlash against market or scientific forces. The 'loss of sovereignty' lamented by some anti-globalisation activists can be viewed as a decline in the ability of public opinion to influence outcomes when confronted by market forces or the scientific establishment.

[6] A few studies have estimated the gains from the adoption of biotechnology in farming in the US. See for example Anderson *et al.* (2000), Lin *et al.* (2001), Falk-Zepeda *et al.* (2000), Traxler *et al.* (2000), or Lence and Hayes (2001).

[7] In the US, segregation costs have been estimated at 12% of the current price of corn and 11% of the current price of soybeans (Economic Research Service/USDA, 2000). Buckwell *et al.* (1999) find that in general, identity preservation for speciality crops increases final costs by 5–15%.

believe may contain GMOs with those that cannot contain GMOs. This could eliminate the entire market for many products, such as soy lecithin, corn syrup, and corn starch.

From an economist's point of view, the appropriate policy depends in part on whether the actual purchase behaviour of consumers corresponds to the polling data. If, as suggested by the polls, a large majority of consumers are unwilling to purchase products containing GMOs, banning GMOs is probably the best option, as the expense of creating two tracks of production would not be justified. On the other hand, if the vast majority of consumers behave as if they are indifferent to GMOs, or would purchase products made with GMOs if they sold at lower prices, the production tracks could be safely integrated with little social cost. However, if a considerable segment of the market refuses to purchase products containing GMOs at any price, but another large segment would purchase GM products if they were cheaper, separation of the production tracks and the enforcement of mandatory labelling of products containing GMOs would be worth the expense.

Under a policy of segregation, the threshold level of GMO content, above which a product is considered to be bioengineered, must be specified. Because of the ease of contamination throughout the production chain, it is impossible intentionally to make any product, in whose manufacture GMOs are already authorised, without any trace of GMOs. This technological constraint requires the specification of a threshold above zero below which a product is to be considered as GMO-free and above which the product must be labelled as containing GMOs. The lower the threshold, the greater is the cost of production of GMO-free products. The increase involves the cost of producing very pure seeds, isolating parcels of land, and cleaning storage and transportation containers. The marginal cost of lowering the threshold may be justified if consumers have a strong preference for a low threshold, as is suggested in surveys of public opinion. In our experiment, in addition to studying the willingness to pay for GMO relative to GMO-free products, we also investigate how consumers view the different thresholds.

2. Methodology

2.1. *The Experiment*

The experiment is designed to study the extent that consumers value the absence of GMOs in food products by measuring changes in willingness to pay in response to new information about GMO content. The protocol we use is new to the literature and can be readily applied to study the marginal value of different characteristics of many consumer goods. However, it is similar in spirit to several other experimental protocols in the literature such as the *n*th price auction technique used in Hoffman *et al.* (1993) and the CVX-M calibration method studied in Fox *et al.* (1998). See Shogren (2004) for a survey of experimental techniques of eliciting valuation information. Our protocol differs from many others that appear in the literature in three principal ways.

(1) We train the subjects in the rules and incentive properties of the mechanism with auctions for goods with induced values.
(2) During the training phase, there is an interactive dialogue between the subjects themselves.
(3) When bidding for the products of interest, we do not make the bids public information at any time, so that privacy of valuations is safeguarded, no peer pressure can be mobilised to encourage systematic boycotting of the GMO products and subjects cannot use others' bids to update their own valuations.

In our experiment, subjects bid for real consumer goods using the Becker-DeGroot-Marschak (BDM) mechanism (Becker *et al.*, 1964). In the BDM, a type of auction, bidders have a dominant strategy in bidding an amount equal to their true valuations for the good. There are several advantages to using demand-revealing mechanisms to elicit willingness-to-pay information and other authors have already employed them to study potential consumer demand for food products before their introduction; see for example Fox *et al.* (1998) or Hoffman *et al.* (1993). The first advantage is that unlike survey data, the auction provides a common homogeneous unit, money, to measure preferences. Different respondents may interpret terms 'strongly agree' and 'agree' on a survey differently but the interpretation of £1 is common to all respondents. The use of money as a metric allows for comparisons of intensity of preferences between subjects, as well as between goods. Secondly, in the auction, the subject is committing himself to an actual purchase, unlike in a poll where there is no commitment. Thirdly, in a demand-revealing mechanism, there is a dominant strategy to indicate one's true valuation. In principle, this allows the willingness-to-pay to be directly measured, rather than inferred. The existence of a dominant strategy also simplifies calculation of a participant's best strategy since it is independent of own risk attitudes and beliefs about other players. Fourthly, the bid submitted in the auction weights each characteristic of the product, including GMO content, according to its importance for the purchase decision. Respondents to a survey may express a very strong preference for GMO-free products. However, the survey would not accurately reveal the weight the GMO-free characteristic carries compared to other dimensions such as taste, appearance and price. As suggested earlier, a survey might be expected to accord greater weight to public dimensions, such as negative externalities that result from widespread use of the product, than a bid in an auction market.

Two previous experiments have directly studied willingness-to-pay for GMOs. Both employed subjects from the American Midwest, whose preferences on the GM issue may diverge sharply from European consumers. Lusk *et al.* (2000) study the decisions of American university students. They endow each subject with a bag of genetically modified corn chips and allow him to bid for the right to exchange it for a bag of non-genetically modified chips. Only 30% of subjects indicated a willingness to pay a positive amount for the GMO-free product, and the willingness-to-pay was on average 7 cents per ounce, with 20% willing to pay at least 20 cents per ounce. Huffman *et al.* (2001) investigate bidding behaviour for GMO-containing and GMO-free types of vegetable oil, tortilla chips and Russet potatoes of a sample of American

consumers (mean age of 49 years). They used the random *n*th price auction, in which bidders simultaneously submit sealed bids and the *n* highest bidders each receive a unit of the good. The winners each pay a price equal to the $n + 1$th highest bid. The number *n* is chosen randomly after the bids are made. They found that for all three goods, the average bidder had a lower willingness to pay for the GM variety. The average premium for GMO-free food was 14%.

2.2. *The Participants*

The participants in our experiment were a demographically representative sample of consumers in the Grenoble area. 97 subjects participated, each taking part in exactly one of the ten sessions that comprised the experiment. The sessions took place between July 17thand 24th, 2000. Each session took approximately two hours. The ages of the subjects ranged between 18 and 75 years, and averaged 33 years. 52% were female. The socio-economic level of the sample was representative of the French urban population.

Subjects were recruited by sampling from the telephone directory of the city of Grenoble. The method of recruitment made it highly improbable that subjects communicated with others who participated in an earlier session. Over 1,000 telephone calls were necessary to recruit the 97 who participated in the study. Subjects were screened later in the recruiting process to make the sample more demographically representative after early recruiting attracted a disproportionate fraction of participants under age 25 and over age 60. At the time of recruitment, subjects received no indication that the experiment concerned GMOs or potential risks to the food supply. Subjects were invited to come to the laboratory to sample food products for a government research project which was not linked to private firms or marketing of any particular products. We invited only those respondents who indicated both that they were regular purchasers of biscuits and that they made purchase decisions for their household.

2.3. *The BDM mechanism*

We used the Becker-DeGroot-Marschak (BDM) mechanism to elicit willingness-to-pay information.[8] In the BDM, there is a dominant strategy to bid one's valuation. In other words, it is a best response, no matter what strategy other players adopt, and regardless of the risk attitude of the bidder, to bid truthfully an amount equal to his willingness-to-pay. Therefore in principle, the mechanism has the ability to reveal bidders' valuations.

The rules of the BDM mechanism are simple. Each subject simultaneously submits a bid to the experimenter in a closed envelope to purchase one unit of the good offered for sale. The experimenter then randomly draws a sale price from a

[8] Technically, the BDM procedure is not an auction, since agents are not competing with each other for the items for sale. However, because of their parsimony, we will use the term 'bid' to refer to the submission of a limit price and the term 'the auction' to refer to the process as a whole. The BDM mechanism is theoretically equivalent to a second price sealed bid auction (Vickrey, 1961) where a bidder bids against one demand-revealing opponent.

pre-specified interval, from zero to a price greater than the maximum possible willingness to pay among bidders. Any subject who submits a bid greater than the sale price receives an item and pays an amount equal to the sale price. The others do not receive units and make no payment.

2.4. *The Training Phase*

Though previous studies of the BDM mechanism have shown it to be incentive compatible (Irwin *et al.*, 1998),[9] we nevertheless included a training phase to ensure that subjects learned to use the dominant strategy. This training proceeded in the following manner. At the beginning of a session, each subject received 150 francs (roughly €23) in cash.

We started the training phase of each session with an auction of an actual consumer product, a bottle of orange juice, whose label was visible and that was previously tasted by the subjects. After bidding, all of the bids were posted, the sale price was drawn, the winners were announced and the transactions were implemented immediately. There are two reasons that we introduced this first auction to the training phase. The first reason is that it made subjects aware that others' valuations for goods can differ from their own. The second reason was to provide an easier transition to the GMO phase of the experiment, where subjects would be placed in a situation that is different in three ways from typical market purchases. They buy products whose labels and packaging have been removed, taste products without knowledge of the information displayed on the label, and buy products without knowing the sale price beforehand. We believe it is better to make this leap into the unknown in two steps, with the first step being the auctioning of a product with visible packaging and labelling, which subjects do not taste but whose sale price is not known beforehand. This auction also serves to illustrate to subjects that they are spending real money for real products that they can keep after the experiment and that they are not in a simulation. To render this transparent, a bottle of orange juice is given to each winner, who is required to immediately pay the price determined by the auction from his current cash total.

Subjects then participated in several BDM auctions in which they bid for fictitious items. The fictitious items had induced values; see Smith (1982) for an exposition of induced value theory. Before the auction took place, each subject received a sheet of paper that indicated an amount of money for which he could redeem a unit of the fictitious item from the experimenter, should he purchase it in the auction. The induced value differed from subject to subject and was private

[9] Rutstrom (1998) provides evidence that can be interpreted as suggesting that the BDM leads to bids closer to true valuations than the Vickrey auction. The two auctions both have dominant strategies of truthful bidding. However, the second price auction yields bids that are too high in induced value auctions (Kagel *et al.*, 1987). In auctions for a product with homegrown rather than induced value, chocolate truffles, Rutstrom finds that the BDM yields lower bids than the Vickrey auction, suggesting that it may be the case that the bias toward high bidding is less severe in the BDM than in the Vickrey auction. Bohm *et al.* (1997) point out that the BDM can fail to elicit true valuations when used to elicit willingness to sell information, if the maximum sale price is inappropriately set. Here we do not face this type of problem since we are eliciting willingness to pay information and we can specify the minimum purchase price equal to zero.

information. The ability to redeem an item from the experimenter induced a limit price in the auction, since a subject's payoff if he won the auction equalled the induced value minus the price he paid. The inclusion of the auctions with induced values had three objectives: to teach the subjects and verify their comprehension of the rules of the auction, to reduce the biases and noise that tend to arise in bidding behaviour and to show subjects that the auction involved transactions where real money was at stake.

The dominant strategy of bidding one's valuation in the auctions is not at first obvious to most subjects. We chose not to inform the subjects directly of the dominant strategy. Instead, we used a technique intended to encourage subjects to come to understand the strategies that constitute optimal behaviour on their own. After subjects submitted their bids, the experimenter drew a selling price, wrote all of the valuations on the blackboard and asked subjects if they could identify their own valuations and predict which subjects would be receiving units of the good based on the valuations displayed. Then the experimenter recorded the submitted bids on the blackboard next to the corresponding valuations. He posed the following questions to the group of subjects, who were free to engage in open discussion on the topics.

(a) Which subjects received units in the auction?
(b) How much did the winners pay?
(c) Did anyone regret the bid he submitted?

After the discussion, each of the winners received, in full view of all participants, an amount of money equal to his induced value minus the price he was required to pay. The cash was physically placed on the desk in front of the subject after the auction. A series of identical auctions was conducted using the same procedure. The valuations in each period were randomly drawn from a uniform distribution whose endpoints differed in each period. The auctions continued until at least 80% of the bids were within 5% of valuations. This occurred within 6 periods in all sessions.

2.5. *The GMO Phase*

In the GMO phase we simultaneously auctioned four products, which we referred to as *S, L, C* and *N* during the sessions. All four products were biscuits that are typically available in grocery stores and supermarkets throughout France, and we informed subjects of that fact before bidding began. The products were different from each other, but were close substitutes. The GMO phase of the experiment consisted of five periods, as outlined in Table 1. At the beginning of this phase, subjects received a sample of each of the four products to taste, without its packaging or labelling. Before bidding in the first period, subjects were required to taste each product. They then marked down how much they liked the product on a scale where 'I like it very much' and 'I don't like it at all' were at the extremes of the rating scale (see Combris *et al.*, 1997).[10] Then the auction for period 1 took

[10] Results on the relationship between ratings and bids for these, as well as other products are reported in Noussair *et al.* (forthcoming).

Table 1

Sequence of Events in GMO Phase of an Experimental Session

Period 1	– Information: blind tasting of the four products *S*, *L*, *C* and *N* – Recording of hedonic rating of the four products – Auction
Period 2	– Additional Information: '*S* contains GMOs' and '*N* is GMO free' – Auction
Period 3	– Additional Information: 'No ingredient in *L* contains more than 1% GMOs', 'No ingredient in *C* contains more than 1/10 of 1% GMOs', 'One ingredient in *S* (soy) is derived from an authorised genetically modified product', and 'No ingredient in *N* contains any detectable trace of GMOs' – Auction
Period 4	– Additional Information: general information about GMOs – Auction
Period 5	– Additional Information: the brand names of the four products and the designation 'organically grown' for product *N* – Auction
Transactions	– Random draw of the auction that counts toward final allocations – Implementation of transactions for the period that counts

place. The four products were auctioned simultaneously. Each of the following periods consisted of the revelation of some information about some or all of the products, followed by a simultaneous auction for the four products. The sale price was not drawn for any period until the end of period 5 and no information was given to participants about other players' bids.

Table 1 shows the information made available to subjects at the beginning of each period.[11] At the beginning of period 2, we informed the subjects that product *S* contained GMOs and that product *N* was GMO-free.[12] No information was given about products *L* and *C* in period 2. At the beginning of period 3, we informed the subjects that no ingredient in *L* contained more than 1% GMOs and that no ingredient in *C* contained more than 1/10 of 1% GMOs. We also indicated to subjects that no ingredient in *N* had any detectable trace of GM content, and that *S* contained a GM ingredient, soy, that was authorised in France. At the beginning of period 4, subjects received a four-page handout containing background information about GMOs. The information consisted of

(a) the definition of a GMO,
(b) the criteria for classifying a product as containing GMOs
(c) the list of GM plants authorised in France
(d) the food products sold in France that contain GMOs, and
(e) the current French law regarding GMOs.

[11] We do not reveal bids publicly during the GMO phase, because it is possible that other players' bids might influence some individuals' willingness to pay, when the good being sold has homegrown rather than induced value. Also, in the GMO phase, we auction four goods simultaneously, whereas in the training phase, only one good was auctioned at a time. We felt that confronting the subjects too early in the session with bidding for multiple products simultaneously might have been overwhelming. On the other hand, once they had mastered the rules of the auction for one item, subjects seemed to have little difficulty with the multiple-good simultaneous auction.

[12] See Fox *et al.* (2002) for another example of an experiment in which the impact of new information of willingness-to-pay is studied.

Care was taken to provide an unbiased characterisation because of the sensitivity of auction bids to favourable and unfavourable descriptions of the item sold. Before the last period, we revealed the brands of the four products and the label indicating that product *N* was organic.

3. Results

3.1. *The Impact of GMO Information*

Figure 1 graphs the evolution of the average normalised bid over all subjects over the five periods of the GMO phase for the 4 products. The data in the Figure are normalised by taking each individual's actual bid in period 1 as the base, set equal to 100, tracking that individual's bids over time relative to his bid in period 1 and averaging across all individuals in each period. Table 2 contains the unnormalised averages and variances of bids in each period for each product. The changes in individual bids between periods 1 and 3 are described in Table 3. Only the data from those who bid greater than 0 for the product in period 1 are included in Tables 2 and 3, as well as in Figure 1 (no subject who bid zero in period one ever submitted a positive bid in later periods).[13] The column entitled *Percentage Bidding Zero* indicates the percentage of subjects that bid 0 upon being informed of the product's GMO content. In the column labelled *Percentage Decreasing Bid*, the percentage of subjects that lower their bids for a product, while continuing to bid more than zero, is indicated. The *Percentage*

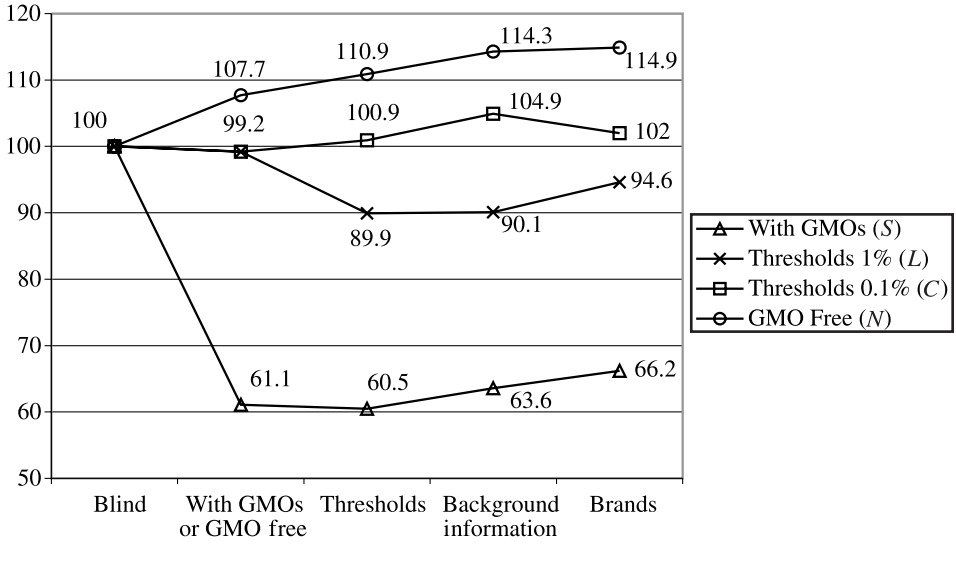

Fig. 1. *Average Bids for the Four Biscuits in Period 1–5*

[13] The number of subjects who bid zero in period 1 was 14 for products *N* and *S*, 13 for product *L* and 29 for product *C*.

Table 2

Average, Variance, and Median of Bids, Periods 1–5, All Products

	Period 1 Blind	Period 2 With GMOs or GMO-Free	Period 3 Thresholds	Period 4 Background information	Period 5 Brands
N GMO Free	15.29FF	16.47FF	16.95FF	17.47FF	17.57FF
	(0.68)	(0.72)	(0.69)	(0.69)	(0.64)
		[+8%**]	[+3%**]	[+3%**]	[+1%]
	{13}	{15}	{15}	{15}	{16}
C Threshold 0.1%	15.02FF	14.96FF	15.16FF	15.75FF	15.32FF
	(0.65)	(0.63)	(0.69)	(0.65)	(0.66)
		[0%]	[+1%]	[+4%**]	[−3%**]
	{12}	{13}	{13}	{14}	{13}
L Threshold 1%	15.48FF	15.30FF	13.91FF	13.95FF	14.65FF
	(0.75)	(0.64)	(0.76)	(0.75)	(0.75)
		[−1%]	[−9%**]	[0%]	[+5%**]
	{14}	{15}	{12}	{12}	{15}
S With GMOs	17.85FF	10.90FF	10.80FF	11.35FF	11.81FF
	(0.69)	(1.03)	(0.96)	(0.93)	(0.91)
		[−39%**]	[−1%]	[+5%**]	[+4%**]
	{15}	{10}	{10}	{10}	{10}

(variance), [increase from previous period], **average significantly different at 1% level from previous period according to pooled-variance t-test, {median}.

Table 3

Percentage Bidding Zero and Decreasing, Increasing, and Holding Constant Their Bids after Learning GMO Content

Product no. of subjects with a positive initial bid	Average initial bid for the product	Percentage bidding zero	Percentage decreasing bid	Percentage with bid unchanged	Percentage increasing bid
N GMO Free *83 subj.*		0%	8.4%	42.2%	49.4%
	(15.29FF)		(18.30FF)	(15.30FF)	(14.79FF)
			(−5.4F)	*(–)*	*(+3.32)*
			[−18.9%]	[0%]	[+22.4%]
C Threshold 0.1% *68 subj.*		4.4%	23.5%	38.2%	33.8%
	(15.02FF)	(8.63FF)	(18.71FF)	(13.51FF)	(14.99FF)
		(−8.63FF)	*(−3.86FF)*	*(–)*	*(+4.24)*
		[−100%]	[−20.6%]	[0%]	[+28.3%]
L Threshold 1% *84 subj.*		10.7%	31.0%	40.5%	17.9%
	(15.48FF)	(9.94FF)	(19.02FF)	(14.27FF)	(17.90FF)
		(−9.94FF)	*(−3.98FF)*	*(–)*	*(+4.07FF)*
		[−100%]	[−26.5%]	[0%]	[+20.9%]
S With GMOs *83 subj.*		34.9%	42.2%	18.1%	4.8%
	(17.85FF)	(13.09FF)	(22.37FF)	(18.04FF)	(12.13FF)
		(−13.09FF)	*(−6.34FF)*	*(–)*	*(+6.10FF)*
		[−100%]	[−28.3%]	[0%]	[+50.3%]

(Average bid in French Francs for observations in category), *(average absolute change in bid, in FF)*, [average percentage change in bid, in FF].

with Bid Unchanged column is the percentage that does not change their bids after learning the GMO content. *Percentage Increasing Bid* is the percentage that increases their bids.

We observe that more consumers value the absence than the presence of GMOs and that the 'average' consumer values the absence of GMOs. In period 2, we revealed that product *N* did not contain GMOs and product *S* did contain GMOs. The GMO-free guarantee raised the limit price for product *N* of the average consumer in our sample by 8%. 41 of the 83 subjects, who bid more than zero for product *N* in period one, raised their bid in period 2 and only 7 lowered it. A sign test (eliminating the ties in which bids were the same in both periods) rejects the hypothesis that a bidder is equally likely to lower as to raise his bid at the $p < 0.001$ level. A pooled variance t-test also rejects the hypothesis that the mean bid for product *N* is equal in periods 1 and 2 at $p < 0.01$, indicating that the 'average' consumer increased his bid in period 2. In contrast, revealing that product *S* contains GMOs lowered its average limit price by 39%. Only 4 participants increased their bid for *S* after learning that it contained GMOs while 64 lowered their bid. Both the sign test and the pooled variance t-test reject the hypothesis of equality at the $p < 0.001$ level. The relatively small increase for the GMO-free product suggests that in the absence of information, consumers typically act as if there is a low probability that products contain GMOs. The average premium for the GMO-free product over the product containing GMOs was 46.7%.

Our subjects appear to view a guarantee that no ingredient contains more than 0.1% GMOs as consistent with the typical GMO content of conventional products (the unlabelled product historically available). They value a 0.1% guarantee more highly than a 1% guarantee and the 1% threshold appears to be seen as a higher level of GMO content than that of a conventional product. Furthermore, the 1% guarantee was viewed differently from the label 'contains GMOs' and the 0.1% guarantee was viewed differently from 'GMO-free'. In period 3, we revealed that no ingredient in product *L* contained more than 1% GMOs and no ingredient in product *C* contained more than 0.1% GMOs. We observed no significant change in the median willingness to pay for product *C* between periods 2 and 3 ($p = 0.38$ for the sign test) but the average bid for product *L* declined by 10% and the decline was statistically significant ($p < 0.05$ for the sign test). A pooled variance t-test of the hypothesis that the mean normalised bids for products *L* and *C* are equal rejects the hypothesis at a significance level of $p < 0.01$. There was no consensus among the participants about whether a product meeting the 0.1% threshold was valued more or less highly than a conventional product. 33% increased their bid (by an average of 28%) after learning the maximum possible GMO content was 0.1% of any ingredient, while 27.9% reduced their bid. 4.4% reduced their bid to zero. The bidding behaviour for product *L* reveals that a product meeting a 1% threshold is viewed very differently from a product labelled as containing GMOs. 17.9% of subjects increased their bid when informed of the 1% threshold, and 40.5% left their bid unchanged. Thus over half of our participants considered a product satisfying the 1% threshold as no worse than the conventional product. The 1% guarantee was viewed as different from the 0.1% guarantee. The mean normalised bids in period 3 for products *N* and *C*, as well as for products *L* and *S*, were significantly different from each other at $p < 0.01$.

The distribution of background information about biotechnology in period 4 led to a slight increase in average limit prices, which was significant at $p < 0.05$ for

three of the four products. The increase was greatest for the GMO-free product *N*. The information did not bring the prices of *L*, with a 1% threshold, or *S*, which contained GMOs, to their levels before any information was revealed. For all four products at least 57% of the bids were unchanged between periods 3 and 4. For product *N*, the GMO-free product, 20 bidders increased their bid while 9 lowered it and we can reject the hypothesis that an individual was equally likely to raise and to lower his bid at the $p < 0.05$ level. However, we cannot reject the analogous hypotheses for the other three products. Thus for each of the products, though the pooled variance t-test indicates that the information increased the bid of the 'average' consumer, the more conservative sign test is not significant and the majority of participants did not change their bids.

Revealing the brand names of the products in period 5 raised the average prices for three of the four products. The effect was significant at $p < 0.01$ for *L* and *S*. The average bid for product *C* was significantly lower in period 5 than in period 4 at $p < 0.01$. However, for all four products, we fail to reject the hypothesis that an equal number of bidders raised and lowered their bids in period 5 relative to period 4. There was no increase in price for product *N* from revealing that it was organically produced, perhaps because revealing its label exerted an offsetting negative effect.

3.2. *Bidder Types and Demographics*

Our consumers can be classified into four categories. In classifying the participants we consider only those who demonstrated a positive willingness to pay for product *S* before it was revealed to contain GMOs. In other words, the classification applies only to those for whom $b_1(S) > 0$, where $b_k(x)$ is the bid in period k for product x. We refer to those consumers whose bids satisfy $b_1(S) > 0$ and $b_2(S) = 0$, as *Unwilling* consumers. Unwilling consumers bid zero for product *S* after learning that it contained GMOs. They comprised 34.9% of our subjects. It is clear that they have lowered their bids in period 2 because of the information about GMO content, because only 1 of the Unwilling also lowered his bid for product *N* in period 2 after finding out it was GMO-free. 14 of the Unwilling consumers submitted $b_2(N) = b_1(N)$ and 13 submitted a bid satisfying $b_2(N) > b_1(N)$, indicating at least a weak preference for the GMO-free characteristic. However, the Unwilling were disproportionately likely to have a low opportunity cost of not purchasing the product, in that 1/3 of them bid less than 50% of the average bid in period 1. We can also consider the percentage that bid zero for products *L* and *C* in period 3 in response to the availability of the threshold information. Specifying a threshold resulted in a lower incidence of zero bidding than the announcement 'contains GMOs'. 10.7% of the subjects bid zero for the product with a maximum of 1% GMO content in any ingredient, and only 4.4% bid zero at 0.1%. That means that over 95% of our participants were willing to accept a level of GMO content that typically results from inadvertent co-mingling if the product is sufficiently inexpensive.

For 18.1% of our consumers, $b_2(S) = b_1(S)$. That is, they did not change their bid for product *S* upon finding out that it contained GMOs. We classify them as

Indifferent consumers. 60% of these indifferent consumers were indifferent for all goods. That is they set $b_2(S) = b_1(S)$, $b_2(N) = b_1(N)$, $b_3(L) = b_1(L)$ and $b_3(C) = b_1(C)$. Another 4.9% of participants were *Favourable*, in that their choices satisfied $b_2(S) > b_1(S)$, demonstrating behaviour consistent with having a preference for GM foods. However only 1 of the 4 Favourable consumers satisfied $b_2(N) < b_1(N)$ (whereas two submitted $b_2(N) = b_1(N)$ and one submitted $b_2(N) > b_1(N)$, suggesting possible confusion on his part about the decision situation), which is consistent with a negative value for the GMO-free characteristic. Thus a full 23% of bidders were willing to accept GMOs in their food at the same price as the conventional product. Despite the current unpopularity of GMOs in food, there is still a group of consumers willing to buy them and to allow them to establish a foothold in the marketplace.

42.2% of our subjects submitted bids that satisfied $0 < b_2(S) < b_1(S)$. They lowered their bid for product S but did not go so far as to bid zero. The average percentage of the decrease was 28.3%. We call this group the *Reluctant* consumers. This group places negative value on GMO content and will lower (raise) its bid prices when faced with products with higher (lower) GMO content. They are willing to trade off GMO content and the price they pay. 36.1% of the Reluctant consumers also exhibited behaviour satisfying $b_3(S)/b_1(S) < b_3(L)/b_1(L) < b_3(C)/b_1(C) < b_3(N)/b_1(N)$. This indicates that their willingness to pay is monotonic in the strength of the guarantee of the maximum GMO content.

We explore the relationship between acceptance of genetically modified organisms and certain demographic characteristics of our subjects. We estimate the following probit model:

$$Y_i = \beta_0 + \beta_1\ Gender + \beta_2\ Age + \beta_3\ Food\text{-}health + \beta_4\ Diploma + \beta_5\ 1st\ cycle + \beta_6\ 2nd\ cycle + \beta_7\ 3rd\ cycle$$

Y_i is a dummy variable that equals 1 if consumer i is classified as Unwilling or Reluctant, and equals 0 if the consumer is Favourable or Indifferent. Therefore Y_i can be interpreted as hostility to GMOs and a positive coefficient on an independent variable as a characteristic that is associated with a preference for consuming foods that do not contain GMOs. The results of the analysis are given in Table 4. The independent variable *Gender* equals 1 if the consumer is female and zero if male. *Age* is given in years. *Food-health* equals 1 is the consumer works in the food or health care industries, and therefore might be better informed about GMOs than the average person. The other four variables are dummy variables that indicate the highest level of education the individual has completed. *Diploma*

Table 4

Relationship between Aversion to GM-Food and Demographic Variables

Ind Var.	Intercept	*Gender* (female = 1)	*Age*	*Food-health*	*Bac.*	*1stCycle*	*2ndCycle*	*3rdCycle*
Coefficient	1.113	0.068	−0.013	−0.055	0.345	−0.301	−0.200	0.560
(std. error)	(0.577)	(0.171)	(0.015)	(0.411)	(0.391)	(0.344)	(0.317)	(0.371)

equals 1 if the Baccalaureate is the highest degree completed. *1st cycle, 2nd cycle* and *3rdcycle* are increasing levels of university education, where *3rd cycle* is roughly equivalent to a Master's degree. All educational variables equal zero for those who have not completed their Baccalaureate. The probit estimates of the model, given in Table 4, show that none of the variables is significant. There is some tendency for those with the highest level of education to demonstrate a stronger preference for GMO-free products and weaker tendencies for younger people, those who work in the food or health industry and for men to be more willing to consume GM food. The individual level data reveal that the incidence of Unwilling consumers is not highly dependent on demographics. 35% of men and 34.9% of women were classified as Unwilling. Profession was not a good predictor of refusal to purchase GMOs. For example, 33.3% of workers in service industries, 33.3% of manual labourers, and 35.9% of students bid zero for the product after finding out that it contained GMOs. The most pronounced difference was between consumers with different educational levels. 20% of those who had not completed a Diploma but 52.6% of 3rd Cycle graduates were classified as Unwilling to purchase the GM product. In general, demographic variables are not strongly related to bidding behaviour and our results are not specific to certain demographic groups.

4. Discussion

Our results show a sharp contrast to the predominantly negative views of French survey respondents toward genetically modified organisms in food products. In our experiments, we observe a wide range of revealed preferences. Whereas 35% of our subjects refused to purchase a product containing GMOs, the remaining 65% of our subjects were willing to purchase a GM product if it was sufficiently inexpensive. Nearly one-quarter of participants showed no decrease in their willingness to pay in response to learning that a product contained GMOs.

The two different thresholds, 0.1% and 1%, generated significantly different bids and were thus were clearly perceived as meaningfully different. Furthermore, the 0.1% threshold was not considered to be GMO-free and the 1% threshold generated higher bids than the classification 'contains GMOs'. This indicates that demand is decreasing in GMO content. 89% of our participants were willing to purchase a product satisfying the 1% threshold, the maximum content that the European Union exempts from labelling. Lowering the threshold to 0.1% would make another 7% of participants willing to purchase products satisfying the threshold, as 96% of our participants were willing to purchase a product, in which no ingredient contained more than 0.1% GMOs, if it were sufficiently inexpensive.

The price patterns we observe underscore the importance of GMOs to many consumers. Changes in prices observed when GM content or thresholds were revealed overwhelm those observed when brand names were revealed. The data also indicate that revealing background information about GMOs had little effect on the behaviour of our consumers. Their prior beliefs overwhelmed the content of the information. This suggests that a public information campaign

intended to lead to a greater acceptance of GMOs may face considerable challenges.

One possible source of differences between the results from survey data and the consumer behaviour observed in the experiment is a configuration of private and public dimensions of preference for GM food in which individuals are willing to consume it but opposed to it in general. For example, this might be the case if GMOs were viewed as carrying an environmental risk but also as safe for human consumption. A consumer's market behaviour would neglect the externality his consumption imposes, whereas his response to a survey would not. This is analogous to the consumer of electricity who is opposed to nuclear power but uses the electricity from the power grid, despite the fact that some of the electricity is generated with nuclear power. This effect is consistent with negative responses to the question 'are you in favour of the use of GM ingredients in food?' or 'are you in favour of the cultivation of GM crops?' combined with a willingness to consume GM food. However, there are also differences between surveys and the experimental results that are inconsistent with this interpretation. For example, the Noussair *et al.* (2001) survey, conducted in the Grenoble area with a sample of participants with similar demographics as those in our study, asked specifically 'would *you* buy [the product] if it contained GMOs?' 91.7% responded negatively for French fries, and 91.7% did so for tomatoes.[14] Therefore, there does appear to be a major difference in the results of hypothetical surveys and consumer behaviour, even when the questions posed ask directly about the consumption decision.

The policy options available to address the arrival of biotechnology in food production can be grouped into three types. The first option is to ban the use of GMOs in food products. The second is to integrate conventional and biotech varieties into one production stream. The third is to create two production tracks and introduce a labelling system (which could be voluntary or mandatory) to allow the consumer to identify the two varieties. Based merely on polls, we would have concluded that the only policy action that would be feasible in France given current public opinion would be the complete interdiction of GMOs in food, or at least a temporary moratorium on their use. However, our results indicate that only slightly more than a third of the population would be unwilling to purchase GMOs. The remainder is willing to purchase GMOs even when no threshold is specified and could receive a welfare gain if GMOs make products cheaper. The data thus argue against the banning of GMOs, which would cause gains from trade to be foregone.

The data also reveal potential welfare costs to consumers from integrating the two production streams. The consumers who are willing to purchase GMOs if they are sold at a discount might be made better off. However, the segment that refuses to purchase GM-products at any price (35% of participants in our sample) would

[14] Surveys that ask specifically about consumption decisions also indicate that some of the opposition to GMOs is based on concerns about personal consumption of GMOs. A poll conducted by Market and Opinion Research International in 1999 found that 77% of French consumers agreed with the statement 'I would be unhappy to eat GM foods'. In *a Sunday Independent* poll of consumers in the UK in early 1999, 68% indicated that they were 'fearful of eating GM foods'. An ABC News poll conducted in June 2001 found that 52% of Americans believed that GM foods were not safe to eat.

experience a decrease in their welfare, and would have to switch to products with ingredients that have no GM varieties.

In our view, our results weigh in favour of segmenting the market between products containing GMOs and products that are GMO-free. In this way, the Unwilling consumers could be assured of GMO-free varieties, while price sensitive consumers could benefit from the cost reductions that the first generation of GMOs provides. As long as the segregation costs are not greater than the welfare gains from market segmentation, the sizes of each of the markets appear to justify the establishment of two separate production tracks. The separation and labelling policy gives the market the role of transmitting information about the safety of GM products, by providing an opportunity and an incentive for consumers to sample the lower cost products made with GMOs voluntarily. Our data indicate that a large fraction of consumers would do so.

We conclude with some thoughts about the future of GM foods in Europe. Following the framework of Nelson (1970) and Darby and Karni (1973) we can divide the characteristics of a product into three groups. A search characteristic is a property, such as colour or shape, which the buyer can identify before purchase. An experience characteristic, such as taste, is only identified at the time the product is consumed and a credence characteristic, such as nutritional value or chemical content, can never be identified, other than from information provided by a third party. Under a mandatory labelling system, the GMO content of a product is a search characteristic for products labelled 'containing GMOs' and a credence characteristic for an unlabelled product. During the introduction of GM foods on the market, their safety and their equivalence to conventional products are also credence characteristics.

We believe that the experience of the segment of the market that purchased and consumed GM products would in time convince a greater percentage of consumers of the safety of GMOs and of the equivalence of products containing GMOs with conventional products. Safety and equivalence would become experience characteristics rather than credence characteristics. If this occurs, the threshold issue would become irrelevant in the long run. This argues for a fairly loose standard of what can be considered GMO-free that is not very costly to meet (such as 1% of any ingredient). Though the actual level of GMO content in a 'GMO-free' product would remain a credence characteristic, who would care?

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