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A Continuum of Consumer Attitudes Toward Genetically Modified Foods in the United States

Pierre Ganiere, Wen S. Chern, and David Hahn

A national telephone survey was conducted in the United States in April 2002 to study the consumer acceptance of genetically modified (GM) foods. Attitudes toward GM foods were examined through the use of a multiple correspondence analysis (MCA), analyzing the interrelationships among many categorical variables. This method was combined with a cluster analysis to construct a typology of consumers' attitudes. Four distinct classes of attitudes were finally extracted, denoted as: Proponents, Non-Opponents, Moderate Opponents, and Extreme Opponents. It was estimated that only 35% of the surveyed population was opposed to GM foods.

Key words: consumer acceptance, correspondence analysis, GM foods, telephone survey

Introduction

The United States is the world's leading country in research, development, and sales of genetically modified organisms (GMOs). In 2002, the U.S. adoption rates of GM soybeans and corn were 75% and 32%, respectively [U.S. Department of Agriculture/National Agricultural Statistics Service (USDA/NASS), 2004]. Consequently, in addition to being a major technological breakthrough, GMOs represent a tremendous economic stake for the biotechnology industry and the agricultural sector in the United States.

Currently, all GM crop varieties present in the U.S. market must be "recognized as safe" by the Food and Drug Administration, and must be certified as not hazardous to human health. Under this policy, labeling of GMOs is not required as long as the GM product is not different from its conventional counterpart (Vogt and Parish, 1999). In fact, contrary to consumers in the European Union or Japan where the labeling of GM foods is mandatory, most Americans now unknowingly eat a significant number of GM foods—especially products with corn or soybeans as ingredients. Thus, with the exception of organic food that cannot contain GM ingredients and a few specially labeled non-GM products, the U.S. consumer does not know whether a food product is GM or non-GM because there is no labeling requirement. Although many studies have shown American consumers are generally supportive of GM food (e.g., Bredahl, Grunert, and

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Frewer, 1998; Hoban, 1999; Chern and Rickertsen, 2001), biotechnology remains a very controversial subject. An example of this controversy is illustrated by the actions of the residents of Mendocino County, California, in March 2004, who approved to prohibit the growing and raising of GMOs in their county.

While there is an extensive literature evaluating consumer acceptance of GM foods, few investigations have attempted to characterize proponents and opponents of the technology in terms of distributional information. This study seeks to fill that gap by assessing the distribution of consumers with regard to their attitudes toward GM foods. We propose to show that various attitudes toward GMOs can be found within the American population. Further, our goal is to present the associated distributional information useful for policy makers in terms of assessing labeling regulation, and for the biotechnology and food industries in terms of market evaluation.

For the purpose of this study, a telephone survey was conducted in the United States in 2002. This comprehensive survey dealt with both stated preferences for GM versus non-GM foods as well as behavioral intentions. "Behavioral intention" reflects a person's decision to perform the behavior, such as buying or consuming (Fishbein and Ajzen, 1975). A multiple correspondence analysis is carried out to analyze the data collected.

Background

Due to the controversy over GM foods arising from the debates on labeling regulations and on trade disputes between importing and exporting countries of GM food products, a number of surveys investigating consumer acceptance of GM foods have been conducted in various countries (Hoban, 1998; Lusk, Roosen, and Fox, 2003; Lusk et al., 2005). These surveys were generally developed for four types of analyses. The first dealt with the qualitative and descriptive analyses of consumer attitudes toward GM foods, mostly using the respondents' answers to selected questions. In this category, previous studies tended to show American consumers were relatively supportive of GM foods. In particular, surveys found that about two-thirds of Americans were positive about biotechnology and supported its application in food production (Hallman and Metcalfe, 1994; Hoban, 1998; Alexander and Schleman, 2003). Earlier results also suggest consumers tend to be more supportive when tangible benefits are associated with GM foods. For instance, Hossain et al. (2003) report that less than 60% of Americans supported the use of genetic technology when it did not bring any tangible benefit to consumers, whereas, when specific benefits were provided (more nutritious, for instance), 75–80% of the same population approved its use.

The second group of studies assessed consumer attitudes or behavioral intentions toward GM foods using linear regression or discrete choice models (Baker and Burnham, 2001; Moon and Balasubramanian, 2004; Hossain et al., 2003). In these models, risk and/or benefit perception and demographic variables were used to explain consumer attitudes or willingness to purchase GM foods. Moon and Balasubramanian (2004) found that sociodemographic factors played an important role in shaping public attitudes about biotechnology.

The third type of survey analysis (and also the most prevalent) focused on the estimation of consumers' willingness to pay (WTP) for GM versus non-GM foods [see Lusk et al. (2005) for the most complete listing of these works]. Most of these studies concluded that consumers were willing to pay premiums for non-GM products over GM products

(Baker and Burnham, 2001; Huffman et al., 2003; Kaneko and Chern, 2005). However, the overall positive premiums estimated for non-GM foods did not mean that all survey respondents were resistant to GM foods, although many surveys mistakenly assumed a priori the superiority of non-GM foods in the stated choice questions. For example, Kaneko and Chern (2005) found certain respondents were willing to pay a positive premium for GM foods in the United States. Lusk et al. (2001) and Lusk (2003) also reported some consumers were willing to pay premiums for GM foods when tangible benefits were provided. Even though the attitudinal and demographic variables were almost always used in the models to explain the purchase intentions (2nd group of studies) or to compute the WTP estimates (3rd group of studies), these studies could not provide an exact delineation of the extent of support for or opposition to GM foods in any population.

The final group of GMO studies assessed the impacts of information on consumers' willingness to consume or willingness to pay for GM foods (Huffman et al., 2003; House et al., 2004). Because these analyses employed experimental auctions, they tended to have limited samples for making any credible inferences as to identification of proponents and opponents of GM foods within the population. Moreover, these experimental auctions often assumed a priori the superiority of non-GM foods in their experimental designs.

The literature has clearly shown that there are different attitudes on GM foods. Furthermore, consumers in general are likely to be willing to pay a premium for non-GM foods, but this does not guarantee everyone is resistant to GM foods, nor that GM foods are always inferior to their non-GM counterparts. There are definitely proponents and opponents of GM foods in the United States, but their distribution has never been delineated in the literature. The goal of our study is to fill this gap. The categorical responses to attitudinal and behavioral intention questions will be used in the correspondence and classification analyses to develop a consumer profile in terms of support or opposition to GM foods, while the results from the stated choice questions and demographic variables will be used to identify the characteristics of this profile.

Survey and Methodology

According to Ajzen's (1988) theory of planned behavior, individuals' performance of a given behavior is best predicted by their intentions to perform the behavior (i.e., behavioral intention). Intentions, in turn, are best predicted by attitudes toward the behavior. Attitudes toward the behavior refer to the extent to which a person positively or negatively evaluates his or her performing the behavior; the more favorable the attitude, the stronger should be the person's intention to do it. Our survey was conducted to specifically investigate these attitudes toward GM foods.

The questionnaire on which the survey was based included various questions dealing with the willingness to consume GM foods in terms of favorable (e.g., if it was more nutritious) or adverse arguments (e.g., if it posed a risk of causing allergic reactions for some); the subjective (how knowledgeable respondents think they are) and objective (textbook knowledge as measured by true/false questions) knowledge of the respondents regarding biotechnology and GMOs; and the regulation of GM foods [see House et al. (2004) for a discussion on subjective versus objective knowledge]. The stated choice questions focused on three specific products—vegetable oil, cornflakes, and salmon—and

asked respondents to make choices between GM and non-GM products under different price scenarios. The first two products (vegetable oil and cornflakes) were chosen because soybeans and corn are the two main GM crops grown in the United States and consumers are familiar with them. The third product (salmon) was selected because it is an animal-based product.[1] Information also was collected on respondents' socio-economic characteristics.

The data were collected in April 2002, through a national telephone survey of randomly selected U.S. households (excluding Hawaii and Alaska). A random-digit dialing procedure was used to select the households.[2] Respondents were limited to food shoppers in the household aged 18 and over in order to decrease the hypothetical bias of including non-food shoppers in the sample. The rationale is that the household food shopper is assumed to reflect the food preferences for the household because he or she is the one making the ultimate decision on food purchases. The survey was conducted within a three-week period, with a mix of day times and evenings. Each working telephone number was called several times (as many as 10 times), at different times of the week, to reach people who were infrequently at home. A total of 1,213 telephone numbers were called in April 2002, with 256 interviews being completed. The results yielded a response rate of 28.6% using the response rate computation method adopted by the American Association for Public Opinion Research (AAPOR), which is the most conservative calculation.[3] The 256 respondents were drawn from 44 states.

In order to validate the representativeness of the sample, two variables were considered: age and gender. The age repartition between the sample and the U.S. population for those aged 20 and over in the *2002 American Community Survey* (U.S. Department of Commerce, Census Bureau) are compared in table 1. This comparison shows that our sample mirrors the age distribution of the U.S. population reasonably well except for those aged 35–44 and 45–54, who were slightly under-represented and over-represented, respectively. Regarding gender, the survey participants are skewed toward women, with a proportion of 77.3% (compared to 51.7% in the U.S. population for persons 18 years of age and over). However, given that Katsaras et al. (2001) found women constitute a disproportionate share of grocery shoppers (83% of shoppers), this skew is not unreasonable. Our target population is not the U.S. population as a whole, but food shoppers in the household, which is more relevant for market assessment.[4]

As noted previously, consumers have different attitudes toward GM foods, and these attitudes can be grouped within distinct profiles. Thus, from the questions assessing the attitudes of the respondents, two individuals can be assumed to have the same attitude if they answered the same way to the questions (i.e., if they chose the same categorical modalities). Moreover, two individuals belong to the same profile if their answers only diverge slightly. Finally, each profile can be described through the people belonging to it. For example, if all of the respondents are women aged 60 years and over, then this gender/age combination is one of the dominant features of this profile.

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[1] The survey covered three types of salmon: non-GM salmon, GM-fed salmon (salmon raised with GM soybean meals), and GM salmon (genetically modified by laboratory scientists).

[2] Generation of random telephone numbers avoided under-coverage of unlisted numbers.

[3] The AAPOR calculation is as follows: number of completed interviews divided by the number of interviews plus the number of non-interviews (refusal, break-off, non-contacts, etc.) plus all cases of unknown disposition codes.

[4] Income was not used for checking the representativeness of the sample because 27% of the sample did not have income information. Note also that our study focuses on grocery shoppers, and they are skewed toward women. Therefore, education cannot be used to check the representativeness of our sample since it differs from the general population covered in the *Census*. Nevertheless, the mean and median statistics are available later in the paper (table 3).

Table 1. Comparison of Age Composition Between the Survey Sample and the U.S. Population (percent)

Age	U.S. Population[a] (2002)	Sample Population (April 2002)
	<---------- (%) ---------->	
20 to 24 years	9.25	2.34
25 to 34 years	19.25	20.70
35 to 44 years	21.99	16.80
45 to 54 years	19.74	18.13
55 to 59 years	7.38	6.25
60 to 64 years	5.71	6.25
65 years and over	16.69	19.53
Total	100%	100%

Source: U.S. Department of Commerce, Census Bureau, *2002 American Community Survey.*

[a] Aged 20 years and over.

The following five questions, used as active variables for this analysis, were designed to assess the attitudes of the respondents toward GM foods.

A. How risky would you say GM foods are in terms of their effects on human health?

B. How willing are you to consume foods produced with GM ingredients?

C. How willing would you be to consume GM food if it reduces the amount of pesticide applied to crops?

D. How willing would you be to purchase GM food if it is more nutritious than similar food that isn't genetically modified?

E. How willing would you be to purchase GM food if it poses a risk of causing allergic reactions for some people?

For each of these questions, respondents answered with the following categorical modalities (stated preferences): 1 = extremely risky/unwilling, 2 = somewhat risky/unwilling, 3 = neither risky nor safe/willing nor unwilling, 4 = somewhat safe/willing, 5 = extremely safe/willing, and 9 = don't know (a choice not spontaneously proposed to the interviewees).

Table 2 reports the descriptive statistics for these five active variables. The results show that more than 48% of respondents felt GM foods were somewhat or extremely risky. However, 43% expressed willingness to consume GM foods, and this percentage increased to nearly 72% if GM foods were more nutritious. With respect to those answering "don't know," there were more respondents who could not assess the perceived risk than those who could not make up their mind on willingness to consume GM foods.

Due to the complexity of simultaneously analyzing 10 two-way cross-tabulations, an exploratory technique intended to reveal features in the data is required.[5] Multiple correspondence analysis (MCA) is one such method to analyze the associations among

[5] In the general case of Q categorical variables, there are $Q(Q-1)/2$ possible two-way cross-tabulations of pairs of variables; in our case, with $Q = 5$ variables, we have 10 categorical modalities.

Table 2. Percentages of Respondents Selecting Each Modality (Answer)

Question (Variable)	Extremely Safe/ Willing	Somewhat Safe/ Willing	Neither Risky nor Safe/ Willing nor Unwilling	Somewhat Risky/ Unwilling	Extremely Risky/ Unwilling	Don't Know
	<---------- (%) ---------->					
A. How risky would you say GM foods are in terms of their effects on human health?	5.5	15.2	16.0	39.5	9.4	14.5
B. How willing are you to consume foods produced with GM ingredients?	4.7	38.3	13.7	23.8	16.4	3.1
C. How willing would you be to consume GM food if it reduces the amount of pesticide applied to crops?	13.7	54.7	9.4	11.3	9.0	2.0
D. How willing would you be to purchase GM food if it is more nutritious than similar food that isn't genetically modified?	18.0	53.9	5.1	9.4	10.9	2.7
E. How willing would you be to purchase GM food if it poses a risk of causing allergic reactions for some people?	3.5	21.5	5.9	26.2	41.4	1.6

Source: Primary data.

many categorical variables, with the purpose of visualizing the most salient relationships and patterns in the data. MCA was selected because it does not require a continuous metric for observed variables. MCA is a nonparametric method designed specifically for variables with categorical responses, whereas a method such as factor analysis is most suitable when all variables are continuous.[6]

MCA is a multivariate extension of correspondence analysis, permitting an analysis of the interrelationships among three or more variables. It is a technique for displaying the rows and columns of a data matrix as points in dual low-dimensional vector spaces (Greenacre, 1984). Each respondent is characterized by the modalities chosen in the survey. For example, for the first question ("How risky would you say GM foods are in terms of their effects on human health?"), a respondent is characterized by the categorical modality he/she chose, such as "somewhat risky" or "extremely safe." Respondents can therefore be represented in a multidimensional space. Since we cannot observe points in a space with more than three dimensions, it becomes necessary to reduce the dimensionality. These points are projected on a lower-dimensional subspace which is chosen to capture as much of the dispersion of the profiles as possible. A new orthogonal

[6] Although there are similarities between multiple correspondence analysis and factor analysis, MCA is designed specifically for the categorical variables. MCA is a nonparametric method which makes no distributional assumption. Factor analysis is a parametric method based on a multivariate normal distribution and is most suitable when all variables are continuous. Even though factor analysis is often used with dichotomous, ordinal, and other types of discrete variables, the parameter estimates may be biased and the goodness-of-fit measures may not be valid. However, if we changed our questionnaire by asking respondents to use a Likert scale of 1 to 10 for ranking their risk perception or willingness to consume GM foods, then the variable, though qualitative, could be measured as a continuous variable. Such variables would be appropriate for factor analysis.

set of axes (the factor axes, or factors) is found, so as to maximize the inertia of the projected points onto the new axes.[7] These axes define a two-by-two factor plane. Each factor represents a salient feature related to consumer acceptance of GM foods. By studying the modalities significantly associated with the main factor axes, one can explain the main oppositions within the population and thus discriminate the respondents. The main variables eliciting consumer acceptance of GM foods can then be extracted from the analysis. Further details on the MCA are provided by Jambu (1991); Benzécri (1992); Greenacre and Blasius (1994); and Nishisato (1994).

MCA is used to construct principal components, which best summarize the individuals' characteristics within the population represented by the sample. To search for a typology of the attitudes related to consumer acceptance of GM foods, an ascending hierarchical classification method can be carried out on the individuals described by the factors (Ward's minimum variance method). Using this method, individuals are grouped into clusters according to their proximity, i.e., their similar characteristics. A class is then defined as a group of individuals with common characteristics or, more specifically in this study, with a similar degree of acceptance of GM foods.

The agglomerate hierarchical clustering algorithm constructs the hierarchical tree starting with the individuals. Ward's method (Ward, 1963) seeks at each step to form a new cluster which minimizes the internal variance of the new merged class. Inertia is computed from the coordinates of the elements to be classified on the factor axes (Lebart, Morineau, and Warwick, 1984). The construction is continued up to the root of the tree, to the cluster containing all the individuals in the sample. A classification that best summarizes the information is then chosen.

Empirical Results

The principal objective of this study is to differentiate the survey respondents according to their attitudes toward GM foods with respect to a range of different arguments. Again, our analysis concentrates solely on shoppers in the household since their attitudes are better predictors of purchasing behavior, thereby decreasing the hypothetical bias of the study.

Note, as with any factorial method, it is possible to include what are known as the "illustrative" variables. These are not used in the construction of factor planes, but can help in the interpretations of the factors, or later in the description of the classes. Here, the illustrative variables included are: the sociodemographic variables, the questions dealing with the knowledge about GM foods and biotechnology, some questions about the regulation of GM foods (especially labeling), and also the questions asking for choices between GM and non-GM foods (specifically vegetable oil, cornflakes, and salmon) under different price scenarios.[8]

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[7] The inertia (or moment of inertia) is defined as the sum of the quantities rd^2, where r is the mass of an object and d is the distance from the centroid. The inertia of a cloud of points is the sum of the inertias of all the points, or the weighted sum of squared distances from the points to their respective centroids. The total inertia is the same in both the row and column cloud of points. It is a measure of the dispersion of the categorical modalities in multidimensional space. The higher the inertia, the more spread out they are.

[8] The two questions assessing the knowledge of the respondents regarding biotechnology and GMOs are the following: (*a*) "Non-GM soybeans do not contain genes while GM soybeans do" [True, False]; and (*b*) "By eating GM foods, a person's genes could be altered" [True, False].

Factor Planes

Typically, in multiple correspondence analysis, analyses of factor planes are guided by the centroid principal: category coordinates are the center of gravity (or centroid) of respondent coordinates occurring in that category. Stated differently, respondents are relatively close to categories they are in and relatively far from categories they are not in.

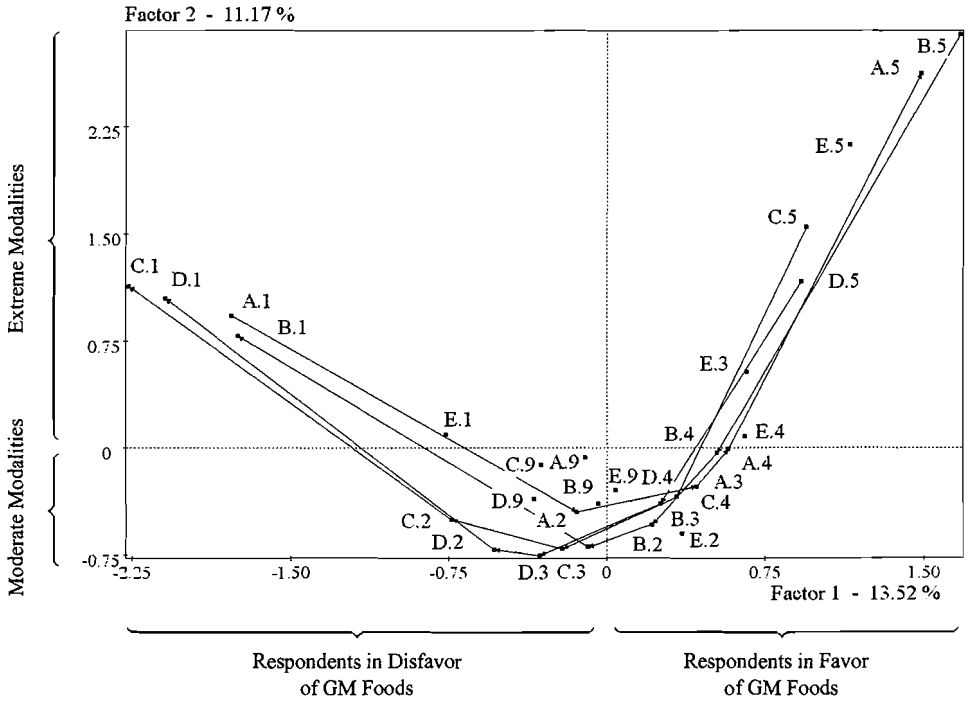
The variable category points are plotted in figure 1, a typical graph produced in MCA (see, e.g., Greenacre and Blasius, 1994). All modalities from the five questions chosen as active variables are represented in the graph. The illustrative variables could also have been represented on this factor plane, but their inclusion would have been detrimental to the clarity of the graph. This first plane represents 24.7% of the total inertia, or one-quarter of the total information. It is a good summary representation of the information since it summarizes on one single plane the answers given to the five questions.

In the correspondence analysis (CA), the so-called weighted Euclidean distance is used to measure the distances between points. In practice, the weighting scheme is such that categorical modalities occurring less frequently contribute more to the creation of the factor, while those occurring more frequently contribute less (we are interested in characterizing the sample, not in finding the common features within the sample). Hence, modalities of higher weight tend to be close to the center of gravity (the origin of the axes represents the center of gravity) while modalities of lower weight are plotted farther from it.

Different regions of consumer acceptance are revealed in figure 1. For example, in the upper right quadrant are the variable categories associated with the most extreme level of acceptance: "extremely safe," "extremely willing to consume GM foods," etc. Thus, respondents in this area of the map are associated with these categories. We can further identify a region of extreme rejection in the upper left quadrant. Moving down in the figure, in the lower center of the map, two clusters of moderate variable categories are identified: modalities in favor of GM foods (e.g., "somewhat willing to consume foods produced with GM ingredients") in the right-hand portion and of rejection in the left-hand portion (e.g., "somewhat unwilling even if it is more nutritious than similar food that is not GM"). Based on the results plotted in figure 1, the MCA has clearly identified four distinct regions related to consumer acceptance of GM foods.

Figure 1 exhibits what is called the "horseshoe" or Guttman effect (Guttman, 1950), where the lines linking the modalities of the active variables exhibit a U-shape. It has a quadratic structure, in the sense that respondents are on or close to a second-degree polynomial in two dimensions. That is, the second dimension is a quadratic function of the first dimension. This effect is often found in CA when the first dimension is dominant. Notice also that the analysis has revealed distinctly nonlinear patterns of consumer acceptance. This illustrates an advantage of nonlinear multivariate analysis. By treating all variables as categorical, we discover patterns in the data which would be hidden by a conventional linear multivariate analysis. Note that the origin of the axes corresponds to the center of gravity of the cloud of points.

Figure 2 shows the plot for question E as embodied in figure 1. The modality "extremely unwilling to consume GM food if it poses a risk of causing allergic reactions for some people" is close to the center of gravity, whereas the other "extreme" modalities



– LEGEND KEY –

Questions Posed to Survey Respondents:

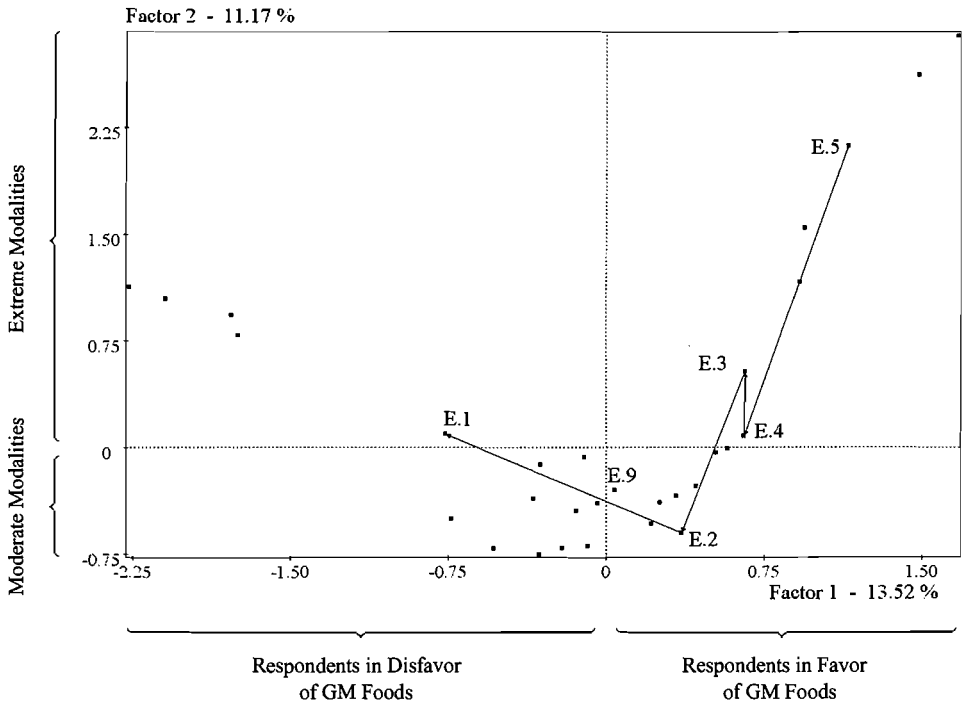
A. How risky would you say GM foods are in terms of their effects on human health?
B. How willing are you to consume foods produced with GM ingredients?
C. How willing would you be to consume GM food if it reduces the amount of pesticide applied to crops?
D. How willing would you be to purchase GM food if it is more nutritious than similar food that isn't genetically modified?
E. How willing would you be to purchase GM food if it poses a risk of causing allergic reactions for some people?

For each of these questions, respondents answered with the following categorical modalities (stated preferences):

1 = extremely risky/unwilling
2 = somewhat risky/unwilling
3 = neither risky nor safe/willing nor unwilling
4 = somewhat safe/willing
5 = extremely safe/willing
9 = don't know*
(*not spontaneously proposed to the interviewees)

Source: Primary data.

Figure 1. Two-dimensional display of the active variables using factors 1 and 2



- LEGEND KEY -

Question Posed to Survey Respondents (from Figure 1):

E. How willing would you be to purchase GM food if it poses a risk of causing allergic reactions for some people?

Respondents answered with the following categorical modalities (stated preferences):

1 = extremely unwilling	4 = somewhat willing
2 = somewhat unwilling	5 = extremely willing
3 = neither willing nor unwilling	9 = don't know*
	(* not spontaneously proposed to the interviewees)

Source: Primary data.

Figure 2. Two-dimensional display of the active variable—*"How willing would you be to purchase GM food if it poses a risk of causing allergic reactions for some people?"*—using factors 1 and 2

(e.g., extremely risky in terms of risk to human health) are located on the left or right extremities of the graphic. The interpretation is that the rejection of GM food, if it poses risks of causing allergic reactions, is widespread among the population (closer to the center of gravity); even those in favor of GM foods tend to be unwilling to consume transgenic foods under this scenario.[9] The graphic representations of factors 1 and 2 are further explained by factor axes created by the MCA.

[9] Note that the curve displayed in figure 2 does not exhibit the usual "horseshoe" shape. This is due to a bad representation of the modality "somewhat willing to consume GM food even if it poses a risk of causing allergic reactions for some people" on the second axis.

Factor Axes

Since factor axes can be considered as summary variables, their interpretation reveals the salient patterns related to the notion of acceptance. The first three axes collectively account for one-third of the total inertia. Even though these three axes appear to be the most important, more dimensions are needed in order to explain the complexity of consumer acceptance of GM foods. In the classification presented later, all axes are used, not just these three. In MCA, the fact that each variable presents different modalities means, when many variables are considered, the percentage of inertia of each factor is small. The three main factors are detailed below.

It is important to determine whether or not a modality is significantly associated with a factor (variables) or a class (individuals), i.e., whether there is a discrepancy of appearance between the modalities in the factor/class. The test-value (TV) method shows the difference is deemed significant, with a level of confidence equal to 95%, if the absolute value of the estimated *TV* is equal to or greater than 1.96. As indicated by the absolute value, *TV* can be positive or negative. The interpretation of the sign depends on whether we consider a factor[10] or a class[11]:

- When modalities are used to characterize a factor, the sign coincides with the coordinate of the modality for the factor. Thus, if a modality has a negative coordinate, then *TV* is negative.
- When modalities are used to characterize a class, a positive sign indicates the modality is over-represented in the class, whereas a negative sign highlights an under-representation.

First Factor Axis

The first factor axis accounts for 13.52% of the inertia. It emphasizes consumer acceptance of GM foods through the attitudes of respondents. There is an ordering along the axis: individuals with an "extreme" rejection of GM foods are plotted on the left side, then moderate opinions, and finally, "extreme" acceptance of GM foods on the right side. Comparing the two extremities of the axis, one side contains all the extreme modalities in favor of GM foods ("extremely"), and on the other side, all the extreme modalities in

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[10] The test statistic for testing the null hypothesis that the projection of modality j on factor axis α is not different than on the other factor axis is the so-called test value (*TV*), expressed as:

$$TV = \hat{\Phi}_{\alpha j} \sqrt{\frac{n - n_j}{(n - 1)n_j}},$$

where $\hat{\Phi}_{\alpha j}$ is the abscissa of category j on factor axis α, n_j is the number of individuals who chose modality j, and n is the total number of individuals. *TV* has a standard normal distribution. For a significance level ($\alpha = 5\%$), the critical value of the test statistics is $Z_{1-\alpha/2} = 1.96$. (For further details, see Lebart, Morineau, and Warwick, 1984.)

[11] For testing the association between modality and class, the test value (*TV*) is given as:

$$TV = \frac{\overline{X}_k - \overline{X}}{S_{\overline{X}_k}},$$

where $\overline{X}_k$ is the mean of modality X in class k, $\overline{X}$ is the mean of modality X in the sample, and $S_{\overline{X}_k}$ is the standard deviation of modality X in class k. The null hypothesis (H_0) is that there is no significant difference between $\overline{X}_k$ and $\overline{X}$. For example, we can use this test to examine if the proportion of men in class 1 is significantly different from the proportion in the sample, i.e., if the modality "male" is characteristic of class 1. Again, *TV* has a standard normal distribution.

disfavor of GM foods. This means that when a respondent supports GM foods, he or she tends to accept all the positions; the contrary is also true. By studying the modalities from both active and illustrative variables associated with this factor, it is possible to characterize the attitudes of rejection and acceptance of GM foods.

The analysis of the illustrative variables (not plotted) reveals that respondents in disfavor of GM foods tend to choose non-GM foods, even when the price associated with the GM counterpart is significantly lower. Those respondents are not too price sensitive, as they consider price to be "extremely unimportant" when deciding whether or not to buy GM foods ($TV = -6.40$). As a consequence, it is not surprising that they prefer mandatory to voluntary labeling ($TV = -2.35$) even if prices are higher by 5% ($TV = -4.11$). This profile of respondents in disfavor of GM foods is also associated with a poor opinion of the U.S. government's performance in food safety ($TV = -3.19$). Last, vegetarians ($TV = -2.80$), respondents indicating zero-consumption expenditures for food away from home ($TV = -2.65$), and African-Americans ($TV = -2.07$) are not positive about GM foods.

Those in favor of GM foods, on the other hand, are more likely to consider both non-GM and GM products as equally good. This absence of differentiation must be linked to apparent higher levels of education (master's degree, $TV = 2.82$) and knowledge (these individuals tend to answer correctly the two questions included in the survey; $TV > 2$ for both), suggesting that the more people know about biotechnology, the more they are in favor of the technology. Given that the products are perceived as being the same (i.e., when they compare two products, GM and non-GM, with the same price, these respondents tend to consider both as equally good), then these individuals tend to choose the cheapest good when price is a decision factor. Furthermore, respondents in favor of GM foods have a high opinion of the U.S. government with regard to its performance in food safety ("excellent performance," $TV = 2.06$).

Second Factor Axis

The second factor represents 11.17% of the information. It contrasts extreme ("extremely") with moderate ("somewhat") modalities, as shown in figure 1. Whereas moderate attitudes are difficult to characterize since they represent the main tendency in the sample, it is possible to find some significant associations with the "extreme" behaviors. Hence, extreme modalities are likely to be linked to a higher level of subjective knowledge (such as "very well informed," $TV = 2.95$). These respondents also have a more extreme attitude regarding the U.S. government's performance in food safety ("poor" and "very poor," respectively, $TV = 2.10$ and 3.62).

The results show that salmon is the only product in the survey significantly associated with extreme attitudes. In addition, respondents are more likely to choose the non-GM product over the GM when the product is salmon, compared to vegetable oil or cornflakes. The following choices between the GM and the non-GM products are noted when they are offered at the same price: 45.1% for non-GM oil, 29.8% for non-GM cornflakes, 59.5% for non-GM salmon when compared to GM-fed salmon, and 68.5% for non-GM salmon when compared to GM salmon. Therefore, respondents are less likely to choose GM salmon or GM-fed than any of the GM plant products included in the study. This finding suggests people are less supportive of the GM technology when it is associated with an animal. This result supports findings reported by earlier research on

public attitudes toward biotechnology indicating consumer acceptance of GM products is affected by factors such as the organisms involved, i.e., plant- or animal-based products (e.g., Hallman et al., 2002; Kinsey and Senauer, 1997).

Finally, "moderate" respondents are more supportive of the mandatory labeling policy of GM foods and are more price sensitive than their "extreme" respondent counterparts.

Third Factor Axis

The third factor, representing 8.7% of the total inertia, highlights the differences between moderately negative attitudes and moderately positive attitudes toward GMOs. In general, respondents moderately in disfavor of GM foods consider themselves to be "very well informed" about GMOs (TV = -3.21) and think that price is "extremely unimportant" when deciding whether or not to buy GM foods. Furthermore, whereas those moderately in favor of GM foods grade the U.S. government highly in food safety ("good," TV = 2.55), the respondents with moderately negative attitudes generally report a "fair" performance (TV = -2.29).

A Consumer Profile

An ascending hierarchical classification is carried out on the individuals described by these factors. For this classification, all the factors created by the MCA are used, not just the three main factors analyzed earlier. Respondents are assigned to a class depending on the answers they chose in the survey. A classification method using four classes is chosen over the usual two classes represented by respondents in favor and disfavor of GM foods in order to decrease the loss of information. Each of the four classes is assigned a name which is deemed to best reflect the overall attitude toward GM foods. These four classes are described below, and their demographic characteristics (age, education level, and income) are provided in table 3.

Class 1: Non-Opponents (61% of the sample)

The name "Non-Opponents" is designated to illustrate the ambivalent position of this class. On the one hand, these consumers are clearly not in disfavor of GM foods since they are willing to consume them. On the other hand, they are not "proponents" in the classical meaning of the term since they do not value GM foods more than non-GM foods. For those reasons, this class is named for its "non-opposition" characteristics. The main attributes of this class are summarized as follows:

- These respondents are characterized by a moderate propensity to consume GM foods. They are "somewhat willing" to consume GM foods (51% of this group, TV = 9.00), and somewhat willing if the amount of pesticide applied to crops is reduced (83% of this group, TV = 11.96).
- Their support for GM foods is primarily due to the potential associated benefits: less pesticide used (TV = 11.96), more nutritious (TV = 8.52). These individuals are mainly interested in health benefits. The only extreme modality significantly associated with this profile is: "extremely willing to purchase GM food if it is more

Table 3. Demographic Characteristics of Survey Respondents by Class

Class/Description	Statistics	Age (years)	Education Level (years)	Income ($ U.S.)
Class 1	▸ Mean	48.4	13.7	70,743
Non-Opponents (61%)	▸ Median	47.0	13.0	50,000
	▸ Standard Deviation	15.9	1.97	77,220
Class 2	▸ Mean	46.9	14.2	88,472
Moderate Opponents (22.7%)	▸ Median	46.0	15.0	65,000
	▸ Standard Deviation	14.8	2.0	82,028
Class 3	▸ Mean	48.3	14.5	51,000
Proponents (4.7%)	▸ Median	48.5	15.0	50,000
	▸ Standard Deviation	13.4	2.3	20,766
Class 4	▸ Mean	52.5	12.7	57,389
Extreme Opponents (11.7%)	▸ Median	49.5	12.5	52,000
	▸ Standard Deviation	18.4	2.0	41,982
Total Sample	▸ Mean	48.0	14.0	72,046
	▸ Median	47.0	13.0	54,000
	▸ Standard Deviation	15.9	5.4	73,992

Source: Primary data.

nutritious" ($TV = 2.20$). In addition, 32% of them ($TV = 3.40$) believe that reducing saturated fat in foods is the most important potential benefit of GM foods. This is in line with consumer behavior theory (Lancaster, 1966; Fishbein, 1967): consumers perceive a product as a bundle of benefits.

- Non-Opponents do not perceive a significant difference between GM and non-GM products. When neither GM nor non-GM products are associated with a specific benefit, respondents tend to answer "both products are equally good" ($TV = 2.20$ for cornflakes and oil). They are more likely to be in favor of the voluntary labeling implemented by the U.S. government ($TV = 2.37$). They think the government has demonstrated a "good" ($TV = 3.02$) if not "excellent" ($TV = 1.66 < 1.96$) performance in food safety.

- Some Non-Opponents would perceive the absence of genetic modification as a benefit if nothing more is associated. Yet, they are likely to change their minds for the GM counterpart when they face a discount (the trend is not significant). The price is an important choice factor, as 81% of respondents consider it to be important ($TV = 2.94$ for "somewhat important" and 2.90 for "extremely important") when deciding whether or not to purchase GM foods.

- Members of this class tend to be less informed than the rest of the sample ($TV = -3.44$ for "very well informed"). As Almås (1997) argues, when somebody believes in "his elders, the chiefs, or the experts," he does not need to choose for himself in difficult situations. They choose for him; he follows them and feels safe. However, Non-Opponents' lack of knowledge on the issue could also be due to a low perceived risk as, according to Cox (1967), consumers' need for information is determined by the perceived risk. If they do not perceive any risk, they do not need to inquire.

- With respect to sociodemographic characteristics, this class (representing 61% of the sample) is difficult to characterize through respondents' personal characteristics. However, it appears African-Americans are less likely to be part of this class, and therefore unlikely to have this profile ($TV = -1.97$).

Class 2: Moderate Opponents (22.7% of the sample)

The main attributes of class 2 are detailed as follows:

- These respondents are "somewhat unwilling" to consume GM foods no matter the arguments mentioned.
- Moderate Opponents consider it extremely important that food products be labeled specifically for GM or non-GM attributes ($TV = 2.63$). They support mandatory labeling (98.3%, $TV = 2.48$).
- Their attitude of moderate opposition is at least partially determined by health concerns. The only "extreme" modality (regarding their acceptance) significantly associated with their profile is "extremely unwilling to purchase GM food if it poses a risk of causing allergic reactions" (56.9%, $TV = 2.56$).
- These respondents have a lower level of confidence in the government than those in class 1. They are likely to consider the U.S. government performs "fairly" with regard to food safety (46.6%, $TV = 2.12$).
- With respect to sociodemographic characteristics, this class is highly represented by those whose employment status is described as technical/sales/clerical (15.5%, $TV = 2.10$) and manager/professional (17.2%, $TV = 1.99$).[12] This class is financially stronger than other classes, with a median income of $65,000 (table 3).[13] Furthermore, these respondents are more likely to be from the Northeastern part of the United States, which would illustrate regional differences.

Class 3: Proponents (4.7% of the sample)

Important Proponent attributes include the following:

- These respondents are "extremely willing" to purchase/consume GM foods (83.3%, $TV = 7.60$). But, in the case where both GM and non-GM products have the same price, these individuals do not appear to be more likely to purchase GM foods than the rest of the sample. Indeed, they consider both products as equally good. If there are price differences, they would choose the cheapest product, revealing these respondents are looking for a benefit. Their choice is then determined by a benefit related to one of the products, such as price.

[12] The following 10 categories describing employment status were proposed to the interviewees: self-employed, education, agriculture, construction, manager/professional, operator/fabricator/laborer, technical/sales/clerical, retired, service, and other.

[13] It should be noted that there were respondents (27%) without income data. The income statistics reported in table 3 were computed only from those respondents who provided income data.

- Proponents consider themselves to be "very well informed" ($TV = 2.80$) and answer correctly the two knowledge questions related to biotechnology ($TV = 2.02$ and 1.34).

- Their sociodemographic characteristics include a seemingly higher education level ($TV = 1.45$ for "master's degree" and 1.27 for "bachelor's degree"; not significant), lower income ($51,000 on average; see table 3), and men representing a large part (50%) of this class ($TV = 1.86$).

Class 4: Extreme Opponents (11.7% of the sample)

These respondents are extremely averse to GM foods, with main attributes including:

- A very high percentage (93.3%) of Extreme Opponents are "extremely unwilling" to consume foods produced with GMOs ($TV = 10.61$), and 56.7% think GM foods are extremely risky for human health ($TV = 7.26$). They remain "extremely unwilling" to consume/purchase any GM products no matter the argument.

- Price is "extremely unimportant" ($TV = 5.4$) in the purchase decision of GM foods, and 66.7% of Extreme Opponents are ready to support GM labeling even if prices were higher by 5% or more.

- These individuals grade the U.S. government poorly in the food safety area ($TV = 3.30$).

- Vegetarians are over-represented in this class ($TV = 2.62$); in other words, vegetarians are found more likely to be Extreme Opponents of GM foods.

- Other sociodemographic characteristics of this class include being older, less educated, and earning lower incomes than the rest of the sample (table 3).[14] These findings are in accordance with previous social studies on risk perception. Results from numerous opinion polls (Peretti-Watel, 2002) suggest risk perception is stronger among people with a lower level of education or the elderly.

Discussion

From the multiple correspondence analysis and hierarchical classification, four distinct attitudes toward GM foods were extracted, confirming that various attitudes toward GMOs can be found within the American population. While the implications of the results are limited by the small sample size, they nevertheless suggest that attitudes are part of a continuum ranging from extreme opposition to extreme acceptance. Clearly, it is too simplistic to consider a population as being composed of consumers either in favor or disfavor of GM foods, since many levels of acceptance exist between these two markers.

[14] This does not mean that vegetarians were less educated or had lower incomes. In fact, when we ran a χ^2 test, we could not reject the independence of vegetarianism and college education. The level of educational attainment was the same between vegetarians and non-vegetarians.

Our findings suggest that people look for incentives. Indeed, acceptance is not synonymous with the purchase of GM foods. From the results of the classification method used for this analysis, proponents of GM foods tend to believe that both GM and non-GM products are equally good, and their choices are then based on a perceived benefit associated with one of the products. These benefits can be a price discount, or a health or environmental attribute. As a consequence, the food industry should highlight the benefits brought by the added GM ingredients if available. In contrast (and quite logically), the biggest threat for GM foods appears to be a perceived risk to human health. The majority of the surveyed households agree they would be unwilling to consume GM food if it posed, for example, a risk of causing allergic reactions for some people. Finally, our results are in accord with James et al. (2002) who suggest that consumers are more interested in the product attributes of a food commodity (such as nutritional value, taste, or theoretical effects on health) than in its process attributes (GM or not).

The confidence people have in the government has also been identified as an important factor associated with consumer acceptance of GM foods (James et al., 2002) The results of MCA and classification show that consumers in disfavor of GM foods tend to hold the government in lower esteem for its performance in the area of food safety. Confidence, as defined by Luhmann (1988), refers to a more or less take-for-granted attitude that the familiar things will remain stable. In fact, public institutions have regulated the risk for people. Trust in abstract systems provides for the security of day-to-day reliability. Consequently, it is not surprising that opposition to GM foods is linked to a weaker confidence in the government in terms of its performance in dealing with food safety.

Furthermore, the results of the MCA and the hierarchical classification show objective and subjective knowledge are important determinants of support for the GM technology: the more informed, the more likely people are to be supportive, as is the case with Proponents (class 3). However, and contrary to House et al. (2004), a respondent's education level is not found to be significantly associated with the level of knowledge (subjective or objective) or acceptance. In our finding, the level of scientific literacy is much more relevant—i.e., whether or not respondents correctly answered the two survey questions dealing with biotechnology. One important implication is that consumers should be provided with more information in order to increase their acceptance, as suggested by Bredahl (1998). Nevertheless, Lewin's (1943) early experiments suggest that a piece of information structured and oriented to stimulate the consumer's aspirations is not sufficient to induce a change in behavior. This notion has been widely examined with focus on the recurrent failures of nutritional information campaigns. In fact, the best way to increase consumer acceptance is to decrease the perceived risk. On that issue, the government plays an important role since it is the entity in charge of the food safety regulation.

It should be emphasized that sociodemographic variables were not found to be very important in our study. This result might be due to a relatively small sample or it might also be due to an overall low perceived risk. Indeed, age is the only variable found to be relevant in the case of a higher perceived risk. As argued by Schilling et al. (2002), GM food is not "a front-runner among issues a typical American tends to think about today." People are often unaware, and therefore do not think about GM food as a high-risk food item.

Based on the results of the hierarchical classification, men appear to be more supportive of GMOs than women. Also, consumer acceptance of GM foods is likely to vary with race and region. A final interesting finding is that people are more supportive of the genetic modification of plants than they are of animals. The acceptance rates for GM-fed and GM-salmon are lower than those found for plant products in this study—vegetable oil and cornflakes.

Concluding Remarks

This study reports results from a U.S. national telephone survey on genetically modified foods. In spite of its small sample (256 respondents), the survey covered 44 states and a fairly representative sample of American food shoppers. The data are analyzed with a multiple correspondence analysis (MCA) and a hierarchical classification method. The use of MCA makes it possible to construct classes based on the simultaneous treatment of multiple questions, thereby enabling us to conduct a much enriched data analysis.

First, four distinct classes of attitudes toward GM foods are extracted: Proponents, Non-Opponents, Moderate Opponents, and Extreme Opponents. The majority of the surveyed population, 66% (comprised of class 1/Non-Opponents and class 3/Proponents), supports GM foods. In the case where both GM and non-GM products are similar (same price, same characteristics), the majority of respondents favor non-GM over GM foods, which is consistent with the literature. However, the results also suggest that at least 5% of the respondents could choose GM over non-GM if a benefit is perceived—for instance, resulting from a reduced usage of pesticides or herbicides. Therefore, the assumption of non-GM being superior to GM from a consumer's acceptance standpoint is incorrect. Some consumers, certainly, would be willing to pay a premium for GM foods in some cases.

Second, the issue of consumer attitudes toward GM foods is found to be more complex than the usual acceptance/rejection contrast. Proponents of GM foods are likely to choose the non-GM alternative if no benefit is perceived, and opponents of GM foods seem to be more extreme in their attitude than the proponents. This analysis has shown that any partition considering only proponents and opponents is too simplistic, since these two classes in combination represent only 17% of our sample. The remainder of the surveyed population, almost four-fifths, is made up of individuals whose opinions are likely to evolve based on perceived risks (such as environmental hazards) and benefits (such as price discount or better nutrition).

Consumers' attitudes toward GM foods in fact are found to comprise a continuum, with attitudes ranging from extreme disfavor to extreme favor. The spread of attitudes is not found to be uniform, with most respondents being in an intermediary position. Our specific recommendations for further research are that the case of the attitude in favor of GM foods be considered and, if possible, the choice of neutrality be permitted in surveys.

The United States has recently enacted voluntary labeling, and the public does not appear to be actively involved in the issue. This strongly suggests that producers and growers can use GM ingredients or seeds without significantly affecting their outcomes in the United States. However, corroborating earlier findings in Canada by West et al. (2002), more than 34% of respondents in our surveyed sample are estimated to be opposed to GM foods. Consumers are concerned about their health and their diet. The

opposition to GMOs by a third of the sample, associated with their support for mandatory rather than voluntary labeling, illustrates the need by some consumers for reassurance, particularly in light of such food scandals as mad cow disease and *E. coli* O157 H:7. Consumers want simple and clear information, easily accessible, assuring them there are no hidden threats in their diets (Fischler, 1990; Noussair, Robin, and Ruffieux, 2002).

As a final recommendation, we stress the need to consider potential foreign markets. For example, despite the European Union's recent revision of its policy regarding GM foods, the majority of the population in that region remains opposed to genetic manipulations. Japan, Taiwan, and Australia (among others) have implemented mandatory labeling, and these markets also represent significant outcomes. A similar study, applied to other markets, would help identify and assess the importance of various target populations.

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