Nutritional Benefits and Consumer Willingness to Buy Genetically Modified Foods

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This study analyzes U.S. consumers' acceptance of genetically modified foods within the ordered-probit-model framework. The willingness to consume three different GM foods is modeled in terms of consumers' economic, demographic, and value attributes. Empirical results indicate that respondents' attitudes and perceptions of biotechnology and their views about various private and public institutions associated with this technology are important determinants of their acceptance of food biotechnology. We find that attitudinal variables have greater influence on the acceptance of food biotechnology than do consumers' economic and demographic attributes. We find significant difference in consumer attitudes between plant- and animal-based bioengineered food products. Compared to plant-based products, there is far less consensus on the acceptance of genetic modification in animals.

Biotechnology is often viewed as the future of food and agriculture. It has the potential not only to meet society's food needs but also bring new and improved food products containing significant health and nutritional benefits. There is growing interest among consumers in these nutritional benefits in foods (Adelaja and Schilling 1999). Despite their promise, genetically modified (GM) foods have so far faced mixed regulatory and public acceptance in the U.S. and elsewhere (Gaskell et al. 1999; Hallman et al. 2002).

Although consumer acceptance of GM foods is critically important for the future of food and agriculture, academic research has yet to fully explore the subject. Most studies have focused on issues such as public awareness and perceptions of this technology and have not formally modeled the acceptance of GM foods as a function of product and consumer attributes (see Bredahl et al., 1998 for a review). A few studies have found evidence that consumer acceptance (or lack thereof) of GM foods is related to their cognitive variables (e.g., level of risk aversion), perceptions of benefits and risks associated with these products (compared to non-GM products), and their views about various institutions associated with biotechnology (Baker and Burnham 2001; Moon and Balasubramanian 2001).

This study contributes to this body of literature by analyzing the willingness to consume GM foods. Recent research has found that public opinion about food biotechnology depends on the type of product (whole or processed food, staple or luxury item, etc.), organisms involved (plants or animals), and the purpose of its use (i.e., whether it brings tangible benefits to society) (Hallman et al. 2002; Hamstra 1998). To explore these issues, we examine consumer acceptance of three different GM food products: orange juice, a fresh food item from plant product; breakfast cereal, a processed food from plant-based products; and hamburger, an animal product. We consider the case where all three GM food products provide omega fatty acid, which is believed to reduce the risk of hearth attacks. This study uses nationwide survey data and an ordered-probit model to analyze the willingness to consume GM foods.

Conceptual Framework

Assume that a consumer faces the choice between a traditional (T) and a GM (G) variety of the same product yielding utilities U_T and U_G, respectively, which are not observable. The observable variables are consumer characteristics (x) and product attribute (a). The utility derived by consumer i from the consumption of the good with attribute a is given by

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(1) $U_{ai} = V_{ai} + \varepsilon_{ai}$, $a = T,G$

where U_{ai} is the latent utility and V_{ai} and ε_{ai} are explainable and random components of U_{ai}. It is assumed that V_{ai} depends on chosen product attribute (a) and consumer characteristics (x).

The choice ordering for the GM (over the non-GM) food, denoted by Y, depends on the extra utility from the GM product relative to that from the non-GM product, denoted by Z_i:

$$(2) \quad Z_i = (V_{Gi} + \varepsilon_{Gi}) - (V_{Ti} + \varepsilon_{Ti}) = (\varepsilon_{Gi} - \varepsilon_{Ti}) - (V_{Ti} - V_{Gi}).$$

Formally, consumer i will be completely unwilling to consume the GM food ($Y_i = 0$) if $Z_i \le 0$, neutral to somewhat willing to consume the GM food ($Y_i = 1$) if $0 < Z_i \le \mu$ (μ is some unknown threshold) and completely willing to consume the GM food ($Y_i = 2$) if $Z_i > \mu$. Since U is random, the choice problem can be expressed in probability terms as

$$\begin{aligned} &P(Y_i = 0) = P[Z_i \le 0] = P[(\varepsilon_{Gi} - \varepsilon_{Ti}) - (V_{Ti} - V_{Gi}) = 0], \\ (3)\quad &P(Y_i = 1) = P[0 < Z_i \le \mu] = P[0 < (\varepsilon_{Gi} - \varepsilon_{Ti}) - (V_{Ti} - V_{Gi}) \le \mu], \\ &P(Y_i = 2) = P[Z_i > \mu] = P[(\varepsilon_{Gi} - \varepsilon_{Ti}) - (V_{Ti} - V_{Gi}) = \mu]. \end{aligned}$$

Under the assumption that ε_i ($\varepsilon_i = \varepsilon_{Gi} - \varepsilon_{Ti}$) follows the standard normal distribution, the above probabilistic model yields the well-know ordered-probit model.

For the empirical analysis, Z_i is modeled as a function of the i^{th} consumer's economic, demographic, and value attributes as

$$(4) \quad Z_i = \hat{\mathbf{a}}'\mathbf{X} + v_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \beta_k x_{ik} + v_i, \; i = 1, 2, \ldots,$$

where x_{ij} denotes the j^{th} attribute of the i^{th} respondent, $\boldsymbol{\beta} = (\beta_0, \beta_1, \ldots, \beta_k)$ is the parameter vector to be estimated, and n is the random error or disturbance term.

Survey Methodology, Variable Definition, and Empirical Model

Data for this study comes from a national telephone survey of U.S. consumers completed during March and April of 2001. A survey instrument was developed to collect information on public perceptions of biotechnology, views about various issues and institutions associated with this technology, attitudes toward GM foods, and socioeconomic attributes of the respondents. The sample targeted a non-institutional U.S. adult civilian population. Using a computer-assisted interview system and a random proportional-probability sampling, a total of 1203 surveys were completed, which represents a response rate of slightly over 50%. Respondents were divided into three equal groups; each third was asked to state their willingness to consume one of the three GM products containing omega fatty acid. However, due to non-response to certain questions, the actual sample sizes used this analysis were as follows: 342 for orange juice, 324 for breakfast cereal, and 330 for Hamburger.

Respondents were asked to indicate their willingness to consume GM foods by responding to the following question: "*Using a scale of 1 to 10, 1 implying no interest and 10 implying fully willing, how willing would you be to consume the GM food (orange juice/breakfast cereal/hamburger) if it tasted and cost the same as the regular (i.e, non-GM) product but had the specific benefit of additional omega fatty acid?"* Using their responses, the dependent variable Y was defined as follows: a respondent was "completely unwilling" ($Y_i = 0$) to consume if his/her willingness to consume was rated between 1 and 4, "neutral to somewhat willing" to consume ($Y_i = 1$) if the willingness to consume was rated between 5 and 7, and "completely willing" ($Y_i = 2$) to consume if the willingness to consume was rated between 8 and 10.

The following empirical equation is specified to model the willingness to consume GM foods:

$$\begin{aligned} (5)\quad Z = {} & \beta_0 + \beta_1 \text{MALE} + \beta_2 \text{WHITE} + \beta_3 \text{YOUNG} + \\ & \beta_4 \text{MATAGE} + \beta_5 \text{LOWEDU} + \\ & \beta_6 \text{HIGHEDU} + \beta_7 \text{MIDINC} + \beta_8 \text{HIGHINC} \\ & + \beta_9 \text{WORSHIP\_NO} + \beta_{10} \text{WORSHIP\_OCC} \\ & + \beta_{11} \text{LIBERAL} + \beta_{12} \text{CONSERV} + \\ & \beta_{13} \text{CONF\_SC} + \beta_{14} \text{SKEP\_CO} + \\ & \beta_{15} \text{SKEP\_REGUL} + \beta_{16} \text{TRSTGVT} + \\ & \beta_{17} \text{CHKLABEL} + \beta_{18} \text{RURAL} + \beta_{19} \text{WEST} \\ & + \beta_{20} \text{SOUTH} + \beta_{21} \text{HIGHSCORE} + v \end{aligned}$$

where the independent variables are defined as follows:

Gender: The dummy variable *MALE* is assigned a value of 1 if the respondent is male and 0 otherwise (i.e., female). The sample of respondents is evenly divided across gender.

Race: The variable *WHITE* is assigned a value of 1 if the respondent is White (Caucasian) and 0

otherwise. About 80% of the respondents are White and 20% belong to other races.

Age: Respondents are classified into three age groups: *YOUNG* (age ≤35 years), *MIDAGE* (age 35–54 years), and *MATAGE* (age ≥55 years). About 32% of those surveyed were classified as *YOUNG*, 46% *MIDAGE*, and 22% *MATAGE*.

Education: Respondents are classified into three groups: *LOWEDU* (high school diploma or less), *MIDEDU* (some college education but less than 4-year college degree), and *HIGHEDU* (4-year college degree or graduate education). About 37% of respondents belong to Category 1, 26% to Category 2, and 37% to Category 3.

Income: Three annual income levels are identified: *LOWINC* (below $35,000), *MIDINC* ($35,000–$75,000), and *HIGHINC* ($75,000 or more). About 30% of the respondents belong to *LOWINC*, 43% belong to *MIDINC*, and 27% belong to *HIGHINC*.

Religiosity: To examine if consumers' religious values affect their acceptance of GM foods, respondents are classified into three groups: *WORSHIP_REG* (attends house of worship several times month or more), *WORSHIP_*OCC (attends house of worship at least once a month), and *WORSHIP_NO* (never attends a house of worship). About 48% of the respondents belong to Group 1, 25% to Group 2 and 27% to Group 3.

Social/Political View: Three groups of respondents are identified on the basis of their self-reported sociopolitical views: *CONSERV* (self-described conservatives), *LIBERAL* (self-described liberals), and *CENTRIST* (between liberals and conservatives). About 27% of the respondents are conservatives, 21% are liberals, and 52% are centrists.

Confidence in Scientists: The dummy variable *CONF_SC* is assigned a value of 1 if the individual somewhat or strongly agrees with the statement, "Scientists know what they are doing, so only moderate regulation on GM products is probably necessary," and 0 otherwise. About one-third of the respondents expressed such confidence in scientists associated with biotechnology.

View about Biotechnology Companies: The binary independent variable *SKEP_CO* is assigned a value of 1 if the respondent *somewhat* or *strongly agrees* with the statement, "Companies involved in creating GM crops believe profits are more important than safety," and 0 otherwise. About 67 of the respondents expressed a skeptical view of biotechnology companies.

Confidence in Government Regulation: The dummy variable *SKEP_REGUL* is assigned a value of 1 if the individual somewhat or strongly agrees with the statement, "Government does not have the tools to properly regulate GM foods," and 0 otherwise. About 58% of the respondents indicate lack of confidence in government's ability to properly regulate GM foods.

Trust in Government: The variable *TRSTGVT* is given a value of 1 if the individual somewhat or strongly agrees with the statement "Government regulators have the best interest of the public in mind," and 0 otherwise. Only about 40% indicated that they had such trust in government.

Rural vs. Urban Consumers: Two groups of consumers are identified by defining a dummy variable *RURAL*=1 if a respondent lives in a small town or rural area and 0 otherwise. About 47% of the respondents are from small towns or rural areas.

Regional Distribution: Regional differences in acceptance of GM foods are explored by grouping consumers into three groups: *EAST* (those from eastern states), *WEST* (those from Western and Midwestern states), and *SOUTH* (those from south). Midwest was merged with west since dummy for Midwest was correlated with other regions.

Knowledge of Science: Survey participants were asked to answer 10 basic questions on science relating to biotechnology. Respondents are classified *LOWSCORE* (as those correctly answering less than 5 questions), *MIDSCORE* (those correctly answering 5–7 questions), and *HIGHSCORE* (those correctly answering 8 or more questions).

The empirical model also includes a dummy independent variable *CHECKLABEL* = 1 for respondents who said that they would check food labels for GM ingredients, and 0 otherwise.

Model Estimation and Empirical Results

Three ordered-probit models (one for each GM food product) were estimated using the Maximum-Likelihood (ML) procedure. The estimated model coefficients, their associated t-ratios, and model-summary statistics are reported in Table 1. The coefficients of most demographic variables are not statistically significant, while those of attitudinal and value characteristics are significant in most cases.

Table 1. Estimated Model Coefficients and t-ratios: Ordered-Probit Models.

	Orange Juice		Breakfast Cereal		Beef Hamburger	
	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio
CONSTANT	1.153	3.53	0.311	0.87	1.320	3.56
MALE	-0.060	-0.42	0.092	0.62	-0.149	-1.02
WHITE	0.020	0.13	0.426	2.55*	-0.092	-0.54
YOUNG	0.075	0.48	0.313	1.86**	0.548	3.13**
MATAGE	-0.217	-1.17	-0.381	-2.07**	-0.196	-1.01
LOWEDU	0.086	0.58	-0.139	-0.81	0.001	0.01
HIGHEDU	-0.347	-1.44	0.284	1.26	-0.294	-0.98
LOWINC	0.179	1.05	0.194	1.06	0.259	1.41
HIGHINC	0.075	0.45	0.241	1.14	0.005	0.03
LOWSCORE	-0.321	-2.00*	-0.190	-1.11	-0.298	-1.68**
HIGHSCORE	-0.359	-2.16*	-0.262	-1.32	-0.341	-2.02*
RURAL	-0.009	-0.06	0.370	2.38*	0.060	0.42
WEST	-0.095	-0.48	0.070	0.32	-0.145	-0.63
SOUTH	0.329	2.10*	0.107	0.64	0.109	0.69
WORSHIP_OCC	0.216	1.42	-0.173	-1.03	0.655	3.74*
WORSHIP_NO	0.115	0.72	-0.178	-0.92	0.331	1.82**
LIBERAL	-0.237	-1.66**	-0.028	-0.15	-0.191	-1.68**
CONSERV	-0.179	-1.27	0.027	0.15	-0.282	-1.86**
CONF_SC	0.105	0.75	0.290	1.90**	0.115	0.73
SKEP_CO	0.027	0.19	-0.313	-2.02*	0.097	0.66
SKEP_REGUL	0.032	0.22	-0.022	-0.14	-0.065	-0.41
TRSTGVT	0.491	3.56*	0.534	3.52*	0.383	2.47*
CHKLABEL	-0.620	-4.32*	-0.716	-4.49*	-0.661	-3.68*
μ	1.307	13.52*	1.4211	13.83*	1.484	6.79*
LL Function	-323.59		-315.62		-305.62	
Restricted LL	-357.30		-338.32		-345.32	
Chi-Square (df = 22)	67.41		45.40		79.40	
DF	22		22		22	
Prediction Success	52%		52%		64%	

* significant at .10 level.
** significant at .05 level.

Specifically, the estimated results show no difference between males and females in terms of their willingness to consume GM foods. While there is no difference among consumers of different age groups in terms of their acceptance of GM orange juice, younger consumers (age less than 35 years) are more willing to consume breakfast cereal containing GM ingredients than are those in the 35–54 age group. Consumers 55 years or older are less willing to consume GM beef hamburger than are those in the 35–54 age group.

The estimated model coefficients suggest no difference in the willingness to consume GM foods among consumers in different income and education groups. However, acceptance of GM foods appears to be related to consumers' knowledge of science: compared to those with moderate level of knowledge, those with lower and higher levels of knowledge seem to be less inclined to consume GM foods. This is reflected in the negative signs of both *LOWSCORE* and *HIGHSCORE* in two of the three models, breakfast cereal being the exception.

Consumers who reside in the rural areas are more willing to consume GM breakfast cereal than are those living in the urban areas, while there is no difference between these rural and urban consumers in terms of their willingness to consume

Table 2. Marginal Effects of Independent Variables on the Willingness to Consume GM Foods.

	Orange Juice		Breakfast Cereal		Beef Hamburger	
	Marginal Effect	t-ratio	Marginal Effect	t-ratio	Marginal Effect	t-ratio
CONSTANT	na	na	na	na	na	na
MALE	-0.023	-0.47	0.033	0.61	-0.059	-1.45
WHITE	0.007	0.13	0.153	2.54*	-0.036	-0.75
YOUNG	0.029	0.44	0.113	1.87**	0.216	3.99*
MATAGE	-0.083	-1.12	-0.137	-1.80**	-0.077	-1.33
LOWEDU	0.033	0.55	-0.050	-0.80	0.000	0.01
HIGHEDU	-0.132	-1.45	0.102	1.13	-0.116	-1.78**
LOWINC	0.068	1.15	0.070	1.15	0.102	1.91**
HIGHINC	0.028	0.40	0.087	1.21	0.002	0.03
LOWSCORE	-0.122	-1.81**	-0.069	-1.07	-0.117	-2.36*
HIGHSCORE	-0.137	-1.75*	-0.094	-1.33	-0.134	-2.22*
RURAL	-0.004	-0.062	0.133	2.19*	0.024	0.56
WEST	-0.036	-0.46	0.025	0.34	-0.057	-0.97
SOUTH	0.125	2.10**	0.038	0.61	0.043	0.91
WORSHIP_OCC	0.082	1.24	-0.062	-1.09	0.258	5.54*
WORSHIP_NO	0.044	0.63	-0.064	-1.06	0.130	2.72*
LIBERAL	-0.090	-1.70**	-0.010	-0.14	-0.075	-1.60
CONSERV	-0.068	-1.12	0.010	0.16	-0.111	-2.28*
CONF_SC	0.040	0.65	0.104	1.75**	0.095	1.99*
SKEP_CO	0.010	0.18	-0.113	-2.05*	0.038	0.85
SKEP_REGUL	0.012	0.22	-0.008	-0.14	-0.025	-0.57
TRSTGVT	0.187	3.38*	0.192	3.60*	0.151	3.39*
CHKLABEL	-0.236	-3.23*	-0.258	-4.67*	-0.261	-5.46*

Note: Standard errors of the marginal effects are obtained by bootstrapping methods using 250 replications.
*significant at .10 level.
**significant at .05 level.

GM orange juice and beef hamburger. There is no strong evidence to suggest significant regional differences in consumer acceptance of GM foods; only in the case of orange juice do we find that consumers from the southern states are more willing to consume GM food, relative to those in the eastern states.

The estimated coefficients of *WORSHIP_OCC* and *WORSHIP_NO* are statistically insignificant in the models for orange juice and breakfast cereal, whereas they are positive and significant in the model for beef hamburger. This suggests that consumers' religiosity is negatively related to their acceptance of animal-based GM products whereas it has no influence on their acceptance of plant-based GM products.

Relative to the centrists, self-described liberals are less willing to consume two of the three products—the effect is insignificant in the model for breakfast cereal—while conservatives are less willing to consume GM hamburger. One possible way to reconcile these findings is that while social liberals oppose agricultural technology because of environmental concerns, conservatives oppose its use in animals on religious grounds. Confidence in scientists has positive effects and negative views about biotechnology companies have negative effects on the acceptance of GM breakfast cereal; these variable have insignificant effects in other two models. While lack of confidence in regulators has no effect, trust in government has significant positive influence on the willingness to consume in all three models. Finally, those who check food labels at the time of food purchase are significantly less likely to consume any GM foods.

The estimated-likelihood functions and likeli-

hood ratio based chi-square tests of model significance indicate that all three models have significant explanatory power. These models correctly predict between 52 percent and 64 percent of the responses.

The estimated marginal effects and the associated t-ratios are presented in Table 2. Since we are interested in the willingness to consume GM foods, we report the marginal effects for the category "Completely Willing" (Y = 2). These estimates suggest that the largest marginal effects are associated with the variable *CHKLABEL*: those who check food labels during purchase are about 25 percent less likely to consume GM foods. Trust in government also has quite large marginal effects on the dependent variable. Consumers' age, religiosity, and knowledge of science seem to have important marginal effects on the acceptance of GM foods. In general, demographic variables have smaller marginal effects than do attitudinal variables on consumer acceptance GM foods.

Conclusions

This study analyzes the consumer acceptance of food biotechnology where GM foods added nutritional benefit. Specifically, it examines the relationship between the willingness to consume GM foods and consumers' economic, demographic, and value attributes. Empirical results indicate that consumers' attitudes and perceptions towards biotechnology, their views about various private and public institutions associated with this technology, and their personal values are important determinants of their acceptance of GM foods. We find that attitudinal variables have greater influence on the acceptance of GM foods than do consumers' economic and demographic attributes. There is some indication that young consumers are more likely to accept GM foods. However, there is no difference across genders or income classes and very little evidence to suggest difference across various regions of the country. Our results also suggest that consumer attitudes do not vary widely when the GM food is a plant-based product; however, there is major difference of opinion about products based on genetic modification of animals. This study finds that public trust and confidence in public and corporate institutions associated with biotechnology and consumers' knowledge of basic science are critically important for wide acceptance of food biotechnology. Sound science is necessary but not sufficient to ensure consumer acceptance of GM. Finally, as GM products with tangible consumer benefits appear in the marketplace, public perceptions of risk and benefits of GM foods, and hence the acceptance of these foods, are likely to change in the future.

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