Public Perceptions of Biotechnology and Acceptance of Genetically Modified Food

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Public debate on biotechnology is embroiled in controversy over the risks and benefits associated with this emerging technology. Using data from a national survey, this study analyzes public acceptance of biotechnology in food production. Empirical results suggest that while there is general optimism about biotechnology and support for its use in plants, public approval of its use in animals is perhaps more limited. Younger and more-educated individuals are generally more supportive of biotechnology. Attitudes toward biotechnology differ substantially between males and females, and between whites and non-whites. While people's religious and social views and confidence in scientists, corporations, and government have significant influences, income and regional differences do not have significant effects on public acceptance of biotechnology.

Biotechnology is viewed by many as the frontier of the next revolution with enormous social and economic consequences. Genetic modification of plants and animals has the potential to revolutionize the way society organizes its production and distribution of food, fiber, and feeds. With billions of dollars already invested in research and product development, some products of biotechnology are already in the marketplace. Science and industry are poised to bring consumers a wide variety of genetically modified (GM) products that have the potential for meeting basic food needs as well as for delivering a wide range of benefits.

However, public perception of biotechnology and approval of its use in food production have been mixed in the United States and elsewhere (Gamble et al. 2000; Hoban 1999; Kelley 1995; Macer et al. 1997; Hallman et al. 2002). Public debate on the subject is embroiled in the controversy over the risks and benefits of GM products. Supporters of biotechnology highlight the potential benefits to society via reduction of hunger, prevention of malnutrition, cure of diseases and promotion of health, and quality of life (Isserman 2001). Opponents view its use as an unnecessary interference with nature that has unknown and potentially disastrous interactions with human genetics and natural ecosystems (Nelson 2001).

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Genetically modified crops have already entered the U.S. food supply chain without evoking major public resistance. Public concerns about biotechnology appear to be limited to a small number of interest groups (Nelson 2001). In fact, Hoban (1998) reported broad support among consumers for biotechnology use in food production, although other studies report a more mixed reaction among the public on this issue (Miranowski 1999; Josling et al. 1999; Hallman et al. 2002). In contrast, until recently Europe imposed quite restrictive regulations on GM crops in any portion of their food chain (Grossman and Endres 2000). In the United Kingdom there were multiple incidents of protestors damaging GM crops (Grossman and Endres 2000; Juanillo 2001). The recent rejection by Zambia of U.S. food aid containing GM corn exemplifies this opposition to GM foods in other countries. Consumer concerns have made food companies reluctant to use GM food products (McDonalds and Frito-Lay have refused to use GM potatoes).

While some are opposed to biotechnology, alleging (perceived) risks to humans and the environment, others oppose it on moral and ethical grounds. Some oppose the concept of genetic engineering, particularly gene transfer across species, arguing that it is tantamount to "playing God" or a violation of the "Law of Nature." Since genes are naturally occurring entities, many find the practice of granting patent rights on genetic discoveries and processes ethically untenable. Some are concerned that biotechnology can lead to permanent dependency of farmers on the multinational seed and chemical companies. Others are worried that the spread of this technology will benefit only the industrialized countries at the expense of the third world (Junne

1991), although there is disagreement on this issue (e.g., Watanabe 1985).

Scientific challenges notwithstanding, public acceptance of the use of biotechnology in food production remains a critical factor that will affect the future of agricultural biotechnology. Despite the critical importance of the subject, only a handful of studies have explored the issue. Moon and Balasubramanian (2001) found that public acceptance of agricultural biotechnology was influenced not only by their perceptions of risks and benefits of GM products but also by their moral and ethical views. Furthermore, consumers' views about corporations, knowledge of science, and trust in government had significant influence on their acceptance of biotechnology. Baker and Burnham (2001) found that consumers' cognitive variables (e.g., opinions about GM products or levels of risk aversion) were important determinants of their acceptance of food containing GM products, whereas the socio-economic variables were not significant.

This study analyzes how public acceptance of the use of biotechnology is related to the consumers' economic, demographic, and value attributes. First, consumers' acceptance of biotechnology is examined by modeling their views about the potential of biotechnology to improve the quality of human life. Some previous studies have found that public reception of biotechnology depends on, among things, whether it involves plants or animals (Hallman et al. 2002; Hamstra 1998). To explore this issue further, this study analyzes and compares the effects of consumers' socio-economic and value characteristics on their approval of the use of biotechnology in plants and in animals.

This study examines the relationship between consumers' approval of food biotechnology and their economic, demographic, and value attributes. This analysis contributes to a better understanding of public attitudes about biotechnology and willingness to accept GM food products. It also may help companies involved in the manufacturing and marketing of food in developing a profile of consumers most likely to accept GM food. Results of this study can be useful for various institutions associated with food biotechnology in identifying consumer concerns and in formulating appropriate private and public policies pertaining to the use of genetic technologies in agriculture and food production.

Conceptual Framework

The purpose of this study is to identify and estimate the influence of consumers' socio-economic and value attributes on their perceptions of biotechnology and acceptance of its use in plants and animals, and to develop a profile of likely consumers of GM food products. It is assumed that a consumer's attitude toward agricultural biotechnology in general and GM foods in particular is determined by his or her perceptions of risks and benefits of this technology. The perceived risks arise from the uncertainty about the safety of GM foods as well as the potential negative social and environmental effects of biotechnology. The benefits may include potential nutritional, economic, and environmental benefits (e.g., reduced pesticide use to grow crops). A consumer's acceptance of biotechnology will ultimately depend on his or her perception of the *net benefit*—the difference between benefits and risks—of this technology.

Let Z_i denote consumer i's perceived net benefit associated with the use of biotechnology in agricultural and food production. However, people with different personal attributes may hold different views about the risks and benefits of biotechnology. Accordingly, Z_i is modeled as a function of the i^{th} consumer's economic, demographic, and value attributes as follows:

$$(1)\quad Z_i = \boldsymbol{\beta}'\mathbf{X} + \nu_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_k x_{ik} + \nu_i, \quad i = 1, 2, \ldots, n$$

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 ν is the error-disturbance term. Consumer i's attitude toward biotechnology can be modeled in terms of the net benefit (Z_i) as follows. Consumer i will *strongly disapprove* of food biotechnology if Z_i is lower than some threshold negative value (i.e., $Z_i \le -\mu_1$), *somewhat disapprove* of this technology if Z_i is negative but greater than $-\mu_1$, *somewhat approve* of the use of this technology if Z_i is positive but lower than some threshold positive value (i.e., $0 \le Z_i \le \mu_2$), and *strongly approve* of food biotechnology if Z_i is greater than μ_2. Formally, consumer i's attitude toward food biotechnology (denoted by Y_i where Y = 0 implies *strongly disapprove*, Y = 1 implies *somewhat disapprove*, Y = 2 implies *somewhat approve*, and Y = 3 implies *strongly approve*) can be expressed in probability terms as follows:

$$
(2)\quad \begin{aligned} P(Y_i = 0) &= P[Z_i \le -\mu_1], \\ P(Y_i = 1) &= P[-\mu_1 < Z_i \le 0], \\ P(Y_i = 2) &= P[0 < Z_i \le -\mu_2], \\ P(Y_i = 3) &= P[Z_i > -\mu_2], \end{aligned}
$$

Under the assumption that the error term in equation follows the standard normal distribution, the above probabilistic model yields the well known ordered probit model. In this setting, the probabilities that $Y_i = 0$, 1, 2, and 3 are given by:

$$
(3)\quad \begin{aligned} P(Y_i = 0) &= \Phi(-\mu_1 - \mathbf{ß}'\mathbf{X}_i), \\ P(Y_i = 1) &= \Phi(-\mathbf{ß}'\mathbf{X}_i) - \Phi(\mu_2 - \mathbf{ß}'\mathbf{X}_i), \\ P(Y_i = 2) &= \Phi(\mu_2 - \mathbf{ß}'\mathbf{X}_i) - \Phi(-\mathbf{ß}'\mathbf{X}_i), \\ P(Y_i = 3) &= 1 - \Phi(\mu_2 - \mathbf{ß}'\mathbf{X}_i), \end{aligned}
$$

where Φ is the cumulative function of the standard normal distribution. This model is chosen because the dependent variable is discrete in nature and has a natural ordering. The β-vector and the μs can be jointly estimated using the maximum-likelihood (ML) procedure which yields consistent and asymptotically efficient estimators. The marginal effects of the independent variables can be estimated using the estimated coefficients of the model (Greene 2002).

Survey Methodology, Variable Definition, and the Empirical Model

The data used in this study were obtained via a national telephone survey of U.S. consumers. A survey instrument was developed at the Food Policy Institute at Rutgers University to gather information on public attitudes toward food biotechnology. Specifically, the survey was designed to gather information on public awareness of various issues pertaining to the use of biotechnology in food production, public approval of the use of biotechnology in plants and animals, and public views about various private and public institutions associated with biotechnology research and product development. The survey also sought information on the respondents' economic, demographic, and value attributes. These included respondents' age, gender, ethnicity, education, income, family size, employment status, religiosity and political ideology as well as their views about scientists, companies and government regulators associated with food biotechnology.

The survey was conducted in March and April 2001 by American Opinion Research, a Princeton, New Jersey-based public-polling firm. The targeted sample frame for the survey was the non-institutional U.S. adult civilian population (18 years or older). A random proportional-probability sample drawn from the more than 97 million telephone households in the United States was purchased from Survey Sampling, Inc. The objective was to attain a sample size of 1200 to achieve a sampling error rate of ±3 percent. Quotas were set to ensure a balanced representation of male and female individuals. In addition, careful efforts were made to ensure that the sample drawn for this study was representative of the U.S. population.

Each working telephone number was called a maximum of five times, at different times of the week, in order to reach people who were infrequently at home or were hard to reach. A computer-assisted telephone interview (CATI) system was used to complete the survey. While 1203 respondents completed the questionnaire, another 1231 individuals either refused to participate or terminated the interview before completing it. This gave us a response/cooperation rate of about 50 percent[1]. However, responses to some of the questions in the survey were not usable for the analysis, thus excluding some respondents from the sample during empirical analysis. As a result of excluding these respondents, a total of 978 completed questionnaires were used for empirical analysis.

In one part of the survey, respondents were asked a series of questions regarding their views about biotechnology and the extent to which they approved of its use in plants and animals. Specifically, each respondent was asked to express his or her opinion about this technology by responding to the following questions:[2]

[1] However, if the response rate was defined as the total number of completed surveys divided by the total number of in-frame sample observations (i.e., the number of household telephone numbers that the CATI system attempted to call), the resulting response rate would be about 27 percent. The difference between this definition of response rate and the one reported in the text is due to the fact that the latter excludes cases such as respondents with language problems, calls picked-up by answering machines, and unanswered telephone calls.

[2] In addition to the four possible responses listed, respondents were allowed to choose the option "not sure." Less than 0.1 percent of the respondents refused to answer Question 1, and none refused to answer Questions 2 and 3. Individuals who responded "not sure" were excluded from the empirical analysis.

1. "From what you know or have heard, do you think genetic modification will make the quality of life for people such as yourself better or worse?" (Possible responses were "much better," "somewhat better," "somewhat worse," or "much worse.")
2. "In general, do you approve of creating hybrid plants using genetic modification?" (Possible responses were "strongly approve," "somewhat approve," "somewhat disapprove," or "strongly disapprove.")
3. "In general, do you approve or disapprove of creating hybrid animals using genetic modification?" (Possible responses were "strongly approve," "somewhat approve," "somewhat disapprove," or "strongly disapprove.")

The first question elicited consumers' broad view about the potential of agricultural biotechnology to improve the overall quality of human life. The idea here is that an individual who feels biotechnology will improve the quality of his or her life is more likely to approve of its use. The dependent variable Y (representing *approval of food biotechnology*) was defined as follows: $Y_i = 0$ if the response to Question 1 was "much worse," Y = 1 if the response was "somewhat worse," Y = 2 if the response was "somewhat better," and Y = 3 if the response was "much better."

The other two questions were designed to explore whether there were significant differences in public acceptance of the use of genetic technologies in plants and animals for food production. In each of these two cases the dependent variable was defined as follows: Y = 0 if the response was "strongly disapprove," Y = 1 if the response was "somewhat disapprove," Y = 2 if the response was "somewhat approve," and Y = 3 if the response was "strongly approve."

The model explanatory variables included the economic, demographic, and value attributes of the respondents. These variables were selected based on recent studies of public attitudes toward agricultural biotechnology (see Hallman et al. 2002 for a broad overview). The specific definitions of the independent variables and the rationale for their inclusion in the empirical model are provided below.

Age: In order to examine how public approval of food biotechnology varies across consumers of different ages, four separate age groups are identified: below 35 years (*YOUNG*), between 35 and 44 years (*MIDAGE1*), between 45 and 54 years (*MIDAGE2*), and 55 years or more (*MATAGE*). About 31 percent of the respondents belong to Group 1, 22 percent belong to Group 2, 21 percent belong to Group 3, and the remaining 26 percent belong to Group 4. Although there is no *a priori* expectation as to how public support for biotechnology would vary among different age groups, some studies found greater support for biotechnology among younger consumers.

Income: In order to explore how pubic approval of food biotechnology is related to their income, four different (annual) income levels are identified: below $35,000 (*LOWINC*), between $35,000 and $50,000 (*MIDINC1*), between $50,000 and $75,000 (*MIDINC2*), and $75,000 or more (*HIGHINC*). About 32 percent of the respondents have income less than $35,000, 18 percent between $35,000 and $50,000, 24 percent between $50,000 and $75,000, and the remaining 25 percent have income of $75,000 or more. No *a priori* assumption is made about the effect of income on an individual respondent's approval of the use genetic technology in agricultural and food production.

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 almost evenly divided across gender. No *a priori* assumption is made regarding the effect of gender variation on the dependent variable.

Race: Respondents are classified into two groups on the basis of their race or ethnicity. Accordingly, a dummy independent variable *WHITE* is defined by assigning a value of 1 if the respondent is white (Caucasian) and 0 otherwise (i.e., all other racial or ethnic backgrounds). About 80 percent of the respondents are white; the remaining 20 percent belong to other races. The effect of this variable on the dependent variable is an empirically open question.

Political Ideology: As was discussed earlier, biotechnology is often criticized for its possible negative social and environmental impacts. Since liberals and conservatives often disagree on these issues, respondents' political ideology is included in the empirical model as an independent variable. Respondents are classified into three groups on the basis of their self-reported ideology: conservative (*CONSER*), liberal (*LIBERAL*), and between liberal and conservative (*CENTRIST*). About 28 percent of the respondents identified themselves as conserva-

Table 1. Descriptive Statistics of Explanatory Variables Used in the Analysis.

Variable	Description of variable	Mean	Std. dev
YOUNG	1= age less than 35 years; 0 = otherwise	0.31	0.46
MIDAGE1	1 = age is between 35 and 44 years; 0 = otherwise	0.22	0.43
MIDAGE2	1 = age is between 45 and 54 years; 0 = otherwise	0.21	0.41
MATAGE*	1 = age 55 years or higher ; 0 = otherwise	0.26	0.44
MALE	1 = respondent is male; 0 = otherwise	0.49	0.50
WHITE	1 = respondent is white (Caucasian); 0 = otherwise	0.80	0.40
HISCHOOL	1 = education up to high school; 0 = otherwise	0.38	0.49
SCOLL	1 = some college but less than 4-year college degree; 0 otherwise	0.28	0.46
COL_4YR	1 = 4-year college degree; 0 = otherwise	0.21	0.41
GRAD*	1 = graduate degree; 0 = otherwise	0.13	0.33
LOWINC	1 = (annual) income less than $35,000; 0 = otherwise	0.32	0.46
MIDINC1	1 = (annual) income between $35,000 and $50,000; 0 = otherwise	0.18	0.39
MIDINC2	1 = (annual) income between $50,000 and $75,000; 0 = otherwise	0.24	0.43
HIGHINC*	1 = (annual) income greater than $75,000; 0 = otherwise	0.25	0.33
LIBERAL	1 = identifies himself/herself as liberal; 0 = otherwise	0.21	0.40
CONSERV	1 = identifies himself/herself as conservative; 0 = otherwise	0.28	0.45
CENTRIST*	1 = identifies him/herself inbetween; 0 = otherwise	0.51	0.50
WORSHIP_NO	1 = never attends church (or other house of worship); 0 = otherwise	0.24	0.43
WORSHIP_OCC	1 = attends church (or other house of worship) less than once a month to at least once a month; 0 = otherwise	0.28	0.44
WORSHIP_REG*	1 = attends church (or other house of worship) at least once a week to several times a month; 0 = otherwise	0.48	0.50
SKEP_CO	1 = holds skeptical view of biotech companies; 0 = otherwise	0.68	0.46
CONF_SC	1 = has confidence in scientists involved in biotech research and product development; 0 = otherwise	0.36	0.48
GVT_REGUL	1 = has confidence in the ability of regulators; 0 = otherwise	0.65	0.48
TRUST_GVT	1 = trusts regulators to do common good; 0= otherwise	0.40	0.49
GMQUIZ	Number of correct responses to 10 questions on science	6.36	1.80
RURAL	1 = if respondent lives in small town or rural area; 0 = otherwise	0.48	0.50
SUBURB	1 = if respondent lives in suburban area; 0 = otherwise	0.22	0.41
CITY*		0.30	0.46
FAMSZ	Number of people in the household	3.21	2.05
MARRIED	1 = married; 0 = otherwise	0.60	0.49
EMPLOYED	1 = employed full-time; 0 = otherwise	0.70	0.46

* Implies that the variable was dropped during estimation to avoid dummy variable trap.

tive, 21 percent as liberal, and the remaining 51 percent as centrist. There is no *a priori* expectation about the effect of this variable on the dependent variable.

Education: Although some studies have found more-educated individuals to be more supportive of food biotechnology (Hill et al. 1998), the evidence is far from conclusive (House et al. 2002). To examine this issue, respondents are classified into the following four categories: high school diploma or less (*HISCHOOL*); some college, but less than a 4-year college degree (*SCOLL*); 4-year college degree (*COL_4YR*); and graduate degree (*GRAD*). About 38 percent of the respondents have a high school diploma or less, 28 percent have some college education but not a 4-year degree, 21 percent have a 4-year college degree, and the remaining 13 percent have a graduate degree.

Religion: As was discussed earlier, biotechnology is often criticized on religious or moral grounds. Such opposition is not specific to any particular religion. Rather, it reflects the conflict between mainstream religious beliefs and the very concept of genetic modification of living organisms. To explore the influence of a person's religiosity on his or her attitude toward food biotechnology, respondents' religiosity is included in the model as an independent variable which is measured by their attendance at church or other similar house of worship. Respondents are classified into three groups: those who regularly (once a week to several times a month) attend a church or other house of worship (*WORSHIP_REG),* those who occasionally attend a church or other house of worship (*WORSHIP_OCC*), and those who never attend church or other house of worship (*WORSHIP_NO*). Approximately 48 percent of the respondents are regular worshipers, 28 percent occasional worshipers, and the other 24 percent report that they never attend a church or other house of worship. *A priori*, it is expected that more-religious individuals are less likely to approve of food biotechnology.

Family Size: In order to examine whether the presence of children in the household affects a person's approval of food biotechnology, family size (denoted by *FAMSZ*) is included as an explanatory variable in the model. The number of people in the household measures family size. The average household in the sample has 3.2 members. No particular effect of this variable on the dependent variable is expected *a priori*.

Employment Status: To explore if a person's employment status is related to his or her view about food biotechnology, the model includes a dummy independent variable *EMPLOY* that is assigned a value of 1 if the individual holds a full-time job and 0 otherwise (student, retired, unemployed, homemaker, etc.). No particular effect of this variable on the dependent variable is envisioned.

Marital Status: To examine if a person's marital status is related to his or her view about food biotechnology, the model includes a dummy independent variable *MARRIED* that is assigned a value of 1 if a respondent is married and 0 otherwise (i.e., single, separated, or widowed). About 60 percent of the respondents belong to the first category, and the other 40 percent belong to the second category. No specific relationship between a person's marital status and his or her views about food biotechnology is expected *a priori*.

Place of Residence: To account for potential rural-urban differences in the acceptance of food biotechnology, respondents' place of residence is included in the empirical model. Respondents are classified into the following three groups: those who live in small towns and rural areas (*RURAL*), those who live in suburban areas (*SUBURB*), and those who live in large and medium cities (*CITY*). About 47 percent respondents are from small towns and rural areas, 22 percent from suburban areas, and the other 31 percent are from large and medium cities. The effect of this variable on the dependent variable is an empirically open issue.

Views about Corporations: Consumer perceptions of food biotechnology may depend on their views of the biotechnology industry and this in turn may affect their approval of the use of this technology in food production. To examine such a possibility, the empirical model includes a dummy independent variable *SKEP_CO* that takes 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 two-thirds of the survey participants are found to be skeptical about biotechnology companies.[3]

[3] For the attitudinal questions, the possible responses were "strongly agree," "somewhat agree," "somewhat disagree," or "strongly disagree." In addition, participants were allowed to respond "not sure." These individuals and those who refused to answer were excluded from the analysis.

Confidence in Government Regulation: Since government regulators are generally responsible for ensuring the safety of GM products, consumer acceptance of food biotechnology may depend on confidence in government regulators. To explore this issue, the empirical model includes a dummy independent variable *SKEP_REGUL* that takes a value of 1 if the respondent somewhat or strongly agrees with the statement "Government does not have the tools to properly regulate GM foods," and 0 otherwise. About two-thirds the respondents are skeptical about government's ability to properly regulate GM products.

Confidence in Scientists: Public confidence in the safety of GM foods is likely to be related to views about scientists associated with biotechnology, which may influence acceptance of GM foods. To explore this issue, the empirical model includes a dummy independent variable *CONF_SC* that 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 regulations on GM products is probably necessary," and 0 otherwise. About 36 percent of the respondents revealed such confidence in scientists associated with biotechnology research and product development.

Trust in Government: Research in public perceptions of risk has found that public trust in risk managers can greatly facilitate the acceptance of a new technology (Fischhoff and Fischhoff 2001). It is therefore possible that consumer acceptance of food biotechnology is related to trust in government as protector of public interest. To examine this issue, the model includes a dummy independent variable *TRUST_GVT* that takes a value of 1 if a respondent somewhat or strongly agrees with the statement "Government regulators have the best interest of the public in mind," and 0 otherwise. This variable reflects public trust in the regulators' intent (rather than ability) to act in the interest of the common people. Only 40 percent of the respondents expressed such trust in government regulators.

Knowledge of Science: Some studies have found that a person's view about food biotechnology is related to his or her knowledge of science (Sheehy, Legault, and Ireland 1998). To explore this, the empirical model includes respondents' knowledge of science as an explanatory variable. In order to obtain an objective measure of respondents' knowledge of science, each participant was asked a set of 10 basic questions on science (relating to food biotechnology). Their responses to these questions were evaluated and the number of correct responses was used as a measure of the respondent's knowledge of science (denoted by *GMQUIZ*).

Using the above variable definitions, the following empirical model is specified to model consumers' approval of food biotechnology and their economic, demographic and value attributes:

$$
\begin{aligned}
Y = {} & \beta_0 + \beta_1 YOUNG + \beta_2 MIDAGE1 + \beta_3 MIDAGE2 \\
& + \beta_4 MALE + \beta_5 WHITE + \beta_6 MARRIED + \\
& \beta_7 EMPLOY + \beta_8 FAMSZ + \beta_9 HISCOOL + \\
& \beta_{10} SCOOL + \beta_{11} COL\_4YR + \beta_{12} GMQUIZ + \\
& \beta_{13} LOWINC + \beta_{14} MIDINC1 + \beta_{15} MIDINC2 \\
& + \beta_{16} WORSHIP\_NO + \beta_{17} WORSHIP\_OCC + \\
& \beta_{18} RURAL + \beta_{19} SUBURB + \beta_{20} LIBERAL + \\
& \beta_{21} CONSER + \beta_{22} CONF\_SC + \beta_{23} SKEP\_CO + \\
& \beta_{24} SKEP\_REGUL + \beta_{25} TRUST\_GOV + \varepsilon.
\end{aligned} \tag{4}
$$

Model Estimation and Empirical Results

Three different ordered probit models are estimated to explain and predict public approval of the use of biotechnology in food production. The estimated coefficients, associated t-ratios, and marginal impacts are reported in Tables 2 through 4. These tables also report the estimated log-likelihood functions of the unrestricted and restricted (i.e., all slope coefficients are zero) models, McFadden's R^2, and percent correctly predicted.

Potential of Biotechnology to Improve the Quality of Human Life

About 70 percent of the respondents believed that biotechnology would make the quality of much better (56 percent) or somewhat better (14 percent). The other 30 percent of the survey participants believed that it would make the quality of life somewhat worse (20 percent) or much worse (10 percent). The estimated model coefficients, associated t-ratios, marginal effects, and the model-summary statistics are reported in Table 2. The likelihood-ratio-based chi-square test of overall model significance yields a test statistic of 267.16, which is greater than its 95-percent critical value. This implies that the model has significant explanatory power. The model yields a value of 0.16 for McFadden's R^2 (a measure of goodness of fit). The model correctly predicts 665 out of 978 (68 percent) sample observations.

Table 2. Public View About the Potential of Biotechnology to Enhance Quality of Life.

Variables	Coefficient	t-ratio	Marginal effect	
			Y = 2	Y = 3
Constant	1.096	3.66	na	na
YOUNG	0.376*	2.84	0.058	0.067
MIDAGE1	0.275*	1.98	0.050	0.051
MIDAGE2	0.081	0.61	0.012	0.015
MALE	0.201*	2.21	0.033	0.037
WHITE	-0.009	-0.08	-0.001	-0.002
MARRIED	-0.015	-0.15	-0.002	-0.003
EMPLOY	-0.147	-1.36	-0.022	-0.027
FAMSZ	-0.015	-0.84	-0.002	-0.003
HISCHOOL	-0.316*	-2.08	-0.057	-0.064
SCOLL	-0.278**	-1.84	-0.051	-0.052
COL_4YR	-0.029	-0.19	-0.004	-0.005
GMQUIZ	0.415*	3.28	0.064	0.072
LOWINC	-0.062	-0.45	-0.009	-0.011
MIDINC1	0.018	0.13	0.003	0.003
MIDINC2	-0.014	-0.11	-0.002	-0.003
WORSHIP_NO	0.012	0.11	0.002	0.002
WORSHIP_OCC	-0.015	-0.14	-0.002	-0.003
RURAL	-0.085	-0.69	-0.031	-0.016
SUBURB	-0.229*	-2.27	-0.038	-0.042
LIBERAL	-0.205**	-1.84	-0.034	-0.038
CONSER	0.152	1.45	0.022	0.028
CONF_SC	0.385*	3.94	0.066	0.070
SKEP_CO	-0.585*	-5.71	-0.086	-0.107
SKEP_REG	-0.364*	-3.83	-0.058	-0.067
TRUST_GVT	0.407*	4.34	0.064	0.074
Threshold 1	0.894*	13.07	na	na
Threshold 2	2.766*	28.21	na	na

LL	-744.95		**Predicted**			
Restricted LL	-858.53	**Actual**	0	1	2	3	Total
Chi square (df = 25)	267.16	0	55	8	11	24	98
McFadden's R^2	0.16	1	13	116	19	48	196
		2	8	31	66	32	137
		3	12	26	81	428	547
		Total	88	181	177	532	978

* α=. 05 and ** α=. 10.

The estimated coefficients suggest that male, younger, and more-educated individuals are more optimistic about biotechnology's potential to improve the quality of human life. Similarly, individuals who trust government (vs. those who do not) and have confidence in scientists (vs. those who lack such confidence) are more likely to share the same optimistic view of the promise of this technology. Also, individuals with better scientific knowledge seem to be more optimistic about this technology. The statistically significant negative coefficients suggest that individuals who identify themselves as liberals, live in suburban areas (vs. in cities), are skeptical about biotechnology companies, and lack confidence in the government regulations are much less optimistic about the potential benefits of biotechnology and are therefore less likely to approve of its use. Respondents' race, income, employment and marital statuses, and religiosities were insignificant. It is possible that there is not much difference in the opinion among different races, income groups, employment and marital statuses and religiosities because knowledge of the subject is still low and the long-term impact of genetic modification is yet to be analyzed and resolved. As Hallman et al. (2002) point out, it will take time for most people to attain a better understanding of biotech issues; only then one can judge the impact of biotechnology on life.

The estimated marginal effects of the independent variables suggest that, compared to the excluded group (age ≥ 55 years), younger people (age < 45 years) are between 5 and 7 percent more likely to be supportive of food biotechnology. Respondents' knowledge of science has a similar marginal impact on their views about this technology. Those who have confidence in scientists and trust in government are 6 to 7 percent more likely to believe in biotechnology and are therefore more likely to approve its use in food production. While males are about 3 percent more likely to support this technology (vs. females), suburban consumers (relative to city residents) and political liberals (compared to political centrists) are about 4 percent less likely to do the same. However, low levels of education and lack of trust in biotechnology companies and government regulators have somewhat greater negative effect on public attitudes toward biotechnology and, hence, acceptance of its use in agriculture and food production.

Public Approval of the Use of Biotechnology in Plants

About 64 percent of the respondents either strongly approved (19 percent) or somewhat approved (45 percent) of the use of biotechnology in plants; the other 36 percent either somewhat disapproved (19 percent) or strongly disapproved (17 percent). The estimated coefficients, associated t-ratios, marginal effects, and model summary statistics are presented in Table 3. The chi-square statistic of overall model significance is 352.29, which is clearly greater than the 95-percent critical value for this test. Therefore, the model has significant explanatory power. The McFadden's R^2 is 0.18, and the model correctly predicts 72 percent of the observations.

The estimated coefficients suggest that younger (age ≤ 45 years), male, and white people are more likely to approve the use of biotechnology in plants. Similarly, respondents' education and knowledge of science are positively related to their support for the use of biotechnology in plants. Individuals who have confidence in scientists and trust government are also more likely to approve of the use of this technology in plants. Individuals who identify themselves as liberals, live in suburban areas, regularly attend a church or other house of worship, and are skeptical of biotechnology companies and government regulations are clearly less likely to support the use of biotechnology in plants. It is possible that public approval of the use of this technology is unrelated to income, family size, and employment and marital statuses because knowledge of the subject is still low and the long-term impact of genetic modification is yet to be analyzed and resolved.

The estimated marginal effects of the explanatory variables show that public confidence in various institutions associated with biotechnology has the largest impact on their approval of the use of genetic biotechnology in plants. This is clearly reflected by the relatively larger marginal effects of CONF_SC, TRUST_GVT, SKEP_CO, and SKEP_REGUL. Respondents' age and education also have considerable effects on approval of this technology in plants. Specifically, compared to those 55 years or older, younger individuals (age < 45 years) are 6 to 8 percent more likely to approve the use of biotechnology in plants. However, compared to those with a graduate degree, individuals with less than a 4-year college degree are between 6 and 7 percent less likely to do the same. Respondents' religiosity and

Table 3. Public Approval of the Use of Biotechnology in Plants.

Variable	Coefficient	t-ratio	Marginal effect	
			Y = 2	Y = 3
Constant	0.664	2.26	na	na
YOUNG	0.344*	2.63	0.076	0.082
MIDAGE1	0.292*	2.12	0.058	0.067
MIDAGE2	-0.103	-0.74	-0.013	-0.025
MALE	0.184*	2.05	0.037	0.044
WHITE	0.235*	2.18	0.049	0.057
MARRIED	0.047	0.50	0.006	0.011
EMPLOY	-0.126	-1.15	-0.015	-0.030
FAMSZ	-0.004	-0.17	0.001	-0.002
HISCHOOL	-0.274*	-2.04	-0.061	-0.066
SCOLL	-0.295*	-1.99	-0.063	-0.069
COL_4YR	-0.113	0.72	-0.038	-0.028
GMQUIZ	0.357*	5.83	0.079	0.085
LOWINC	-0.011	-0.08	-0.001	-0.003
MIDINC1	0.000	0.00	0.001	0.001
MIDINC2	0.049	0.38	0.006	0.012
WORSHIP_NO	0.227*	2.01	0.052	0.055
WORSHIP_OCC	0.227*	2.21	0.051	0.055
RURAL	-0.118	-1.17	-0.014	-0.028
SUBURB	-0.020	-0.17	-0.003	-0.005
LIBERAL	-0.234*	-2.22	-0.053	-0.057
CONSER	0.121	1.15	0.015	0.029
CONF_SC	0.307*	3.33	0.072	0.074
SKEP_CO	-0.584*	-5.98	-0.138	-0.141
SKEP_REG	-0.343*	-3.78	-0.079	-0.083
TRUST_GVT	0.555*	2.91	0.132	0.135
Threshold 1	0.711	12.76	na	na
Threshold 2	2.150	26.98	na	na

LL	-802.82		**Predicted**			
Restricted LL	-958.47	**Actual**	0	1	2	3	**Total**
Chi-square (df = 25)	351.29	0	71	45	27	21	164
McFadden's R^2	0.18	1	16	148	17	7	188
		2	14	26	381	19	440
		3	12	19	51	104	186
		Total	113	238	476	151	978

* α=. 05 and ** α=. 10.

political ideology seem to have some influence on their attitudes toward plant biotechnology: regular worshipers (vs. those who do not worship regularly) and political liberals (relative to centrists) are about 5 percent less likely to approve the use of genetic technology in plants. The estimated marginal effects also indicate that male (relative to female) and white (relative to non-white) individuals are somewhat (about 5 percent) more supportive of the use of biotechnology in plants.

Public Approval of the Use of Biotechnology in Animals

Although survey results indicate broad support for biotechnology in general and plant genetics in particular, public support for the use of this technology in animals is more limited. This is reflected by the fact that only 31 percent of the respondents either strongly approved (8 percent) or somewhat approved (23 percent) of genetic modification of animals, whereas 64 percent approved of genetic modification of plants (19 percent strongly approved and 45 percent somewhat approved). The empirical results pertaining to public approval of the use of genetic modification in animals are present in Table 4. The chi-square statistic of model significance is 319.68, which clearly exceeds its 95-percent critical value and implies that model has significant explanatory power. The McFadden's R^2 is 0.17, and the model correctly predicts 70 percent of the actual responses.

The estimated coefficients suggest that, compared to those 55 years or older, only the young (age < 25 years) are more supportive of the use of biotechnology in animals. Although individuals in the 35–44 year age group are more likely to support the use of biotechnology in plants, they are no more likely to approve its use in animals than are those 55 years or older. The coefficients of the three dummy variables corresponding to different education levels are all negative and significant. This suggests that only individuals with a graduate degree approve of the use biotechnology in animals. Those with a 4-year college degree are less likely to approve of genetic modification of animals, although they are no less supportive of such modification in plants. The positive and significant coefficient of GMQUIZ reinforces the findings in the other two models that individuals' knowledge of science is positively related to acceptance of food biotechnology. Individuals who never attend a church or other house of worship are more likely than are those who regularly attend a house of worship to approve animal biotechnology.

The acceptance of genetic modification of animals among people who occasionally attend a house of worship is no different from that of regular worshipers, although the former are more supportive of such modification in plants than are the latter. The coefficients of the variables representing respondents' perceptions of various institutions associated with biotechnology are similar to those in the other two models. Individuals who have confidence in scientists and trust in government are more likely to approve of genetic modification in animals than are those who lack such confidence and trust. People who are skeptical of biotechnology companies and government regulations are, however, less likely to do the same. As in the other two models, respondents' income, family size, and employment and marital statuses do not have any effect on their views about the use of biotechnology in animals. However, unlike in the other two models, public approval of the use of genetic technology in animals is unrelated to political ideology or to place of residence. This insignificance may also be related to level of knowledge and the long-term impact of genetic modifications, which are not clear at the moment.

The estimated marginal effects suggest consumers' education, knowledge of science, and confidence in scientists and biotechnology companies have fairly large effects on their approval of genetic modification of animals. Specifically, individuals with less than a graduate degree are 7 to 12 percent less likely than are those with a graduate degree to approve of genetic modification of animals. While individuals who have confidence in scientists (vs. those who lack confidence) are 9 to 11 percent more likely to approve, those who are skeptical of biotechnology companies (vs. those who are not skeptical) are 10 to 12 percent less likely to do so. Individuals 35 years or younger and those who never attend a house of worship are somewhat (5 to 7 percent) more likely to approve animal genetics. The empirical results also suggest some degree of gender and racial/ethic disparity in the acceptance of food biotechnology: male and white individuals are 4 to 7 percent more likely to approve of genetic modification in animals than are their female and non-white counterparts.

Table 4. Public Approval of the Use of Biotechnology in Animals.

Variable	Coefficient	t-ratio	Marginal effect	
			Y = 2	Y = 3
Constant	0.204	0.65	na	na
YOUNG	-0.030	-0.22	-0.007	-0.004
MIDAGE1	-0.049	-0.34	-0.011	-0.006
MIDAGE2	-0.066	-0.47	-0.015	-0.008
MALE	0.216*	2.48	0.042	0.038
WHITE	0.300*	2.59	0.069	0.048
MARRIED	-0.133	-1.37	-0.031	-0.017
EMPLOY	-0.024	-0.23	-0.006	-0.003
FAMSZ	0.014	0.59	0.003	0.002
HISCHOOL	-0.579*	-3.71	-0.124	-0.094
SCOLL	-0.396*	-2.73	-0.091	-0.065
COL_4YR	-0.363*	-2.38	-0.084	-0.066
GMQUIZ	0.367*	2.45	0.075	0.069
LOWINC	0.061	0.46	0.014	0.008
MIDINC1	0.055	0.40	0.013	0.007
MIDINC2	0.116	0.97	0.027	0.015
WORSHIP_NO	0.329*	2.89	0.063	0.054
WORSHIP_OCC	0.149	1.46	0.034	0.019
RURAL	0.005	0.05	0.001	0.001
SUBURB	-0.130	-1.07	-0.030	-0.017
LIBERAL	-0.139	-1.23	-0.032	-0.018
CONSER	0.082	0.79	0.019	0.011
CONF_SC	0.460*	5.04	0.106	0.085
SKEP_CO	-0.549*	-5.81	-0.126	-0.097
SKEP_REG	-0.209*	-2.26	-0.048	-0.042
TRUST_GVT	0.244*	2.67	0.037	0.038
Threshold 1	0.769*	15.13	na	na
Threshold 2	1.814*	22.42	na	na
LL	-804.28			
Restricted LL	-964.12			
Chi-square (df = 25)	319.68			
McFadden's R^2	0.17			

	Predicted				
Actual	0	1	2	3	Total
0	198	61	11	4	274
1	69	304	20	8	401
2	19	48	150	8	225
3	8	22	11	37	78
Total	294	435	192	57	978

* α=. 05 and ** α=. 10.

Discussion

As innovations in biotechnology continue, science and industry are poised to bring forth a wide range of products that may have significant impacts on the production of food, fiber, feeds, fuels, and pharmaceuticals. However, public opinions about biotechnology are divided, and the debate over the desirability of this technology is far from over. Consumer acceptance of bioengineered foods will be a key factor that will influence the future of food biotechnology. Sound science alone is not sufficient to ensure broad public acceptance of genetically modified foods.

The results of this study suggest that American consumers are not ideologically opposed to the use of genetic technology in agricultural and food production. The overall public attitude towards food biotechnology may be described as an ongoing tension between optimism about benefits of this technology and concern about unforeseen consequences of its use. While not resoundingly supportive of this technology, consumers clearly demonstrate greater support for genetic modification in plants than in animals. Similar results were reported by Davison, Barns and Schibeci (1997), Hamstra (1998), and Zechendorf (1998), among others. These findings suggest that a majority of consumers may not be ready for the use of this technology in animals. Therefore, scientists and the biotechnology industry should consider limiting its use to develop plant-based products only until consumers are more comfortable with bioengineered foods.

There is considerable evidence to indicate that younger people are more supportive of the use of biotechnology in food production. Similar results were reported by Grimsrud et al. (2002) in the context of Nordic countries. Furthermore, the empirical evidence supports the notion that more-educated individuals and those with higher levels of scientific knowledge are more receptive of this technology. A similar pattern of support for biotechnology was found by Grimsrud et al. (2002) among the Norwegians, and by Boccaletti and Moro (2000) among the Italians. This finding suggests the need for a well-designed and effective program to educate the public about various issues relating to the use of biotechnology in agricultural and food production.

The results of this study suggest that peoples' trust and confidence in various private and public institutions associated with biotechnology have significant influences on their acceptance of this technology. This points to an important dilemma for governments who are responsible for regulating GM products but may also want to promote the biotechnology industry as part of industrial and economic policies. Government efforts to encourage the biotechnology industry may undermine public confidence in the safety of GM foods if the government is perceived to be biased in favor of the industry. This suggests that the government needs to carefully protect its credibility as a protector of public good as it tries to foster the emerging biotechnology industry.

The food and biotechnology industries also need to enhance their standing among consumers in order to promote public acceptance of this technology. Scientists need to communicate with the public at large with complete information and on a proactive basis. In order to enhance public trust in these institutions, all interested parties, including those opposed to GM foods, should be involved in the decision process surrounding issue of risks associated with biotechnology. The food industry should reconsider their current reluctance to label foods containing GM ingredients and recognize that there may be potential advantages to labeling these products. Such labeling will allow companies to explain the purpose of genetic modification, highlight the potential benefits (nutritional or otherwise), and signal to consumers that the industry is confident about the safety of GM products. In this context, Frewer, Howard, and Aaron (1998) cite the marketing success of Zeneca GM tomato paste. Despite carrying the GM label, the product was widely accepted by consumers without raising significant public concern.

Conclusions

This study examined the relationship between consumer reception of the use of biotechnology in food production and their economic, demographic, and value attributes. The results indicate that a majority of U.S. consumers do not have any entrenched position on the desirability of this technology. Despite having reservations, particularly about its use in animals, Americans are not prepared to reject this technology altogether. Most consumers appear to be undecided, perhaps waiting for more evidence about the safety of GM foods before reaching a

firm decision.

Results of this study indicate that public acceptance of food biotechnology is related not only to their demographic characteristics but also to their value attributes. Younger people were generally more optimistic about this technology. Results also suggested a considerable gender gap in the attitudes towards biotechnology. Female consumers were clearly less supportive of this technology than were their male counterparts. More-educated individuals and those with higher levels of scientific knowledge were usually more optimistic about biotechnology. Although there were some indications that suburban consumers (who are typically more affluent) were more hesitant about this technology, there was no evidence to suggest that an individual's acceptance of food biotechnology was related to his or her income. There was some evidence to suggest that public acceptance of this technology was influenced by political ideology and religiosity.

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