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Public Perceptions of Biotechnology and Acceptance of Genetically Modified Food

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 towards biotechnology differ substantially between males and females, and between whites and non-whites. While people's religious and social views, confidence in scientists, corporations and government have significant influence, income and regional differences do not have significant effects on public acceptance of biotechnology.

Introduction

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 fundamentally 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 delivering a wide range of benefits.

However, public perception of biotechnology and acceptance of its use in the production of food have been mixed in the U.S. and elsewhere (Einsiedel, 1997; 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 associated with GM products. Supporters of biotechnology highlight the potentials benefits to society via reduction of hunger, prevention of malnutrition, cure of diseases and promotion of health and quality of life (Isserman, 2001). Opponents often view its use as an unnecessary interference with nature that has unknown and potentially disastrous interactions with human genetics and natural ecosystems (Nelson, 2001).

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 the production of food. However, some other studies report a more mixed reaction

among the public in this issue (Miranowski, 1999; Jostling *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 U.K., there were multiple incidents of protestors damaging GM crops (Grossman and Endres, 2000; Juanillo, 2001). Such oppositions to the use of biotechnology in plants and animals are also observed elsewhere. For example, India and Brazil have refused to approve GM crops.

Similarly, 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 environment, others oppose it citing moral and ethical concerns. Some oppose the concept of genetic engineering, particularly the transfer of genes across species, arguing that it is tantamount to "playing God" or a violation of "Law of Nature". There are also ethical concerns among many about the patenting of genetically modified organisms. Some are worried that biotechnology can lead to permanent dependency of farmers on the multinational seed and chemical companies. Others are concerned that the spread of this technology will benefit only the industrialized countries at the expense of the Third word (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 remain a critical factor that will affect the future

of agricultural biotechnology. Despite the enormous importance of the subject, only a handful of studies have systematically explored the issue. In a recent study, Moon and Balasubramanian (2001) found that consumer acceptance of biotechnology was significantly influenced not only by their perceptions of risks and benefits associated with GM products, but also by their moral and ethical views. In addition, 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., respondents' levels of risk aversion, opinions about GM food products) 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' socio-economic attributes and other personal attributes. Specifically, we explore the following issues. First, we examine consumer acceptance of biotechnology 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 others, 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 (i) plants and (ii) animals.

Using data collected from a national telephone survey of the U.S. adults, this study implements a logistic model to estimate the relation between consumers' personal attributes and their approval of biotechnology. This analysis will contribute towards a better understanding of public attitudes towards biotechnology and their willingness to accept GM food products. It will also 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 will 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 agricultural and food production.

Methodology

A survey instrument was developed to gather information on consumers' attitudes towards the use of biotechnology in food production. One section of the survey focused on colleting information on consumers' socio-economic and value characteristics. These included respondents' age, gender, ethnicity, education, income, family size, employment status, religious practice and social/political views. Information was also collected on their views of scientists and companies involved in biotechnology, their confidence in the government's ability to properly regulate GM products, and willingness to protect the interests of the common people.

In order to obtain an objective measure of respondents' knowledge of

science and technology, each individual was asked a set of 10 basic questions on science (relating to food biotechnology), and their responses were evaluated. The number of correct responses was used as a measure of the individual's knowledge of science relating to food biotechnology.

In another part of the survey respondents were asked a series of questions regarding their views about biotechnology, and the extent to which they approved its use in plants and animals. Specifically, the survey participants were asked to express their opinion about biotechnology by responding to the following three questions:

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 included "much better" or "somewhat better" or "somewhat worse" or "much worse.")
2. In general, do you approve of creating hybrid plants using genetic modification? (Possible responses included "strongly approve" or "somewhat approve" or "somewhat disapprove" or "strongly disapprove.")
3. In general, do you approve or disapprove of creating hybrid animals using genetic modification? (Possible responses being "strongly approve" or "somewhat approve" or "somewhat disapprove" or "strongly disapprove."). The first question elicited consumers' broad view about

the positive potential of biotechnology to improve human life. The idea here is that an individual who feels biotechnology will improve the quality of his/her life is more likely to approve its use. The other two questions were designed to explore if there were significant differences in public acceptance of the use of genetic technologies in plants and animals for food production.

The data used in this study were obtained via a national telephone survey of the U.S. consumers. The survey was completed in March-April, 2001, by American Opinion Research, a division of Integrated Marketing Services, Princeton, New Jersey, on behalf of the Food Policy Institute at Rutgers University. 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 U.S. was purchased from Survey Sampling, Inc. The target sample size was set at 1200 to achieve a sampling error rate of +/-3%. Each working telephone number was called a minimum of three times, at different times of the week, to reach people who were infrequently at home. Quotas were set to ensure that representative numbers of males and females were interviewed. In developing the survey instrument, special attention was paid to both the wording and the order of questions in the survey. Using a computer-assisted telephone interview (CATI) system, a total of 1203 phone surveys were completed, with a response rate of slightly over 50 percent.

However, after excluding the non-respondents to specific questions relevant for this study, a total of 978 completed surveys were used for empirical analysis.

Model Specification

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. Specifically, the logistic model approach is used to estimate the impacts of consumers' socio- economic characteristics and personal values on the probability of their acceptance (reflected by their approval) of food biotechnology. The logistic model, a commonly used model in situations with a binary dependent variable, is selected because the asymptotic characteristics of the model constrain the predicted probabilities between 0 and 1. Since the data represents individual, rather than group, observations, the standard choice of estimation method is the maximum likelihood (ML) method (Gujarati 1992). The ML estimator has the desirable properties of consistency and asymptotically efficiency (Pindyck and Rubinfeld 1997).

The empirical model assumes that the probability of accepting food biotechnology (defined by a respondent's approval of genetic modification in the production of food), P_i, depends on a vector of independent variables (X_{ij}) associated with consumer i and variable j, and a vector of unknown parameters β:

$$P_i = F(Z_i) = F(X_i\beta) = 1/(1+\exp(-Z_i)) \quad (1)$$

where:

$F(Z_i)$ = the value of logistic cumulative density function associated with each possible value of the underlying index Z_i;

P_i = the probability that an individual approves of food biotechnology, given the independent variables X_i.

In the above equation, $\sum X_i$ is a linear combination of the independent variables so that

where:

Z_i = unobserved index level or the log odds of choice for the i^{th} observation;
i = observation;

x_{ij} = j^{th} attribute of the i^{th} respondent;

β = parameters to be estimated;

ε = random error or disturbance term.

The dependent variable Z_i in equation (2) is the logarithm of the probability that a particular choice will be made. The estimated parameters of equation (1) do not directly represent the marginal effects of the independent variables on P_i. For a continuous variable, the marginal effect of x_j on the probability P_i that the dependent variable (y) takes the value $y_i = 1$ is

given by:

$$\frac{\partial P_i}{\partial x_{ij}} = \beta_j P_i (1 - P_i) \qquad (3)$$

However, if the independent variables are also qualitative or discrete in nature, as is the

case for all the independent variables used in this study, $\partial P_i / \partial x_{ij}$ does not exist. In such cases,

the marginal effect of a discrete independent variable is obtained by evaluating P_i at alternative values of x_j. Marginal effects of such variables are determined as:

$$\Delta P_i / \Delta x_{ij} = P(y_i : x_{ij} = 1) - P(y_i : x_{ij} = 0) \qquad (4)$$

In empirical analysis, the following model is used to predict the probability that an individual would approve the use of biotechnology in food production:

Approve □ □0 □ □1YOUNG □ □2 MIDAGE □ □3LOWINC □ □4 MIDINC □ □5MALE □ □6WHITE □ □7COLLEGE □ □8GRAD □ □9 LIBERAL □ □10CONSERV □ □11WORSHIP _ NO □ □12WORSHIP _ OCC □ □13SKEP _ CO □ □14GVT _ REGUL □ □15TRST _ GVT □ □16CONF _ SC □ □17MIDSCORE □ □18HISCORE □ □.

5where:

APPROVE = 1 if the respondent approves of biotechnology use, and 0 otherwise. YOUNG = 1 if the respondent's age is less than 35 years, and 0 otherwise.

MIDAGE = 1 if respondent's age is between 35 and 54 years, and 0 otherwise. MATAGE = 1 if respondent's age is 55 years or higher, and 0 otherwise.

LOWINC = 1 if the respondent's annual household income is less than $35,000, and 0 otherwise.

MIDINC = 1 if the respondent's annual household income is between $35,000 and $75,000, and 0 otherwise.

HIGHINC = 1 if the respondent's annual household income is $75,000 or higher, and 0 otherwise.

MALE = 1 if the respondent is male, and 0 otherwise (i.e., female). WHITE = 1 if the respondent is a white (Caucasian), and 0 otherwise.

HISCHOOL= 1 if the respondent has a maximum of High School diploma, and 0 otherwise.

COLLEGE = 1 if the respondent has some or full four-year college education, and 0 otherwise.

GRAD = 1 if the respondent has graduate education, and 0 otherwise

LIBERAL = 1 if the respondent identifies himself/herself as liberal, and 0 otherwise. CONSERV = 1 if the respondent identifies himself/herself as conservative, and 0 otherwise.

CENTRIST = 1 if the respondent identifies himself/herself in between liberal and conservative, and 0 otherwise.

WORSHIP_NO = 1 if the respondent never attends church or similar house of worship, and 0 otherwise.

WORSHIP_OCC = 1 if the respondent occasionally (once a month or less) attends church or similar house of worship, and 0 otherwise.

WORSHIP_REG = 1 if the respondent regularly (several times a month or more) attends church or similar house of worship, and 0 otherwise.

SKEP_CO = 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.

GVT_REGUL = 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.

TRST_GVT = 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.

CONF_SC = 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.

LOWSCORE = 1 if the respondent correctly answered less than 5 (out of 10) basic science/ biology questions, and 0 otherwise.

MIDSCORE = 1 if the respondent correctly answered between 5 and 7 (out of 10) basic science/biology questions, and 0 otherwise.

HISCORE = 1 if the respondent correctly answered 8 or more (out of 10)

basic science/ biology questions, and 0 otherwise.

Data Description and Summary Statistics

The dependent variable of interest in this study is the consumer approval of the use of biotechnology in food production. Three different models are estimated to examine the relationship between consumers' acceptance of biotechnology and their personal attributes. The first model explores how individuals with different socio-economic and value characteristics view the positive potential of biotechnology to improve the overall quality of human life. An individual survey participant expressed his/her broad views about biotechnology by choosing either "much better" or "somewhat better" or "somewhat worse" or "much worse" when asked if he/she thought biotechnology would improve his/her quality of life. For empirical analysis, a binary dependent variable, *APPROVE*, was created by assigning a value of 1 if the response to the above question was "somewhat better" or "much better", and 0 if the response was "somewhat worse" or "much worse". Approximately 70 percent of the respondents thought that biotechnology would make the quality of life either "somewhat better" or "much better".

The second and third models examine consumers' approval of the use of genetic technologies in plants and animals, respectively. For each of these two models, the binary dependent variable *APPROVE* is defined by assigning a value of 1 if the respondent chose either "strongly approve" or "somewhat approve" in expressing his/her approval of genetic modifications in plants and animals (i.e.,

question 2 and 3, respectively), and 0 otherwise.

Approximately 64 percent of the survey respondents approved the use of biotechnology in plants, while only about 31 percent approved its use in animals. This suggests that there are significant differences in public support for plant and animal biotechnology, a fact that is also confirmed by formal statistical test.

The independent variables in the model included economic, demographic, and value characteristics of the respondents. Descriptive statistics on the explanatory variables used in the analysis are presented in Table 1. Specific variables included in the model are:

Age: Three age groups are identified as follows: (1) below 35 years (*YOUNG*); (2) between 35 and 54 years (*MIDAGE*); and (3) 55 years or more (*MATAGE*). Approximately 31 percent of the respondents belong to category 1, 43 percent belong to category 2, and the remaining 26 percent belong to category 3. Although there is no *a priori* expectation as to how public support for biotechnology would vary among different age groups, some earlier studies found greater support for biotechnology among younger consumers.

Income: Three different (annual) income levels are identified and accordingly three dummy variables are defined as follows: (1) below $35,000 (*LOWINC*); (2) between $35,000 and to
$75,000 (*MIDINC*); and (3) $75,000 or more (*HIGHINC*). About 32 percent of the respondents have income below $35,000, 43 percent have income between $35,000 and $75,000, and the remaining 25 percent have annual income of $75,000 or more. It is not clear *a priori* how income variation is likely to affect public approval of biotechnology.

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: The dummy variable *WHITE* is assigned a value of 1 if the respondent is white (Caucasian) and 0 otherwise (i.e., belonging to other racial groups). About

80 percent of the respondents are white while the remaining 20 percent belong to other races. No particular effect of the racial background of the respondent on the dependent variable is expected *a priori*.

Social/Political View: Three categories of respondents are identified on the basis of their self- reported social/political views. These are: (1) conservative (*CONSERVE)*; (2) liberal (*LIBERAL*); and (3) centrist i.e., in between liberal and conservative (*CENTRIST*). About 28 percent of the respondents identified themselves as conservative, 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: Three different education levels are identified and accordingly three dummy variable are created as follows: (1) the variable *HISCHOOL* is assigned a value of 1 if the respondent has a high school diploma or less, and 0 otherwise; (2) the variable *COLLEGE* is assigned a value of 1 if the individual has an associate or a four-year college degree, and 0 otherwise; and (3) the variable *GRAD* is assigned a value of 1 if the respondent has graduate education, and 0 otherwise. Approximately 38 percent of the respondents have high school diploma or less, 49 percent have an associate or a four-year college degree, and the remaining 13 percent have graduate education. Previous studies have found that individuals with higher education are generally more supportive of the use of biotechnology (Sheehy *et al.*, 1998).

Religious Practice: Respondents are classified into three groups on the basis of how often they attend church or similar house of worship. Accordingly, three dummy variables are defined as follows: (1) the variable *WORSHIP_NO* is assigned a value of 1 if the individual never attends church or similar house of worship, and 0 otherwise; (2) the variable *WORSHIP_OCC* is assigned a value of 1 if the individual occasionally (once a month or less than once a month) attends church (or other house of worship), and 0 otherwise; and (3) the variable *WORSHIP_REG* is assigned a value of 1 if the individual regularly (i.e., several

times a month) attends church (or other house of worship), and 0 otherwise. About 24 percent of the respondents fall in category 1, 27 percent fall in category 2 and the remaining 49 percent belong to category

3. It is commonly believed that religious individuals may find genetic modifications to be morally unacceptable, especially in the case of animals. Therefore, it is expected that more

religiously inclined persons will be less likely to approve the use of biotechnology in food production.

View about Corporations: This variable shows individual opinions about biotechnology companies, and thus somewhat reflects his/her view about corporations in general. The dummy 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," 0 otherwise. About two-thirds of the survey participants are found to be skeptical about biotechnology companies.

Confidence in Government's Regulatory Ability: The dummy variable *GVT_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. As is apparent, this variable reflects individual respondent's confidence in the ability of the government to properly regulate GM products in the best interest of the public. About 65 percent of the survey participants are skeptical about government's ability to properly regulate GM products (category 1).

Confidence in Scientists: This variable captures the extent of public confidence of scientists engaged in biotechnology research. 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 regulations on

GM products is probably necessary," and 0 otherwise. About 36 percent of the respondents revealed such confidence in scientists engaged in biotechnology research (category 1).

Trust in Government: The dummy variable *TRST_GVT* is assigned 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. It reflects public trust in the government to do the "right thing" for common good. It is different from the variable *GVT_REGUL* in the sense that it reflects the intent (or lack thereof) rather than the ability of the government to properly regulate GM products. Approximately 40 percent of the responses fall in category 1 while the remaining 60 percent fall in category 0.

Knowledge of Science: Individual's basic knowledge of science relating to biotechnology is likely to influence their support for the use of biotechnology in food production. To obtain an objective measure, individuals were asked to correctly answer a set of 10 questions. Their answers were evaluated and used to measure their basic knowledge of science. Respondents are classified into three groups as follows: (1) those correctly answering less than 5 questions (*LOWSCORE*); (2) those correctly answering between 5 to 7 questions (*MIDSCORE*); and (3) those correctly answering 8 or more questions (*HIGHSCORE*). About 25 percent of the respondents fall in category 1, 50 percent in category 2, and the remaining 25 percent fall in category 3.

Initially, during the estimation stage, variables such as employment status, family size, marital status, residence (e.g., whether the respondent lived in a big city or suburban areas) and whether the respondent was the primary shopper were included as explanatory variables.

Similarly, regional dummy variables were included to account for potential

regional differences in public approval of the use of biotechnology in food production. All these variables were found to be statistically insignificant in all three models, and consequently, they were dropped from the final analysis.

Model Estimation and Empirical Results

Three different logistic models are estimated to explain and predict public approval of the use of biotechnology in food production. The maximum likelihood estimates of the model parameters are obtained by using the econometric software LIMDEP. The estimated model coefficients, the associated t-ratios and the marginal impacts of the explanatory variables on the dependent variable 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 prediction success.

Potential of Biotechnology to Improve the Quality of Human Life

First, we report the empirical results relating to public views about the potential of biotechnology to improve general quality of human life. Nearly 70 percent of the respondents believe that biotechnology will either much improve or somewhat improve their quality of life. The estimated model coefficients, the associated t-ratios and the marginal effects are reported in Table 2. As can be seen from Table 2, the coefficients of YOUNG, MALE, WHITE, COLLEGE, GRAD, CONF_SC, TRST_GVT, MIDSCORE and HISCORE are positive and statistically significant at 10% or lower level. These estimated coefficients suggest

that younger (less than 35 years of age), male, white individuals and those with higher education (i.e., above high school level) are more likely to believe in biotechnology's potential to improve the quality of human life compared to individuals 55 years or older, female, non-white and those with only high school education or less. Similarly, individuals with confidence in scientists, trust in government and better understanding of science (relating to biotechnology) are more likely to do the same. Individuals with these attributes, therefore, are more likely to approve the use of genetic technologies in food production.

The statistically significant negative coefficients of LIBERAL, SKEP_CO, and GVT_REGUL suggest that individuals who identify themselves as liberals, skeptical about biotechnology companies and lack confidence in the government's ability to properly regulate GM products are less likely to believe in the potential benefits of biotechnology, and therefore, less likely to approve its use. The estimated model coefficients indicate that respondents' religious practices and household income do not affect their broad view about biotechnology.

The estimated marginal effects of the independent variables included in the model suggest that individuals with the best understanding of science are 28 percent more likely to accept biotechnology compared to those with the least knowledge of science. People who trust government, and have moderate knowledge of science are 16 and 14 percent, respectively, more likely to approve the use of biotechnology. Respondents who have confidence in scientists are 13

percent more likely than those who lack such confidence, while males are 11 percent more likely than females to believe in the potential of this emerging technology. However, young (i.e., age less than 35 years) and college educated individuals are only less than 10 percent more likely to believe in biotechnology's promise. On the other hand, people who are skeptical about biotechnology companies are 24 percent less likely to hold an optimistic view about biotechnology. Similarly, liberals and those who lack trust confidence the government's ability to properly regulate GM product are 7 and 14 percent, respectively, less likely to believe in biotechnology, and hence, less likely to approve its use in food production.

The likelihood ratio test of overall model significance yields a test statistic of 294 which is greater than the 95 percent critical value of Chi-square distribution with appropriated degrees of freedom. This implies that the model has significant explanatory power. Estimated

McFadden's R^2 is 0.31. The estimated model correctly predicts 790 out of 978 sample observations with a prediction success rate of 81 percent.

Public Approval of the Use of Biotechnology in Plants

About 64 percent of the survey participants approve the use of biotechnology in plants. The estimated model coefficients, the associated t-ratios, and the marginal effects are presented in Table 3. The coefficients of YOUNG, MALE, WHITE, COLLEGE, GRAD, WORSHIP_NO, WORSHIP_OCC, CONF_SC, MIDSCORE, HISCORE and TRST_GVT are positive and statistically significant (at 10 percent or lower level). This suggests that, compared to older (55 years or older), female, and non-white respondents, young (35 years or less), white and male individuals are more likely to approve the use of biotechnology in plants. Similarly, individuals who have college education, and either do not attend or only occasionally attend church (or other house of worship) are more supportive of plant biotechnology compared to those who do not have college education, and regularly attend church (or other house of worship). Also, people who have confidence in scientists, trust government and have better understanding of science (relating to biotechnology), are more likely approve of the use of biotechnology in plants.

The negative and statistically significant coefficients of LIBERAL, SKEP_CO, and GVT_REGUL suggest that individuals who are liberals, skeptical about biotechnology companies and lack confidence in the government's ability to

regulate GM products are less likely to approve the use of biotechnology in plants. Empirical results further indicate that income distribution does not have significant influence on public acceptance of the use of plant biotechnology in food production.

The estimated marginal effects of the explanatory variables show that knowledge of science, graduate education, racial difference and confidence in scientists have the largest influence on public acceptance of plant biotechnology. Individuals with the best understanding of science are 24 percent more likely, while those with moderate knowledge of science are 14 percent more likely, to accept plant biotechnology. Whites and individuals with graduate education are each 15 percent more likely, while those who have confidence in scientists are 12 percent more likely to approve plant biotechnology. Young (35 years if less), and those who either do not attend or only occasionally attend church (or other house of worship) are about 9 percent more likely to accept plant genetics. Whites, males and college educated (i.e., with associate or four-year college degree) individuals, and those who trust government are between 7 and 9 percent more likely to approve the use of biotechnology in plants. On the other hand, individuals who are skeptical about biotechnology corporations are 26 percent less likely to approve the use of plant biotechnology. Similarly, people who do not have confidence in the government's ability to properly regulate GM products and self-described liberals are 15 and 9 percent, respectively, less likely to approve the use of plant

genetics for food production.

> The estimated likelihood ratio statistic for the null hypothesis of no model significance is

272.8 which is greater than the 95 percent critical value of Chi-square distribution with appropriated degrees of freedom. This implies that the model has significant explanatory power. Estimated McFadden's R^2 is 0.27. The estimated model correctly predicts 739 out of 989 sample observations with a prediction success rate of 78 percent.

Public Approval of the Use of Biotechnology in Animals

Although our survey results indicate broad support for biotechnology in general and plant biotechnology in particular, public support for the use of biotechnology in animals is more limited. This is reflected by the fact that only 31 percent of our survey respondents either somewhat approve or strongly approve of genetic modification of animals compared to a 64

percent approval rate for plant biotechnology. The estimated results of the logistic model of public approval of animal biotechnology are present in Table 4. Among the explanatory variables, WHITE, MALE, GRAD, WORSHIP_NO, CONF_SC, HISCORE and TRST_GVT
are positive and statistically significant. These results suggest that white, males, individuals with graduate education and the best understanding of science (relating to biotechnology) are more likely to approve the use of biotechnology in animals. Similarly, those who never attend church (or other house of worship), have confidence in scientists involved in genetic research, and have trust in government to do common good are more likely to approve of animal biotechnology.

On the other hand, individuals who are skeptical of biotechnology companies and do not have confidence in the government's ability to properly regulate GM products are less likely to approve the use of animal biotechnology. The variables YOUNG, COLLEGE, WORSHIP_OCC, and MIDSCORE (variables that which have positive and significant influence on public approval of plant biotechnology) are not statistically significant in this model. This implies that young (age less than 35 years), those who have an associate or a four-year college degree, attend church (or other house of worship) occasionally, and have moderate knowledge of science (who are more likely to approve the use of plant biotechnology) are not any more likely to support the use of biotechnology in animals. Similarly, there is no difference among individuals with different

social/political views (i.e., liberal to conservative) in terms of their approval of biotechnology in animals.

The estimated marginal effects suggest that people with confidence in scientists, a graduate education and the best understanding of science are 20 percent, 13 percent and 11 percent, respectively, more likely to approve animal biotechnology. Males, whites and individuals who never attend church (or other house of worship) are about 9 percent more likely

to approve genetic modification of animals compared to females, non-whites and those who attend church (or other house of worship) at least occasionally. Also, people who trust government to do good for the common people are 8 percent more likely to approve the use of animal biotechnology. On the other hand, individuals who are skeptical of biotechnology companies and lack confidence in the government's ability to regulate GM products are 20 percent and 7 percent, respectively, less likely to support the use of biotechnology in the case of animals.

The likelihood ratio test of the null hypothesis that all coefficients (except the intercept) are simultaneously zero yields a test statistic of 183.38. Since the estimated value of test statistic is greater than the 95 percent critical value of Chi-square distribution with appropriated degrees of freedom, the null hypothesis is rejected, implying that the model has significant explanatory power. Estimated McFadden's R^2 is 0.19. The estimated model correctly predicts 708 out of 978 sample observations with a prediction success rate of 72 percent.

Discussion

As biotechnology research continues to make progress, science and industry are poised to bring a wide range of products that may have significant influence on how we organize our production of food, fiber, feeds, fuels and pharmaceuticals. However, public attitudes towards biotechnology are divided and the debate over the desirability of this technology is far from over.

The results of this study suggest that there is considerable divergence in

public approval of the use of biotechnology in food production. While there is broad optimism about the potential of biotechnology to improve the lives of common people and general support for its use in plants, there is far less consensus about the use of such genetic technology in the case of animals.

Our findings in this respect are consistent with those reported by Davison, Barns and Schibeci (1997), Hamstra (1998), and Zechendorf (1994), among others.

The results of this study suggest that although young people share a more positive view about biotechnology and approve its use of in plants, they are not any more supportive of its use in animals than older people. A similar pattern of optimism about biotechnology and support for its use in plants, but not in animals, is evident among people with college (but not graduate) education, and those with moderate understanding of science. Although previous studies have found that people with higher education and scientific knowledge are more supportive of biotechnology (e.g., Sheehy *et al*., 1998; Hill *et al*., 1998), our results indicate that the support for the use of genetic technologies in both plants and animals is limited only among the most educated and those with the best scientific knowledge.

The results of this study also suggest that people's confidence and trust in government and scientific community, and public image of biotechnology companies have significant influence on public perceptions of food biotechnology. Confidence in scientists and trust in government increases the acceptance; Conversely, skepticism about biotechnology companies and lack of confidence in the government's ability to properly regulate GM products have negative influence on public acceptance of biotechnology in food production. Similar findings were reported by Moon and Balasubramanian (2001) in the context of public acceptance of genetically modified organisms.

Some recent studies have found evidence of mistrust of the biotechnology industry, as well as lack of public confidence in government as a protector of public interest (Hallman *et al.,* 2002). For example, a recent Eurobarometer poll found that only 30 percent of Europeans believe that "the industry developing new products through the use of biotechnology does a good

work for society." Results of this study show that such lack of confidence in private and public institutions associated with biotechnology may have serious negative impacts on public acceptance of food biotechnology.

Public debate over biotechnology has also raised some important moral, religious and ethical questions. Some opponents of biotechnology argue that modern genetic research has taken us to areas that belong "only to God." Many consider genetic modifications, particularly gene transfer across species, as against "Natural Law." Our study finds that, compared to regular worshipers, individuals who less religious are more optimistic about biotechnology and more supportive of its use in plants. However, they are not any more supportive of its use in animals compared to more religious individuals. Social liberals seem to be less optimistic about biotechnology and less supportive of its use even in plants. Further, our results indicate the presence of significant gender and racial differences in the acceptance of the use of genetic technologies in food production. On the other hand, this study finds no regional difference in the acceptance of biotechnology. Also, variables such as income, family size, employment, and marital status do not seem to have significant influence public acceptance of food biotechnology.

Conclusions

This study examines how people's perception of biotechnology and their approval of its use in plants and animals are influenced by their socio-economic characteristics, social/political and religious views, their education and scientific

knowledge. Results of this study indicate that the public are generally optimistic about the potential of biotechnology to enhance the quality of human life and are broadly supportive of the use of this technology in plants. However, people are far less ready to support its use in the case of animals. This study finds that nearly half of the survey respondents who approve of the use of biotechnology in plants do not support its use for animals. Similarly, the estimated logistic models confirm that some segments of the population who are more likely to support the use of plant genetics than others are not any more supportive of its use in animals.

The empirical results of this study indicate that people's view of biotechnology and their approval of its use in plants and animals are influenced not only by their socio-economic attributes, but also by their social/political and religious orientation. An individual's education, especially his/her knowledge of science (relating to biotechnology), has significant influence on his/her acceptance of food biotechnology. Also, people's trust and confidence in private and public institutions (e.g., scientific community, biotechnology corporations and government regulators) have important influence on public perceptions of biotechnology and their willingness to approve its use in food production. To promote a broad based acceptance of this technology among the general population, it is vitally important that the actions and policies of private and public institutions be undertaken in ways that work to promote people's trust and confidence in these institutions. Effective communication among scientific

community, private corporations, government and the general public can make enormous contribution towards general acceptance of food biotechnology among ordinary citizens.

This study does not explore how public approval of the use of biotechnology may be affected by the extent to which this technology can deliver clear and observable benefits. It would be interesting to examine how individual reluctance to accept biotechnology, especially its use in animals, changes when this technology delivers products with specific health or economic benefits. Similarly, individuals who are currently unwilling to accept the use of biotechnology, particularly in animals, may become more supportive of it under a well-designed and effective regulatory system. It would be worthwhile to explore what kind of regulations of GM foods may

be appropriate that will minimize public fear about the technology while at the same time allow the society the opportunity to maximize the potential of biotechnology. Future research should address these and other important and relevant issues.

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
MIDAGE	1 = age is between 35 and 54 years; 0 = otherwise	0.43	0.50
MATAGE*	1 = age 55 years or higher ; 0 = otherwise	0.26	0.44
MALE	1 = respondent is male; 0 = otherwise	0.49	0.50
HISCHOOL*	1 = education up to high school; 0 = otherwise	0.38	0.49
COLLEGE	1 = some or full four-year college education; 0 otherwise	0.49	0.50
GRAD	1 = graduate education; 0 = otherwise	0.30	0.42
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 in between; 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	0.27	0.44
WORSHIP_REG	1 = attends church (or other house of worship) at least once a week to several times a month; 0 = otherwise	0.49	0.50
LOWINC	1 = (annual) income less than $35,000; 0 = otherwise	0.32	0.47
MIDINC	1 = (annual) income between $35,000 and $75,000; 0 = otherwise	0.43	0.50
HIGHINC*	1 = (annual) income greater than $75,000; 0 = otherwise	0.25	0.44
SKEP_CO	1 = holds skeptic view about biotech companies; 0 = otherwise	0.68	0.46
CONF_SC	1 = has confidence on 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
TRST_GVT	1 = Trust regulators to do common good = otherwise	0.40	0.49
LOWSCORE*	1 = correctly answered less than 5 (out of 10) basic question on biological science; 0 = otherwise	0.25	0.43
MIDSCORE	1 = Correctly answered between 5 to 7 (out of 10) basic questions on biological science; 0 = otherwise	0.50	0.50
HIGHSCORE	1 = correctly answered more than 7 (out of 10) basic question on biological science; 0 = otherwise	0.25	0.43

Notes: Asterisk implies that the variable was dropped during estimation to avoid dummy variable trap.

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

	Coefficient	t-ratio	Marginal Effect
CONSTANT	-0.1642	-0.30	-0.030
YOUNG*	0.3724	2.16	0.068
MIDAGE	0.1564	0.65	0.028
WORSHIP_NO	-0.1435	-0.59	-0.026
WORSHIP_OCC	-0.0104	-0.05	-0.002
LIBERAL**	-0.3041	-1.85	-0.065
CONSERV	0.0221	0.10	0.004
WHITE*	0.2679	2.00	0.049
COLLEGE**	0.3056	1.73	0.055
GRAD*	0.1709	2.34	0.031
SKEP_CO*	-1.3212	-5.59	-0.240
GVT_REGUL*	-0.7842	-3.64	-0.142
LOWINC	0.2355	0.85	0.043
MIDINC	0.0895	0.38	0.016
MALE*	0.6037	3.17	0.110
CONF_SC*	0.7167	3.27	0.130
MIDSCORE*	0.7647	2.29	0.139
HIGHSCORE*	1.5385	4.38	0.279
TRST_GVT*	0.8961	4.32	0.163

LL	-326.38
Restricted LL	-473.52
Chi Square	294.28
DF	18
McFadden's R^2	0.31

		PREDICTED	
ACTUAL	0	1	**TOTAL**
0	160	132	292
1	56	630	686
TOTAL	216	762	978

* denotes that the variable is significant at 0.05 level.

** denotes that the variable is significant at 0.10 level.

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

	Coefficient	t-ratio	Marginal Effect
CONSTANT	-0.225	-0.44	-0.049
YOUNG*	0.427	3.40	0.091
MIDAGE	-0.194	-0.84	-0.042
WORSHIP_NO**	0.434	1.91	0.093
WORSHIP_OCC**	0.400	1.90	0.086
LIBERAL*	-0.437	-1.96	-0.094
CONSERV	0.107	0.50	0.023
WHITE*	0.706	3.16	0.152
COLLEGE**	0.291	1.82	0.063
GRAD*	0.678	2.08	0.146
SKEP_CO*	-1.204	-5.76	-0.260
GVT_REGUL*	-0.699	-3.58	-0.151
LOWINC	-0.009	-0.04	-0.002
MIDINC	0.072	0.32	0.015
MALE**	0.327	1.85	0.071
CONF_SC*	0.532	2.66	0.115
MIDSCORE*	0.670	2.04	0.144
HIGHSCORE*	1.119	3.30	0.241
TRST_GVT**	0.305	1.84	0.066

LL	-361.68
Restricted LL	-498.08
Chi Square	272.8
DF	18
McFadden's R^2	0.27

		PREDICTED	
ACTUAL	0	1	**TOTAL**
0	187	152	344
1	65	574	639
TOTAL	252	726	978

* denotes that the variable is significant at 0.05 level.

** denotes that the variable is significant at 0.10 level.

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

	Coefficient	t-ratio	Marginal Effect
CONSTANT	-1.4744	-2.85	-0.320
YOUNG	-0.1692	-0.67	-0.037
MIDAGE	-0.0783	-0.34	-0.017
WORSHIP_NO**	0.4119	2.05	0.089
WORSHIP_OCC	0.1839	0.89	0.040
LIBERAL	-0.1988	-0.88	-0.043
CONSERV	0.0940	0.46	0.020
WHITE*	0.3961	2.91	0.086
COLLEGE	0.2368	1.17	0.051
GRAD*	0.6098	2.04	0.132
SKEP_CO*	-0.9205	-5.12	-0.200
GVT_REGUL**	-0.3045	-1.68	-0.066
LOWINC	0.0888	0.35	0.019
MIDINC	0.3060	1.43	0.066
MALE**	0.4118	2.34	0.089
CONF_SC*	0.9233	4.96	0.200
MIDSCORE	-0.1481	-0.41	-0.032
HIGHSCORE**	0.4823	1.83	0.105
TRST_GVT**	0.3617	2.05	0.078

LL	-395.96
Restricted LL	-487.65
Chi Square	183.38
DF	18
McFadden's R^2	0.19

		PREDICTED	
ACTUAL	0	1	**TOTAL**
0	563	81	643
1	189	145	335
TOTAL	752	226	978

* denotes that the variable is significant at 0.05 level.

** denotes that the variable is significant at 0.10 level.