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Application of Biotechnology in Agriculture and Medicine: United States versus Europe

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Application of Biotechnology in Agriculture and Medicine: United States versus Europe

Abstract

Discrepancies in the attitude between US and UK consumers toward application of biotechnology in crop production and medicine were examined using data from mail and online surveys. Results showed that more than 31% (46%) of US (UK) respondents were opposed to biotech foods while only 16% (18%) opposed biotech medicine, respectively. Perceived risks and benefits of agro-biotechnology and medical biotechnology were significant in determining overall attitude toward application of biotechnology in agriculture and medicine i.e., perceived risks (benefits) caused consumers to oppose (support) application of biotechnology in food production and medicine.

Application of Biotechnology in Agriculture and Medicine: United States versus Europe

Background:

Application of biotechnology in agriculture and medicine has produced a growing number of organisms and products. Along with the increasing commercial success of application of biotechnology, a widespread debate focusing on the ecological, human health and socio-economic effects of biotechnology is taking place at national and international levels. There is a remarkable disparity in the level of support to applications of biotechnology between the United States and European countries. While more than 70 percent of US consumers surveyed in 1992, 1995, and 1998 supported the application of biotechnology in food production (Moon and Balasubramanian, 2001; Hoban, 1998), European consumers have voiced intense health and environmental concerns about foods containing genetically modified (GM) organisms (Zechendorf, 1998; Gaskell *et al.*, 1999). Although a majority of the Europeans are opposed to the idea of applying biotechnology in food production, they are increasingly supportive of the use of biotechnology in the field of medicine. A study to capture attitudes of Swedes to marginal donors and xenotransplantation confirmed increased acceptance of use of biotechnology for specific medical purposes (Lundin and Idvall, 2003). Such cautious support to medical biotechnology is found across the polls in the United States and Europe (Singer and Lamias, 1998; Priest, 2000). Several studies have addressed consumers concerns regarding agro-biotechnology and medical biotechnology by measuring consumer willingness-to-pay for nonGM food products using contingent valuation or nonhypothetical lab experiments (Lusk *et al.*, 2001, Huffman *et al.*, 2001; Moon and Balasubramanian, 2003). They showed that some segment of the US

population were willing to pay a certain size of premium to avoid GM food products. A majority of literature on genetically modified (GM) food products, however, does not address those consumers who are indifferent to the risk of consuming GM foods. These consumers typically choose “don’t know” (DK) option when asked about the concerns regarding biotechnology. Motivation behind such selection may have been primarily lack of adequate knowledge of biotechnology. Wang (1997) listed a feeling of being inadequately informed regarding the proposed issue as a reason for DK response. There are several strategies adopted to address the issue of DK. Wang (1997) suggested that one of the ways to treat DK responses was by dropping such responses based on the assumption that socioeconomic and other characteristics of DK respondents were the same as the remaining sample. Haener and Adamocwitz (1998) demonstrated alternative ways of treating DK responses including dropping them and recoding them. Moon and Balasubramanian (2003) deleted DK responses while evaluating the attitude toward agrobiotechnology among US consumers. It is important, however, to consider the DK respondents in examining the consumer attitude toward biotechnology particularly when the size of such response is large in relation to the sample size.

There are several important questions relating to the application of biotechnology in agriculture and medicine. First is the impact of DK respondents on the overall attitude toward biotechnology. Second question is related to the role of risks and benefits perceptions, and other socio demographic attributes of consumers in forming the attitudes toward biotechnology. This paper offers some empirical insights into these issues using consumer surveys administered in December, 2000, online in the United Kingdom (2,568 respondents) and via mail in the US (3,060 respondents). While consumer sentiments about biotechnology vary across countries within the European Union, the United

Kingdom is most likely to represent the middle ground among its 15 member nations. For example, Gaskell (2000) shows that Greece, Austria, and Luxembourg belong to the group least supportive of agrobiotechnology (14%-30%), and the Netherlands, Spain, and Finland are most supportive (69%-75%). The UK is in the middle group along with Germany and Belgium (47%-50%). Hence, it seems reasonable to use the UK as a proxy for the EU (Moon and Balasubramanian, 2001). The database includes an array of variables measuring consumer acceptance, perceptions, and trust of regulatory agencies that shed light on current trends in public sentiment about biotechnology. Our study first examines survey results of particular relevance to addressing the questions raised above. Then a two-stage ordered probit regression model is developed to evaluate the relationship between the attitude toward agro-biotechnology and medical biotechnology, and an array of socio-demographic and attitudinal variables.

Survey Design

A survey instrument was designed to measure attitudes and perceptions as related to agro-biotechnology, and medical biotechnology. The surveys were administered by mail survey in the US and online survey in the UK using household panels maintained by the National Panel Diary (NPD) group, a marketing consulting firm specializing research on consumer behavior and food marketing. Survey methods that use an established panel are called “permission-based surveys” and are increasingly used in exploring various aspects of consumer behavior for academic or commercial purposes. Questionnaires were distributed to 5,200 households (a subsample of NPD panel), selected across the United States by random sampling. The US sample was stratified by geographic regions, head of household age, education, and income, consistent with the US census for adults. The

same instrument was administered to consumers in the United Kingdom using online methods. Questionnaires were sent to about 9,000 participants of the online panel via emails, and 2,568 consumers completed the online survey within the next seven days.

Results

Public Acceptance

Public acceptance of biotechnology in agriculture and medicine was measured using a six-point Likert scale ranging from "Strongly oppose" to "Strongly support." Unsure respondents could select the option "Don't know." Table 1 shows the distribution of responses for the entire sample and also across the US and UK. While responses were equally split between "oppose" and "support" in case of agro-biotechnology, more respondents supported application of biotechnology in medicine than opposed it. Most notably, the percentage of US respondents that supported application of biotechnology in agriculture (32.4%) in our survey was considerably lower than the 70% reported by Hoban up to 1998. This finding corroborates the declining trend in the public acceptance rate in the US over the last few years (Moon and Balasubramanian, 2001). Yet the figure displays a key discrepancy across the US and UK. While almost half of the respondents opposed agro-biotechnology in UK, only about third of the respondents opposed in the United States. The percentage of consumers who selected "Don't know" was significantly larger in the US (35.5%) than UK (15.8%). This result suggests that a significant segment of US consumers have not developed attitudes toward application of biotechnology in agriculture. This result has been found elsewhere (Hoban, 1998).

It is interesting to compare and contrast the evolution of the attitudes of consumers toward biotechnology in the pharmaceutical and food domains. In this study,

almost 60% of the overall respondents supported application of biotechnology in medicine, compared to a third of the respondents in food production. Such support is further accentuated when analyzed across countries. Historically, public opinion in the US and Europe has been more positive about medical biotechnology than agricultural biotechnology. Our survey result mirrors this trend: 30.8% (46.4%) of US (UK) respondents were opposed to biotechnology for foods while only 16.2% (17.5%) opposed biotechnology for medicine, respectively. A study evaluating Swedish consumers' opinions about gene technology (Hursti et al., 2002) reported that respondents were more positive to applications of "GM bacteria for medical purposes" than in food production. Although both biotech foods and biotech medicine are subject to regulatory oversight by the FDA and the European counter parts, a plausible explanation for these differences stems from the extent of control mechanisms in place to enhance consumer welfare. That is, the field of biotech medicine has professional gatekeepers (i.e., physicians who command a high degree of consumer trust) that prescribe, direct, and control the consumption of such products to benefit consumers (Moon and Balasubramanian, 2001). Moreover, the dosage and regimen associated with the consumption of biotech drugs is tailored to the needs of the individual. Such gate-keeping or tailoring activities do not exist for biotech foods. Another plausible explanation that has been advanced is that medical applications of the technology offer tangible direct benefits to consumers whereas the first generation of GM foods has offered only indirect benefits. Further, due to lack of sufficient data many of the health and environmental questions associated with agricultural biotechnology are not answered conclusively.

Benefits and risks of application of biotechnology

Table 2 presents the distribution of responses to the seven questions dealing with perceived risks and benefits of application of biotechnology in various fields including crop production. Questions pertaining to perceived risks included health risks from application of biotechnology, environmental hazards, moral issues, role of multinational corporation as a main beneficiary of the benefits of biotechnology, and control of food supply by multi-national corporation as a result. The benefit perceptions included increase in yield, reduced use of chemical and fertilizers, and improved nutrition. Percentage distribution for UK sample is presented in parentheses. Mean tests were conducted using Tuckey procedure (SAS, 2004). Mean values with same letters indicated that there were not significant difference between USA and UK at 0.05 critical value.

Overall, UK respondents showed a greater level of consensus about the perceived risks as well as benefits of application of biotechnology than US respondents. More US consumers (24.4%) reported DK about moral issues regarding the application of biotechnology than UK consumers (8.1%). It seems UK consumers were more certain about moral issues than US consumers and more of them disagreed that application of biotechnology was morally wrong. Also, greater percentage of UK consumers agreed that the application of biotechnology in crop production resulted in higher yield rate than US consumers; more of them also agreed that the technology was hazardous to health and environment. About 65% of UK respondents were concerned about adverse environmental effects resulting from agro-biotechnology. The beneficiaries of biotechnology also determined the consumer acceptance of biotechnology. If there were only commercial interests but no obvious benefits to the consumers the acceptability is low among the European consumers (Moon and Balasubramanian, 2001; Grov-White et

al., 1997). In this study, 71% of UK respondents perceived multinational corporations as being the primary beneficiaries of biotechnology with consumers assuming most of the risks. Multinational corporations were seen increasingly to control farming. There was also a divergence in the percentage of respondents across the US and UK who selected DK: the US consumers were much more predisposed to choose the DK option than UK consumers across all questions (25%-50% in the US vs. 8%-28% in the UK).

A regression analysis to evaluate the factors influencing the attitude toward application of biotechnology in crop production and medicine

A regression analysis is conducted to provide detailed analysis of the relationship between various behavioral and socio-economic factors, and attitude toward the application of biotechnology in crop production and medicine. As shown in Table 1, 13 to 35% of the respondents have reported DK responses. Due to the presence of such high DK responses, the empirical model is developed using a two-stage framework. In the first stage, respondents who reported, DK to the questions regarding their attitude toward biotechnology in crop production and medicine were compared with those with definite opinion about biotechnology. One alternative to treat the DK responses is to drop the DK responses based on the assumption that socio-demographic and other personal characteristics of such respondents are the same as the rest of the respondents (Wang, 1997). Such deletion is effectively censors the data causing results to be bias (Long, 1989). One approach to estimating regression with censored data was proposed by Heckman (1976) using a two-stage estimator in which one of the parameters is estimated in the first stage and used in correcting the biasness of the results. Following this approach, the relationship between explanatory variables and the dependent binary

variable representing DK or otherwise responses to attitude question is analyzed. This is done using a binary Probit model.

In the second stage, only those respondents who chose one of the six answers ranging from strongly oppose to strongly support the application of biotechnology in crop production and medicine were included. At this stage, an ordered probit regression model was selected as the appropriate empirical model given that the attitude variable was measured using a scale that allowed for the ranking of the outcomes. Ordered probit models have been widely used in agricultural economics, particularly to study consumer preferences for foods (e.g., Misra, Huang, and Ott, 1991; Huang, Kan and Fu, 1999; Fu, Liu and Hamint, 1999). The empirical model was defined as

$$(1) \quad Y^*_t = \beta X_t + \epsilon_t$$

where Y^*_t is an unobserved attitude toward application of biotechnology and medicine; X_t is a vector of variables (Table 3) including socio-demographic attributes of the respondents hypothesized to affect the attitude toward agricultural and medical application of biotechnology; β is the vector of unknown parameters and ϵ_t is the independently and identically normally distributed error term. While Y^*_t is unobserved, respondents actually report acceptance of application of biotechnology in agriculture or medicine by selecting one of the six categories (Y_t) representing consumers' support and opposition to biotechnology. Values for Y_t are 1,2,3,4,5 and 6 where 1 represents strongly oppose (SO) to the statement "Please indicate your attitude about the use of biotechnology in *crop production*" and "Please indicate your attitude about the use of biotechnology in *medicine*" and 6 represents strongly support (SS). The unknown parameter vector, β , in equation (1) were estimated using LIMDEP (7) software.

Independent Variables:

The first group of independent variables included consumers' general food related attitude and purchase behavior. Attitude toward application of biotechnology in agriculture may be reflected in consumers' general food related attitude and purchase behavior. In this section, consumers were asked questions relating to their perception about the safety of food supply and the influence of food prices and food safety in their food purchase decisions. These variables were expected to be associated with attitude toward application of biotechnology in food production only. Attitude toward the government role in safety of the food supply (FOOD_SUPPLY), importance of food safety (FOOD_SAFETY), price (FOOD_PRICE) in food purchasing decisions, and consumption frequency of organic food products (FOOD_ORGANIC). Consumers who are risk averse are likely to be more concerned about safety of food, hence generally have less favorable attitude toward application of biotechnology. One of the promises of agro-biotechnology is higher yield rates and increased food supply resulting in lower prices of food in general. The importance of price (FOOD_PRICE) in food shopping is anticipated to impact attitude toward agro-biotechnology positively. The consumption frequency of organic food products (FOOD_ORGANIC) is expected to be negatively related to attitude toward agro-biotechnology.

A high correlations (ranging from 0.54 to 0.76) among consumer perceptions about the perceived drawbacks of biotechnology found, implying that it would be difficult to isolate the impact of each negative factor on the attitude toward application of biotechnology in food production and medicine. To cope with potential multicollinearity problems in estimating the empirical models, an index of perceived risks (RISKS) was constructed by adding consumer responses to the five questions

describing the negative attributes. Theoretically, the index could range from 5 (representing complete disagreement with the negative aspects of agrobiotechnology) to 30 (representing complete agreement). Similarly, a benefit index (BENEFIT) was created using consumer responses to positive attributes. The benefit index could range from 3 (representing complete disagreement with the positive aspects of the application biotechnology in food production and medicine) to 18 (representing complete agreement). It is anticipated that perceived risks of biotechnology will have negative impact of the attitude. Consumers who strongly agreed that applications of biotechnology have many negative attributes would tend to oppose such application in food production and medicine.

Consumers' level of awareness about biotechnology was measured by asking how much have they read or heard about GMOs (HEAR_GM). As discussed above, a generally positive attitude of US consumers toward agro-biotechnology along with high percentage of "don't know" responses may have been the artifact of less knowledge about biotechnology compared to the European consumers. On the other hand, European consumers were more positive toward application of biotechnology in medicine due to a greater level of awareness. Therefore a positive association between level of awareness and attitude toward application of biotechnology in medicine is expected. The results for agro-biotechnology, however, are expected to be just the opposite. Consumers' concern of health hazard (HEALTH_GM) due to GM food demonstrates that consumers are generally averse to the idea application of biotechnology. Hence, those who have a higher level of concern are expected to have negative attitude towards the application of biotechnology in food production and medicine.

Prior literature suggests that demographic characteristics affect consumer' perceptions and attitudes about biotechnology. Surveys show that the level of education and gender makes a significant difference in explaining public acceptance of biotech foods: males and respondents with higher education were more likely to accept biotech foods (Alger, 2002; Nature of Science, 2000). Heiman, Just, and Zilberman (2000) also showed that education had a significant role in explaining Israel consumers' attitudes toward biotech foods. Hence, gender, age, income, and education were considered in this study. Impact of education is measured using two variables: those with college education and those with science degree in college.

Regression Models:

Two separate regression models with three data sets were estimated. The first regression equation evaluated the consumer attitude towards agro-biotechnology. Models were estimated using ALL sample, USA sample, and UK sample. Similarly, the second equation evaluated the attitude toward medical biotechnology using three sample sets.

The regression models were specified as follows:

Model 1: Two-stage model to evaluate attitude towards agro-biotechnology

First Stage:

$$DK (=0) \text{ or otherwise responses to attitude toward agro-biotechnology } (=1) = \mathbf{N} + \mathbf{C}_1\text{FOOD_SUPPLY} + \mathbf{C}_2\text{FOOD_SAFETY} + \mathbf{C}_3\text{FOOD_PRICE} + \mathbf{C}_4\text{FOOD_ORGANIC} + \mathbf{C}_5\text{HEAR_GM} + \mathbf{C}_6\text{HEALTH_GM} + \mathbf{C}_7\text{RISKS} + \mathbf{C}_8\text{BENEFITS} + \mathbf{C}_8\text{GENDER} + \mathbf{C}_9\text{AGE} + \mathbf{C}_{10}\text{INCOME} + \mathbf{C}_{11}\text{COLLEGE} + \mathbf{C}_{12}\text{SCIENCE} + \varepsilon_1$$

Second Stage:

$$\text{Attitude toward application of biotechnology in Food Production } (0,1,2,3,4,5) = \alpha + \mathbf{\$}_1\text{FOOD_SUPPLY} + \mathbf{\$}_2\text{FOOD_SAFETY} + \mathbf{\$}_3\text{FOOD_PRICE} + \mathbf{\$}_4\text{FOOD_ORGANIC} +$$

$$\begin{aligned} & \$5\text{HEAR_GM} + \$6\text{HEALTH_GM} + \$7\text{RISKS} + \$8\text{BENEFITS} + \$9\text{GENDER} + \$10\text{AGE} \\ & + \$10\text{INCOME} + \$11\text{COLLEGE} + \$12\text{SCIENCE} + \varepsilon_2 \end{aligned}$$

Model 2: Two-stage model to evaluate attitude towards medical biotechnology

First Stage:

$$\begin{aligned} & \text{DK (=0) or otherwise responses to attitude toward medical biotechnology (=1) = H+} \\ & \mathbf{D}_1\text{HEAR_GM} + \mathbf{D}_2\text{HEALTH_GM} + \mathbf{D}_3\text{RISKS} + \mathbf{D}_4\text{BENEFITS} + \mathbf{D}_5\text{GENDER} + \mathbf{D}_6\text{AGE} + \\ & \mathbf{D}_7\text{INCOME} + \mathbf{D}_8\text{COLLEGE} + \mathbf{D}_9\text{SCIENCE} + \delta_1 \end{aligned}$$

Second Stage:

$$\begin{aligned} & \text{Attitude toward medical biotechnology (0,1,2,3,4,5) = R + } \mathbf{F}_1\text{HEAR_GM} + \\ & \mathbf{F}_2\text{HEALTH_GM} + \mathbf{F}_3\text{RISKS} + \mathbf{F}_4\text{BENEFITS} + \mathbf{F}_5\text{GENDER} + \mathbf{F}_6\text{AGE} + \mathbf{F}_7\text{INCOME} + \\ & \mathbf{F}_8\text{COLLEGE} + \mathbf{F}_9\text{SCIENCE} + \delta_2 \end{aligned}$$

Regression Results

In the first stage, respondents who reported DK were compared with those with a definite attitude. In the second stage, only those respondents with specific opinion expressed using the six-point scale were selected. Maximum likelihood estimates were reported only for the second stage results (Table 4 and 5). A simulation analysis was conducted to further analyze the effect of risk and benefit perception on the attitude toward the application of biotechnology in agriculture and medicine. Models were estimated using all sample (AS), US sample (US), and UK sample (UK). A likelihood ratio test rejected the hypotheses that US consumers' attitude toward agro-biotechnology was not different from that of UK consumers. The calculated chi-square value was 45.8 compared to the critical value of 34.1 (d.f.=18) at $\alpha = 0.01$. The chi-square value to test the similarity among US and UK consumers in relation to medical biotechnology was 32.92 compared to the critical value of 29.14 (d.f.=14) at $\alpha = 0.01$. Therefore, the

hypothesis that US and UK consumers were identical in terms of their attitude toward medical biotechnology was also rejected.

Consumers' Food Related Behavior and their attitude toward Agro-Biotechnology

Consumers who expressed trust in public authorities in ensuring safety in food supply (FOOD_SUPPLY) tend to have more positive view of application of biotechnology in food production than those who generally mistrusted government authorities ($\beta_{AS}=0.0798$; P-value<0.0001). In this study, the impact of trust was more substantial in US than in UK ($\beta_{US}=0.0921$; $\beta_{UK}=0.0554$), which is highly relevant to current public debates on bovine spongiform encephalopathy (BSE). UK consumers generally have less trust in their government organizations compared to the US consumers (Moon and Balasubramanian, 2001). On average, more Europeans preferred international organizations such as United Nations and the World Health Organization to their own national or pan-European public bodies (Nature, 1997). Trend are increasing lack of confidence in national political institutions. The generally higher level of trust among American consumers has allowed authorities to manage the BSE situation in USA without any kind of public backlash compared to that in Europe.

Consumers' attitudes toward the agro-biotechnology were shaped by the perceived importance of food safety ($\beta_{AS}=0.0425$; P-value=0.0038) and food prices ($\beta_{AS}=0.0423$; P-value=0.0038) in food purchase decision-making. Among all consumers, food safety seemed to be as important as food prices. Consumers who were concerned about food safety were less likely to have a positive attitude toward agro-biotechnology. US and UK consumers differed in terms of the role of food safety in shaping their attitude

toward agro-biotechnology. UK consumers ($\beta_{UK}=-0.0536$; P-value=0.0068) valued food safety more than US consumers ($\beta_{US}=-0.0226$; P-value=0.3245).

The most highlighted attribute of agro-biotechnology is its ability to increase yield rates, thus increase the agricultural production. The direct impact of such enhanced supply would be on food prices. Therefore, it is consistent that consumers who associate biotechnology as a means to lower food price are supportive of agro-biotechnology. Food prices were more important to US consumers (than their UK counterparts.

A statistically significant association between frequency of organic food purchase and attitude toward agro-biotechnology is found among UK consumers. Those who were purchasing organic food more frequently were likely to oppose agro-biotechnology than who seldom purchased organic food.

Risk and Benefit Perception and Attitude toward Application of Biotechnology in Agriculture and Medicine

Perceived risks and benefits of application of biotechnology as represented by RISK and BENEFIT were highly significant in determining overall attitude toward application of biotechnology in agriculture and medicine i.e., perceived negative (positive) attributes caused consumers to oppose (support) application of biotechnology in food production and medicine. Perception of benefits had more impact on the likelihood of “strongly opposing” the applications of biotechnology than the perception of risks. The effects of risk and benefit perception on consumer attitude were simulated using the estimated parameters and a range of index values (Figure 1 to 4). The perception of benefits reduced the probability of “strongly opposing” the application of biotechnology in medicine by a little more than 40% (30%) among US (UK) consumers

within the range of possible index values. Similar percentage for agro-biotechnology was 20% (7%). Hence, the disparity was much more evident in the results for medical biotechnology than for agro-biotechnology. Perceived benefits were more powerful in alleviating negative attitude than perceived risks in shaping the negative attitude toward the applications of biotechnology. The results were similar but more accentuated among US consumers compared to UK consumers. This has an important implication in policy making. Generally policy debates regarding biotechnology are focused more on potential risks to environment and /or human health. If, however, people are more swayed by potential benefits, then focus needs to be shifted to potential benefits.

Effect of Consumer Awareness and Concern

Consumers who have heard or read about biotechnology were likely to support applications of biotechnology than those who have a lower level of awareness about the issues. The strength of the impact was considerably larger compared to RISKS and BENEFITS across all samples. Moreover, the marginal effect of awareness on the likelihood of “strongly opposing” applications of biotechnology was highest among the US consumers. It implies that greater dissemination of information with particular emphasis on the positive attributes is likely to generate more support from the American consumers than the European consumers.

Gender and science degree were statistically significant among all the samples and for both agro-biotechnology and medical biotechnology models. Females were substantially more unfavorable about the applications of biotechnology than males. Consumers with science degree in college were more likely to favor the applications of biotechnology than those without science degree. Socio-demographic variables seemed to interact with purchase behavior variables resulting in a number of socio-demographic

variables to be statistically insignificant. When purchase behavior variables were excluded in the model dealing with medical biotechnology, the results show that almost all socio-demographic variables were significant in shaping attitudes. For example, higher income consumers were likely to support application of biotechnology in medicine than the lower income consumers. The impact of income is much more larger in UK ($B=0.0024$) than in USA ($B=0.0020$). Older consumers were less supportive of the application of biotechnology of medicine than the younger consumers.

Summary

Discrepancies in the attitude between US and UK consumers toward application of biotechnology in crop production and medicine were examined using data from mail and online surveys. Preliminary results showed that more than 31% (46%) of US (UK) respondents were opposed to biotech foods while only 16% (18%) opposed biotech medicine, respectively. Perceived risks and benefits of agro-biotechnology and medical biotechnology were significant in determining overall attitude toward application of biotechnology in agriculture and medicine i.e., perceived risks (benefits) caused consumers to oppose (support) application of biotechnology in food production and medicine. Consumers who have heard or read about biotechnology were likely to support applications of biotechnology than those who have a lower level of awareness about the issues.

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Table 1: Distribution of consumer responses to attitude toward application of biotechnology in Agriculture and Medicine

	All Sample			United States (United Kingdom)		
	Oppose	Support	Don't Know	Oppose	Support	Don't Know
Attitude about the use of biotechnology in crop production	37.9	34.1	27.9	30.8 ^B (46.4 ^A)	32.4 ^B (37.5 ^A)	35.5 ^A (15.8 ^B)
Attitude about the use of biotechnology in medicine	16.8	59.0	24.2	16.2 ^A (17.5 ^A)	50.5 ^B (69.2 ^A)	32.0 ^B (13.2 ^A)

Note. Six-point scale ranging from "Strongly Oppose" to "Strongly Support" was used. In the table "Oppose" is an aggregation of the first three categories while "Support" is for the last three categories. The numbers in the parenthesis are for United Kingdom. Mean tests were conducted using Tukey process. Means with the same letters are not significantly different at 5%.

Table 2. Perceived risks and benefits of application of biotechnology.¹

	All Sample			United States (United Kingdom)		
	Disagree	Agree	Don't Know	Disagree	Agree	Don't Know
Risks (%)						
Health risks	33.5	32.2	34.3	30.5 ^B (37.2 ^A)	25.6 ^B (40.1 ^A)	43.9 ^A (22.7 ^B)
Environmental Hazards	19.7	46.1	34.2	22.7 ^A (16.0 ^B)	30.3 ^B (65.0 ^A)	47.0 ^A (19.0 ^B)
Morally Wrong	46.7	35.6	17.0	43.0 ^B (50.9 ^A)	31.4 ^B (40.7 ^A)	24.4 ^A (8.1 ^B)
Multinational Corporations ^a (Image)	21.0	61.7	17.3	22.1 ^A (19.7 ^B)	53.3 ^B (71.7 ^A)	24.6 ^A (8.6 ^B)
Control ^b	16.5	60.7	22.8	17.7 ^A (15.0 ^B)	51.6 ^B (71.5 ^A)	29.7 ^A (13.5 ^B)
Benefits (%)						
Increase in Yields	18.6	53.7	27.7	14.8 ^B (23.2 ^A)	47.4 ^B (61.2 ^A)	37.8 ^A (15.6 ^B)
Reduced Chemical Use	24.7	42.6	32.7	16.2 ^B (34.9 ^A)	42.2 ^A (43.0 ^A)	40.6 ^A (22.1 ^B)
Improved Nutrition	31.6	28.8	39.6	21.2 ^B (43.9 ^A)	29.0 ^A (28.5 ^A)	48.8 ^A (27.6 ^B)

¹Six-point scale ranging from "Disagree completely" to "Agree completely" was used. In the table "Disagree" is an aggregation of the first three categories while "Agree" is for the last three categories.

^a Respondents responded to the following statement, "Corporations are the main beneficiaries from agricultural biotechnology, while consumers assume most of the risk."

^b Respondents responded to the following statement, "The development and use of genetically modified seeds will negatively impact family farms by putting more control of the food supply into the hands of multinational corporations."

The numbers in the parenthesis are for United Kingdom. Mean tests were conducted using Tukey process. Means with the same letters are not significantly different at 5%.

Table 3: Descriptive statistics of the variables used in the regression analysis.

Variable	Explanation	Mean		
		ALL	USA	UK
AGBIO	Attitude about the use of biotechnology in <i>Crop Production</i> 1=strongly oppose;6=strongly support	3.30	3.43 ^A	3.18 ^B
MEDBIO	Attitude about the use of biotechnology in <i>Medicine</i> 1=strongly oppose;6=strongly support	4.37	4.31 ^B	4.43 ^A
<i>General Food Related Attitude and Purchase Behavior:</i>				
FOOD_SUPPLY	The government ensures safety of the food supply 1=disagree completely; 6=agree completely	3.86	4.26 ^A	3.35 ^B
FOOD_SAFETY	Safety is an important consideration in food purchasing 1=disagree completely; 6=agree completely	4.70	5.01 ^A	4.34 ^B
FOOD_PRICE	Price is an important consideration in food purchasing 1=disagree completely; 6=agree completely	4.84	5.02 ^A	4.62 ^B
FOOD_ORGANIC	Purchase frequency of organic food 1=Never; 6=All the time	2.54	2.38 ^B	2.73 ^A
<i>Awareness about GM and Concern among the respondents:</i>				
HEAR_GM	How much heard about genetically modified organism (GMOs) 1=Nothing; 6=A great deal	3.00	2.46 ^B	3.64 ^A
HEALTH_GM	Likelihood of health hazard from eating GM foods 1=Extremely low; 6=Extremely high	3.54	3.53 ^A	3.55 ^A
<i>Index of perceived risks and benefits of application of bio-technology:</i>				
RISKS	Index of perceived risks of applications of biotechnology (5 to 30)	19.26	18.53 ^B	20.13 ^A
BENEFITS	Index of perceived benefits of applications of biotechnology (3 to 18)	10.97	11.27 ^A	10.61 ^B
<i>Demographic Characteristics of the Respondents:</i>				
GENDER	Female =1; Male=0	0.50	0.53 ^A	0.45 ^B
AGE	Age of the respondents	40.31	45.48 ^A	34.26 ^B
INCOME	Household income in '000 dollars	12.43	17.88 ^A	5.94 ^B
COLLEGE	1=college education; 0 otherwise	0.36	0.47 ^A	0.23 ^B
SCIENCE	1=Have a science degree from college; 0=otherwise	0.15	0.11 ^B	0.20 ^A

Table 4: Attitude toward agro-biotechnology: Maximum Likelihood Estimates of Ordered Probit Model corrected for sample selection bias caused by “Don’t know” responses

Variables	All Samples (AS)		US		UK	
	Estimated Parameter (β_{AS})	P-Value	Estimated Parameter (β_{US})	P-Value	Estimated Parameter (β_{UK})	P-Value
Constant	2.4484*	0.0000	1.7941*	0.0000	3.3060*	0.0000
FOOD_SUPPLY	0.0798*	0.0000	0.0921*	0.0001	0.0554*	0.0068
FOOD_SAFETY	-0.0425*	0.0038	-0.0226	0.3245	-0.0536*	0.0072
FOOD_PRICE	0.0423*	0.0038	0.0382*	0.0791	0.0308	0.1291
FOOD_ORGANIC	-0.0112	0.4071	0.0308	0.1146	-0.0575*	0.0035
HEAR_GM	0.1277*	0.0000	0.1394*	0.0000	0.1197*	0.0000
HEALTH_GM	-0.1771*	0.0000	-0.1684*	0.0000	-0.1950*	0.0000
BENEFITS	0.1419*	0.0000	0.1526*	0.0000	0.1300*	0.0000
RISKS	-0.1172*	0.0000	-0.1075*	0.0000	-0.1274*	0.0000
GENDER	-0.1342*	0.0001	-0.1516*	0.0030	-0.1244*	0.0167
AGE	-0.0008	0.5547	-0.0016	0.4516	-0.0015	0.5261
INCOME	0.0005	0.2243	0.0008	0.1824	0.0002	0.7598
COLLEGE	-0.0151	0.6937	-0.0033	0.9511	-0.0270	0.6397
SCIENCE	0.1809*	0.0001	0.1398*	0.0629	0.2205*	0.0002
Threshold parameters for Index						
Mu(1)	0.9032*	0.0000	0.8662*	0.0000	0.9470*	0.0000
Mu(2)	1.8242*	0.0000	1.7423*	0.0000	1.9229*	0.0000
Mu(3)	3.0860*	0.0000	2.9301*	0.0000	3.2770*	0.0000
Mu(4)	4.2906*	0.0000	4.0455*	0.0000	4.6183*	0.0000
Log likelihood	-5067.97		-2482.42		-2562.65	
Chi-squared	2182.47		1502.69		668.91	

*Significant at " <10%

Table 5: Attitude toward Medical biotechnology: Maximum Likelihood Estimates of Ordered Probit Model corrected for sample selection bias caused by “Don’t know” responses

Variables	All Samples (AS)		US		UK	
	Estimated Parameter (F_{AS})	P-value	Estimated Parameter (F_{US})	P-value ^{''}	Estimated Parameter (F_{UK})	P-value
Constant	2.3989*	0.0000	2.1770*	0.0000	2.6686*	0.0000
HEAR_GM	0.1489*	0.0000	0.1577*	0.0000	0.1321*	0.0000
HEALTH_GM	-0.1627*	0.0000	-0.1383*	0.0000	-0.1876*	0.0000
REGULATION	0.0074	0.5858	-0.0058	0.7689	0.0259	0.2152
BENEFITS	0.0880*	0.0000	0.0998*	0.0000	0.0768*	0.0000
RISKS	-0.0534*	0.0000	-0.0527*	0.0000	-0.0546*	0.0000
GENDER	-0.1847*	0.0000	-0.1677*	0.0009	-0.1805*	0.0002
AGE	-0.0061*	0.0000	-0.0070*	0.0008	-0.0048*	0.0217
INCOME	0.0023*	0.0000	0.0020*	0.0050	0.0024*	0.0001
COLLEGE	-0.1958*	0.0000	-0.2734*	0.0000	-0.0809	0.1681
SCIENCE	0.1970*	0.0000	0.0790	0.3301	0.2954*	0.0000
Threshold parameters for Index						
Mu(1)	0.4836*	0.0000	0.4557*	0.0000	0.5272*	0.0000
Mu(2)	1.0842*	0.0000	1.0371*	0.0000	1.1558*	0.0000
Mu(3)	2.0032*	0.0000	1.8934*	0.0000	2.1401*	0.0000
Mu(4)	2.9316*	0.0000	2.7902*	0.0000	3.1012*	0.0000
Log likelihood	-5855.27		-2856.91		-2981.90	
Chi-squared	1991.11		1389.70		580.25	

*Significant at " <10%

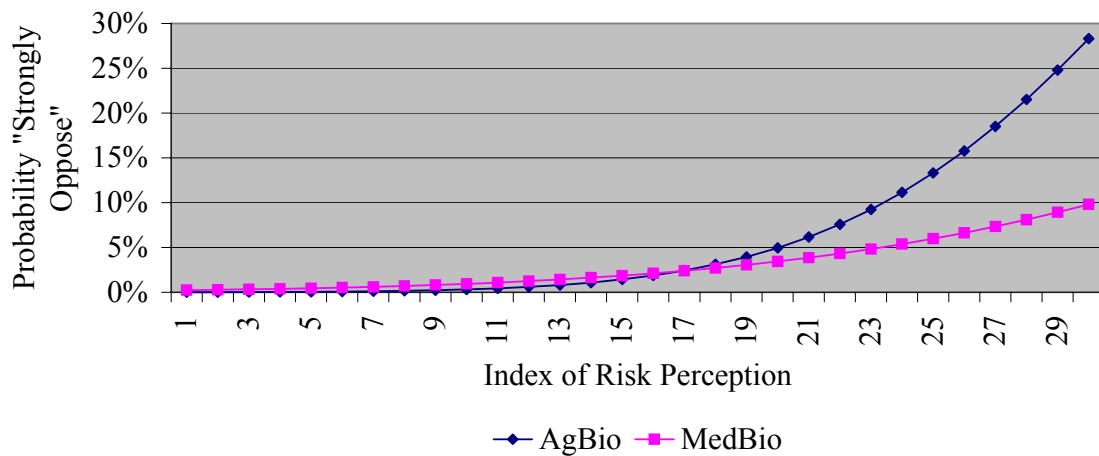


Figure 1: Simulated effect of risk perception on the probability of “Strongly Opposing” application of biotechnology on agriculture and medicine among US consumers

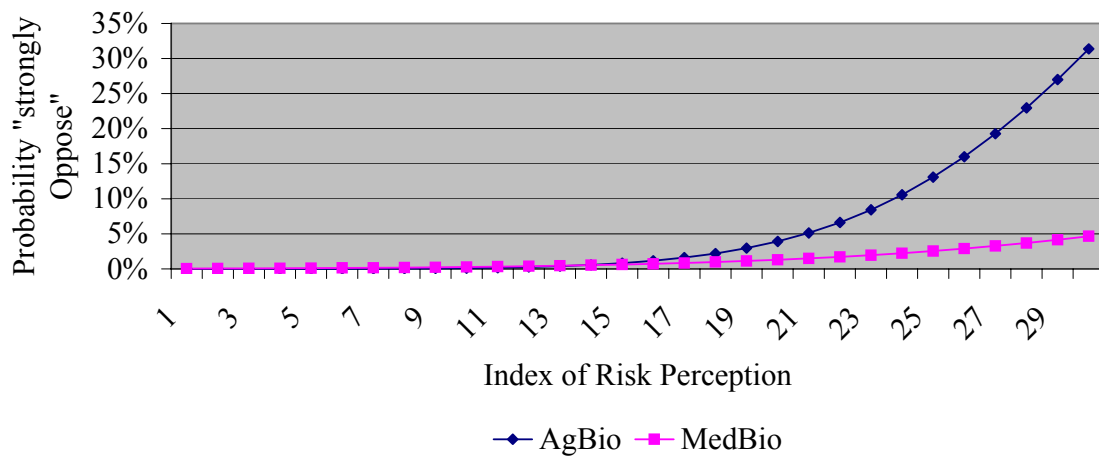


Figure 2: Simulated effect of risk perception on the probability of “Strongly Opposing” application of biotechnology on agriculture and medicine among UK consumers

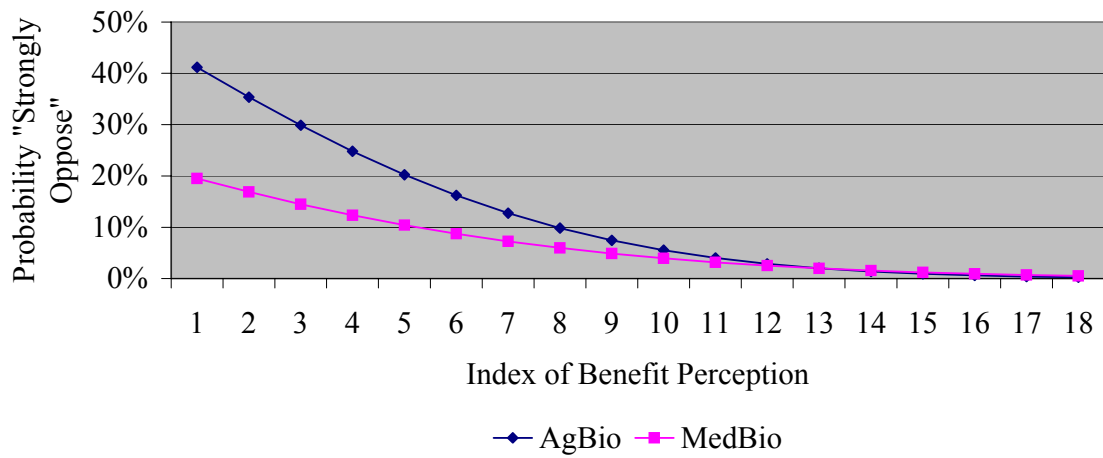


Figure 3: Simulated effect of benefit perception on the probability of “Strongly Opposing” application of biotechnology on agriculture and medicine among US consumers

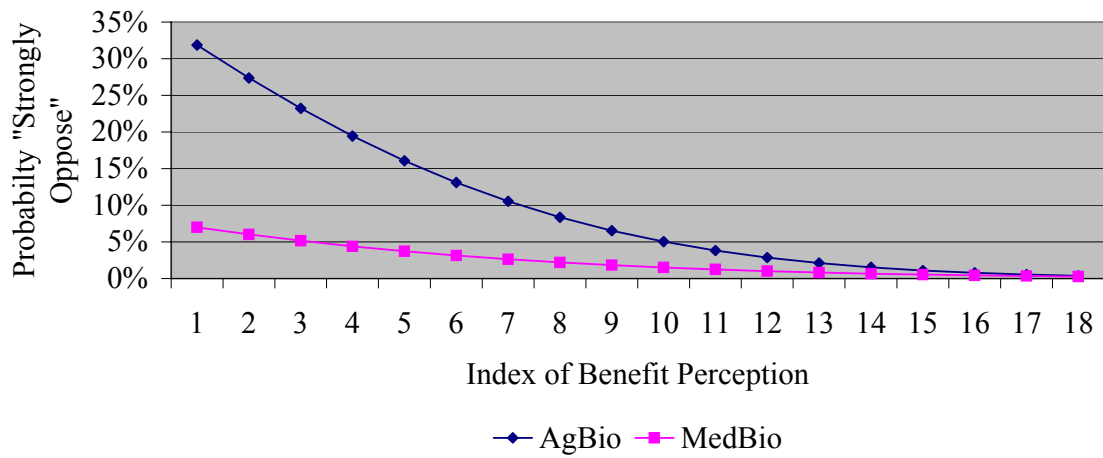


Figure 4: Simulated effect of benefit perception on the probability of “Strongly Opposing” application of biotechnology on agriculture and medicine among UK consumers