Towards a More Holistic Understanding of American Support for Genetically Modified Crops: An Examination of Influential Factors Using a Binomial Dependent Variable

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ABSTRACT. This paper is an investigation into the relative importance of a wide variety of factors in influencing whether members of the American public support or oppose the use of biotechnology in agriculture and food production. To accomplish this end, as well as to facilitate the examination of a large number of independent variables simultaneously, several statistical methods, including factor analyses, instrumental variables analysis, and probit and logistic regressions were performed. It was determined that people's perceptions of risks and moral acceptability were important contributors to opinion formation in this regard. The effects of expected benefits, feelings of trust in information, and knowledge about biotechnology and genetics, were also investigated and found to exert varying levels of influence depending on the identity of the expected beneficiary or information source, as well as the kind of knowledge under consideration. The roles of religious and political party affiliation were also examined and determined to be significant.

Keywords: genetically modified foods, biotechnology, public opinion

Introduction

Innovations in biotechnology have transformed what was once the stuff of science fiction into a part of our everyday lives. Although traditional cross-breeding techniques are still employed, they are quickly being surpassed in importance by methods of direct genomic manipulation. Multi-national life science companies, the majority of which are based in the United States, employ genetic sequencing and polymerase chain reactions to identify stretches of DNA that code for a desired trait, then isolate and replicate them directly, often in bacterial host cells. The newly generated molecules are then transfected (most often using "gene guns") into the nucleus of recipient plant cells, which are cultured to produce entirely new varieties of crops.

Such processes, and the products they yield have inspired widely varying reactions among members of the public and governmental officials. While some nations have launched vehement opposition to the proposed introduction of genetically modified crops onto their farmlands and dinner tables, others have provided little resistance to such efforts. Given such varied reactions, one is left to wonder, "What factors are important in the formation of public opinion regarding GM foods?" and "What leads people to support this technology and its products?"

To answer these questions, a series of statistical analyses were performed on data gathered from 985 participants in the United States Biotechnology Survey, which was conducted between 1997 and 1998. Responses to the question, "Do you support or oppose the use of biotechnology in agriculture and food production?" were examined using probit and logistic regressions, so as to determine the effect of a variety of personal characteristics and beliefs, thought to influence opinion formation in this regard. The factors considered included measures of knowledge, as well as trust in information about biotechnology, perceptions of risks and benefits, moral acceptability of genetically modified foods, political party affiliation, gender and religiosity.

In addition to investigating the effects of some characteristics that have not previously been included in analyses of this type, this work is set apart from previous endeavors through the use of factor analysis and a two-stage regression. These procedures were performed in order to reduce the (substantial) number of original predictor variables to a more manageable number, to uncover their underlying similarities between them, and to account for conceptual overlaps between the many elements thought to influence levels of support. The new variables which resulted from these manipulations not only satisfied these technical goals, they also allowed for the discrimination of new and interesting relationships between the independent variables, and people's levels of support for GM foods.

Most of the perceptions and conditions thought at the outset to be significant contributors to opinion formation were found to be important, however, the magnitudes of their individual effects on people's feelings of support were far from equivalent. Important distinctions were uncovered between the influences of various *kinds* of knowledge, benefits and trust. For example, while benefits accruing to the respondent and their family were found to be significant, those affecting others were not.

In the pages that follow, the reader will be introduced to many of the issues surrounding GM foods in the United States. Some parallels will be drawn with conditions in Europe and elsewhere, however, given that the data were collected from American respondents, this introductory discussion is designed to acquaint the reader with conditions as they are experienced by this group. A description of the factors thought to influence levels of support among members of the public is then provided, followed by a description of the data and methods employed throughout the analyses. Finally, the results are presented and interpreted, and areas of possible future research enumerated.

Background

The techniques of modern biotechnology, among them animal cloning, human genetic testing, and the creation of novel foods through direct genomic manipulation, have been heralded by some as the most important and promising innovations of the modern era. To others, however, they represent a veritable Pandora's box; a dangerous example of man's propensity to tamper with forces beyond his understanding, without due regard for the potentially devastating consequences of such actions. (Beckwith, 2003) Since the first experiments involving the sequencing and manipulation of DNA in the 1970s, debates have occurred as to moral and ethical acceptability of efforts to master the molecules through which life itself is encoded. (Ervin et al., 2000; Lassen et al., 2002)

In the U.S., policies designed to encourage the research and development of novel traits in crop plants abound. Existing patent law, which was originally intended to provide motivation to would-be inventors by granting "ownership" over one's innovations, has been used by those in the biotech industry to acquire legal rights, not only to newly-developed processes and equipment, but to plant species and even to entire genera. Companies' ability to "patent life" raises moral and ethical questions for some, and may have the effect of encouraging the development of highly profitable crop varieties instead of those that would produce the greatest benefits for society as a whole. (Ervin, 2000; Warner, 2001)

Originally overseen by the National Institutes of Health's Recombinant DNA Technology Committee, the extensive investments and research into genetically modified crops commanded executive attention and in 1984, when Reagan's White House Office of Science and Technology Policy published "The Coordinated Framework for the Regulation of Biotechnology." (Vogt, 1999) The Framework was significant in that it established the premise upon which all future regulation of GM crops in the U.S. would be based; namely that it was the products, not the processes of biotechnology that would be subject to review and approval.

The Framework's guiding assumption was that products derived through the processes of modern biotechnology are not substantially different from their conventional counterparts. Hence, no new legislation was deemed necessary to regulate the development, cultivation and distribution of GMOs. Instead, regulatory and oversight responsibilities were divided between three federal agencies concerned with the protection of environmental, food, and human health and safety: the Environmental Protection Agency (EPA), the U.S. Department of Agriculture (USDA) and the Food and Drug Administration (FDA).[1] (Harlander, 2002; Vogt, 1999)

The resulting federal regulatory dynamic has been criticized as granting large multi-national life science companies such as Dupont and Monsanto too much autonomy. (Ervin et al., 2000) The costs and the level of expertise required to perform independent testing of newly-created cultivars have proven prohibitively high, forcing the EPA, FDA and USDA to rely almost exclusively on industry for the provision of information utilized throughout the approval process. Regulators often check the materials submitted by applicants against their own body of knowledge, acquired through years of research and testing of conventional crops and pesticides, yet some outside of government and industry have expressed dissatisfaction with this admittedly limited approach. Fast-track approval systems, which allow for field testing to begin within as few as 30 days of filing for approval, and often permit new products to enter the market without a formal review of their safety for human consumption, have also been implemented. (Ervin et al., 2000; Vogt, 1999)

Since their commercial introduction in 1996, GMOs have become a ubiquitous component of America's food supply. The number of acres in the U.S. dedicated to the cultivation of GM crops far outstrips that of any other nation, accounting for about 63 percent of all such agriculture globally in 2003. Fully 85 percent of U.S. soybeans, 76 percent of the cotton, and 45 percent of the corn grown in that year were genetically modified cultivars. (NASS, 2003) Because the U.S. lacks an established system of identity preservation,[2] genetically modified foodstuffs, once harvested, are routinely intermingled with non-GM crop varieties. (Vogt, 1999) As a result, many widely-available and commonly-consumed foods contain some GM components; this is especially true of processed foods and it is estimated that between 70 and 85 percent of such products contain ingredients derived from GM corn or soy. There is no way for consumers to discern which products contain GM ingredients however, because as they are considered "substantially equivalent" to conventional foods, the FDA has ruled that product labels are not required to divulge the presence of such contents. (Harlander, 2002)

The regulatory and market dynamics, which facilitate the widespread cultivation and consumption of GM crops in the United States, are quite different than those that have developed in other nations. When confronted with the issue of allowing GM seeds and food products to be cultivated and consumed within their borders, many other nations, most notably the members of the European Union (EU), have launched considerable opposition. Citizens have taken to the streets in protest, and those in power have enacted trade embargos and labeling requirements. (Ervin et al., 2000; Gaskell et al., 1999; Besley et al., 2005; Lassen, et al., 2002.; Levidow, 2001; Harlander, 2002; Walker et al., 2000) Clearly, the regulatory agencies and citizens in the U.S. have adopted a much more supportive stance with regard to this issue. While some protests have occurred, they have been relatively few in number and have not prompted significant levels of governmental intervention. (Lassen, et al., 2002; Harlander, 2002.) Given the intense and often intractable disagreements which have erupted in other countries regarding the introduction of genetically modified foodstuffs, why then have they managed to find their way onto Americans' dinner plates with relatively little resistance?

Previous Research

Despite receiving a great deal of attention from researchers, gaining a complete understanding of American's feelings with regard to GM foods has proven difficult. Even attempts aimed at simply gauging the national mood in this regard have produced different, sometimes conflicting results. While some have purported that U.S. citizens are largely opposed to this use of technology, others have found significant levels of support. (Besley et al., 2005; The Mellman Group, 2005; Priest, 2000)

The tendency to consider multiple, and arguably, quite different applications of modern biotechnology simultaneously (such as cloning, genetic testing and GM crops[3]), may be partly to blame for the lack of conclusive findings. (Besley, et al., 2005) Although similar in that they all involve the manipulation of genetic material, and are conducted by large multi-national life science companies, the myriad applications which fall under the umbrella term of "biotechnology" are quite different in their goals, potential consequences and ethical implications. These dissimilarities are likely important factors in the formation of opinions among members of the general public, especially in instances where their factual understanding of the techniques in question is limited. (Besley et al., 2005; Frewer et al., 1997; Gaskell et al., 1999; The Mellman Group, 2005; Lassen 2002) To avoid such confounding effects, the current analysis is confined to understanding people's support for, or opposition to, GM crops.

Previous attempts at identifying what contributes to people's feelings about biotechnology have highlighted three general factors as among the most influential. They include people's perceptions of the associated risks and benefits, trust in manufacturers, regulators and the media, and their individual knowledge of the subject matter. (Beckwith, et al., 2003; Gaskell et al., 1999; Lassen et al., 2002; Poortinga et al., 2005; Priest, 2000; Savadori et al., 2004; Wilson et al., 2004) While it appears that consensus has settled (at least for the moment) on the salience of these issues in opinion formation, the exact nature of their influence, as well as their relative importance, have not been clearly identified.

The level of understanding an individual possesses regarding a technological process and its outputs can influence whether they perceive it to be worthwhile. A lack of scientific understanding on the part of the lay public has often been cited as primarily responsible for the opposition, and inflated perceptions of risk sometimes observed with regard to new technologies. (Beckwith et al., 2003; Hohenemser, 1983; Fischhoff, 1978; Slovic, 1991 and 1987)

In recent years, several large-scale studies have been conducted to determine Americans' knowledge of the processes and products of biotechnology, as well as its regulation. The conclusion of these undertakings has been that the public remains largely uninformed however, the impacts of this lack of understanding are not altogether clear. (Beckwith et al., 2003; Bucchi, 2002; The Mellman Group, 2005; Wilson et al., 2004) Some have observed that better-informed individuals tend to me more supportive of foods produced through genetic modification, while others concluded that the opposite is in fact the case. (Bucchi, 2002; Wilson, 2004)

The trust that members of the public have in regulators and producers of new technologies, and of GM foods specifically, as well as people's confidence in the media outlets through which relevant information is disseminated, have also been found to be critical in shaping people's perceptions and levels of support. (Besley et al., 2005; Gaskell et al., 1999; Nisbet et al., 2001; Poortinga et al., 2005; Seigrist et al., 2000) Foods are "credence goods," a designation that reflects the fact that purchasing decisions are always characterized by some degree of uncertainty. (Phillips, et al., 1998) This uncertainty stems from consumers' inability to independently verify claims made about the products (such as caloric content, ingredients, etc.) either before or after purchase. When trust in the producers and the relevant regulatory agencies is high, decisions about whether to buy and/or consume a particular product are simplified, thereby increasing the likelihood of such outcomes. (Savadori et al., 2004)

Generally speaking, the higher the level of trust in relevant institutions and individuals, the greater the level of support for GM technology, yet measures of trust have differed across studies. (Gaskell et al., 2004; James, 2003; Poortinga et al., 2004; Savadiri et al., 2004; Siegrist, 2000) Two related, but fundamentally different types of trust are relevant with regard to GM foods: trust in "overall hazard management" and trust in information sources. (Savadori et al., 2004) The former concerns how confident people are that all necessary precautions are being taken, and that any unexpected negative consequences can be dealt with effectively. The measures of trust considered here however, are of the latter variety; what Savadori et al. refer to as “source credibility.”

Perhaps the best researched relationship with regard to people’s perceptions of GM foods has been that between risk perception and levels of support. It is widely accepted that the greater the risk something is thought to pose, the less likely it is to enjoy widespread support. In light of this relationship, the method by which members of the public judge the inherent riskiness of complex and recently-developed technologies (such as those of modern bioengineering) has been the subject of extensive research. The general conclusion of these investigations has been that members of the public consider risk through fundamentally different lenses than do scientists and others who have received professional training in fields relevant to the technology under consideration. Experts are thought to conduct what have been deemed “rational” risk assessments, which involve quantifying the hazard and the likelihood of a negative consequence occurring, and then assessing its possible ramifications. The average citizen however, relies not on such methodical thought processes, but instead depends heavily on heuristics in judging the magnitude and severity of potential risks. (Siegrist, 2000; Savadori et al., 2004, Hohenemser et al., 1983; Slovic, 1987 & 1991)

The now-famous “psychometric paradigm” of risk perception developed by Paul Slovic and Baruch Fischhoff is the taxonomic scheme which has been used as a conceptual starting point for considering lay people’s reactions to biotechnology. (Bolohm, 1998; Gaskell et al., 2004) The paradigm breaks risk perception into two essential components, “dread risk” and “unknown risk,” [4] which are based upon a set of measures developed by Chauncey Starr in attempt to answer the question “How safe is safe enough?” with regard to technological risks. (Fischhoff, 1978; Slovic, 1987) It has been determined that participants experienced a high level of “dread risk” and a moderately high level of “unknown risk” when thinking about DNA technology. These ratings closely resemble those reported for nuclear power, a technology which is often cited as among the most dreaded and hence, least popular of modern man’s accomplishments. (Priest, 2000; Savadori et al, 2004; Slovic 1991)

A condensed set of the factors upon which the psychometric paradigm is constructed has been identified by Peter Sandman and others as the most influential in causing the public to become outraged, a condition which serves to heighten risk perceptions. Voluntariness is arguably the most important of these factors, hence, the less able people are to avoid assuming a particular risk if they so choose, the more likely they are to become outraged. Since foods containing GM products are not required to display labels divulging this fact, it could be argued that any potential risks associated with their consumption are largely assumed involuntarily. Controllability is also critical because the more influence the individual believes to exert over a potential hazard, the less risky it seems. Whether risks accrue disproportionately to some individuals also contributes to outrage, as does the process by which decisions concerning the risk are made by those in power.[5] (Sandman, 1987; Beckwith, 2003) Some have suggested that for this reason, the decision by manufacturers to target their efforts towards designing crops whose benefits[6] are realized by producers rather than consumers is largely to blame for opposition to such products observed among members of the general public. (Walker et al., 2000)

The moral acceptability of a hazard can also influence the level of risk it is thought to pose, as does its familiarity. The latter characteristic is also related to another of Sandman's outrage factors, namely "memorability," because while familiar hazards often appear to be less risky than unfamiliar ones, those which can be linked to a memorable and horrific event (such as three mile island) or symbol (for example, an oiled sea bird), are perceived as higher risk than those without such connotations. The level of dread associated with a hazard can also make it appear more or less risky.[7] Finally, the distribution of effects across time and space is also influential with negative outcomes that are concentrated in duration and area creating greater outrage than more dispersed ones.[8] (Sandman, 1987)

Clearly then, risk perception is not a unique category of analysis that can be neatly and singularly incorporated into an equation aimed at determining the factors that influence people's decisions to either support or oppose the use of biotechnology in food production and agriculture. Rather, notions of hazard and risk are fundamentally linked to, and defined by, many of the other factors thought to be important in this regard. (Seigrist et al., 2000; Boholm, 1998; Sandman, 1987) Previous researchers have recognized the existence of this dynamic, and although efforts have been directed towards identifying and describing this delicate interplay of issues and perceptions, much remains unresolved.

Closely linked to people's perception of risk is that of benefit. There is widespread agreement that the comparison of expected gains and losses lies at the heart of feelings of support or opposition, the former occurring in instances where the positive outcomes are expected to outweigh the negative. (Fischhoff, 1978; Hohenemser, 1983; Savadori et al., 2004; Wilson et al., 2004) It has been suggested that people consider benefits at the outset and only think about risks after having concluded that substantial gains could result from a given action. This, they say, is the Achilles heal of foods produced through biotechnology because members of the general public do not see the advantages afforded through such techniques as being appreciably greater than those produced through traditional methods. (Gaskell, 2004)

It is also possible that people do not consider benefits and risks in any predetermined order, or that some, but not all members of the public make use of such a linear thought process. For those who are particularly risk averse, consideration of risks may occur before that of benefits, while others may compare the magnitude of both the positives and the negatives simultaneously. Efforts to describe the effects of perceived benefits and risks on opinions related to technical hazards, have yet to produce a definitive description of the reasoning involved, a fact which likely reflects the highly individualized nature of the processes employed by members of the public. (Salvadori et al., 2004)

Although their influences have not been as completely explored as have those of knowledge, trust and risk/benefit perceptions, people's feelings as to whether the processes and products of biotechnology are morally acceptable, as well as their personal political ideology, have been found to influence levels of support. Previous research indicates that those who perceive this use of technology to be morally sound are more likely to feel supportive of such endeavors, and it has been found that, while morality is conceptually linked to assessments of risk, it also exerts some independent effect in determining levels of support. (Gaskell et al., 1999; Lassen, 2002) Political ideology is also an important individual characteristic in this regard. Those who are more liberal-minded tend to be less supportive of biotechnology, than are more conservative individuals. (Besley et al., 2005)

Differences in perceptions of biotechnology across gender lines have also been investigated. While not all studies have found respondents' sex to be a significant determinant of support, in those instances where its effect was influential, males were more supportive than females. This disparity is thought to arise from the fact that women tend to be more risk averse than men, a characteristic linked to decreased support for undertakings that have the potential to produce negative outcomes, in addition to their promised benefits. (Besely et al., 2005; James, 2003; Savadori, 2004; Siegrist, 2000)

Data and Methods

The data utilized for this analysis were taken from the United States Biotechnology Study, which was conducted between November 1997, and February 1998. The survey was administered via telephone and utilized random digit dialing to eliminate selection bias. A total of 1,067 people completed the survey. Both genders were about equally represented (females comprised about 50.2% of the sample), and the average age was 45. Respondents were queried as to their knowledge and opinions of modern biotechnology, their interest in recent scientific innovations and news events, their level of trust of government, industry and educational institutions, and a variety of other issues, many of which are considered here.

The object of the current analysis was to determine which factors lead members of the public to either support or oppose the use of biotechnology in agriculture and food production. Some previous research that focused on elucidating this relationship chose to represent support using a hybrid dependent variable, composed of measures of respondents' opinions as to whether this technological application can be considered "useful," "morally acceptable" and "should be encouraged." (James, 2003) Such a composite metric was not constructed for this analysis, however, because the instrument used to gather the data included a question that directly asked survey takers whether they support this technological application. Participants were offered two response categories in conjunction with the question of interest (“support” and “oppose”), therefore, a probit and logitistic regressions were selected as the best statistical methods available for uncovering the relationships of interest.

Of the sample, fully 75.2 percent (802 people) indicated that they support the use of biotechnology in agriculture and food production, while 17.2 percent (183 individuals) were in opposition. The remaining 82 respondents indicated that they had not formed an opinion on the matter (coded as “don’t know”), or chose to refrain from answering the question (coded as “won’t say”). It is worth noting that the latter two response categories were not among those offered as part of the survey instrument, but rather were volunteered by the participants.

The decision was made to drop from the analysis, cases in which participants provided either a “don’t know” or a “won’t say” response. This was done because individuals who did not indicate a definite position on the matter were deemed unlikely to be of use in the current endeavor. In short, the motivations underlying either support or opposition were of interest, while factors leading to indecision or refusal to respond were not. Further, it is unlikely that the resulting reduction in sample size was detrimental to the integrity of the analysis. The number of individuals dropped amounted to just 6.6% of the sample and therefore, did not compromise the integrity of the chosen statistical techniques.

Several knowledge-related questions focused on ascertaining people’s basic familiarity with biotechnology, as well as their perceptions of how well informed they were about related subject areas. Early in the survey instrument, individuals were asked if they had ever heard of biotechnology applications in food production and agriculture. Participants also rated how well informed they were about issues related to new technologies, new scientific discoveries and agriculture.[9] These measures of awareness were converted into dummy variables for inclusion in the models (called "informtech," "informsci" and "informag," respectively).[10]

Two questions related to the sources of respondents' knowledge of biotechnology and GM foods were also included. Survey takers were asked whether they had read anything about the use of biotechnology in food production.[11] In addition, participants were asked whether they had discussed issues related to biotechnology with a friend or colleague.[12]

A measure of educational attainment was also included. Respondents who had received a baccalaureate or post graduate degree were specified by the variable "college." This categorization is identical to that employed by James, which was found to be an important contributor to respondents' feelings of trust in GM foods. (James, 2003)

The independent variables discussed thus far, while arguably relevant in this attempt to determine the role of knowledge in shaping people's feelings of support, fall short of conveying their levels of understanding of the science behind genetically modified crops. To capture this dimension of knowledge, two mutually-exclusive scales were constructed, both of which were based on a series of six questions that tested respondents' understanding of DNA, heredity, and related subjects.[13] One scale ("correctscale") measured the number of correct responses given by each participant, the other ("dontknowscale") measured how many times they responded that they "don't know," or "won't say" the answer.

Given the large number of independent variables related to knowledge, and the resulting loss of degrees of freedom within the model of support, the decision was made to reduce the data by performing a factor analysis. A total of three factors were retained, and the associated factor scores used to create three continuous knowledge variables for incorporation into the model in place of the nine original measures. The varimax rotated solutions (rather than their unrotated counterparts) were selected for inclusion in the model because, while both are equivalent with regard to the amount of variation in the original variables which is explained, the rotated version lead to a more even distribution of loadings across the extracted factors, and allowed for some interesting relationships between the original variables to be discerned. (See Table 1, Appendix B)

"Correctscale" and "dontknowscale" loaded most heavily on the first factor extracted. The magnitudes of the loadings, while approximately equal in absolute terms, were opposite in sign, testifying to the inverse relationship between the number of times one provides a correct response as compared to choosing the "don't know/won't say" response category. The new variable created from this factor was called "testable," to reflect the fact that it was primarily based upon respondents' ability to answer the true/false science questions.   The second factor consisted primarily of "readbiotech," "talk," "college" and "heard." Since all of these variables relate to encounters with, and/or sources of information about biotechnology, the resulting variable was called "exposure." The three original variables that measured how informed respondents felt about related subject areas ("informtech," "informsci," and "informag") loaded primarily on factor three, which was subsequently dubbed "informed." Given the conflicting nature of previous findings regarding the effect of knowledge on levels of support for GM foods, it was not clear at the outset whether coefficients associated with the newly constructed variables would be positive or negative in sign.

To measure the effect of trust on support for GM foods, some have chosen to construct measures based upon people's conceptions of issues thought relevant to trust formation, such as perceptions of personal benefit and risk. (James, 2003) The U.S. Biotechnology Survey however, included a set of questions which directly queried respondents about their trust in information provided by a variety of relevant sources, hence their responses were thought to provide the most appropriate measures of such sentiments.

The series of seven questions focused on gauging trust all made use of the same structure, namely: "Would you have a lot of trust, some trust, or no trust in a statement made by (name of organization) about biotechnology?" Responses were coded according to the source to create seven unique variables: "trusttv" (television news), "trustusda" (U.S. Department of Agriculture), "trustmanufacturers" (food manufacturers), "trustscientists" (scientists and university professors), and "trustfda" (Food and Drug Administation).

As with the measures of respondents' knowledge, a factor analysis was performed on the trust variables. Two factors were extracted and, as before, the varimax rotated results were preferred. While in the original (unrotated) solution, all of the trust variables had their highest loadings on Factor 1, the rotated version distributed the loadings somewhat more evenly, with "trustscientists," "trusttv" and "trustmanufacturers" loading predominantly onto Factor 2. (See Table 2, Appendix B)

The new variable created from the first factor was called "trustgov," to reflect the fact that the variables measuring trust in information provided by the two government agencies (the USDA and the FDA) loaded most highly there. The variable created from the second factor, therefore, included all of the non-governmental information sources, and was titled "trustnongov." Before running the regressions, it was thought that both trust variables would be positively related to support, that is, as trust increases, so to does support.

In addition to knowledge and trust, risk is often thought to influence people's support for new technologies. As mentioned previously however, perceptions of risk do not appear to be neatly defined within the human mind, but instead act to influence, and in turn are influenced by, a wide variety of other factors. In light of this conceptual common ground, risk was included in the model of support in two different ways. First, a dummy variable ("risk") was created using survey takers' responses to the question, "The use of biotechnology in food production and drinks is risky for society. Do you definitely agree, tend to agree, tend to disagree, or definitely disagree?"[14]

An instrumental variable was also created to measure people's risk perceptions by running a logistic regression on the "risk" variable. The results were then used to create a new continuous variable, "riskinstrument," which was subsequently entered into the model in place of the dummy variable. While this procedure produced a measure that was considerably less powerful than the "risk" variable (pseudo r^2=0.0819), it was done in order to control for potential correlations between the error terms of the risk variable and those related to trust, perceived benefits, and the other measures included in the model. (See Table 4, Appendix C)

Consideration of benefits is also an important contributor to feelings of support, and to discern its influence with regard to GM foods, a variety of predictor variables were selected for inclusion in the model. As before, a factor analysis was performed both for data reduction purposes and to discern any underlying relationships between the included variables. Two unique factors were extracted, and the rotated solutions were preferred, largely because they acted to create two distinctive categories: benefits to one's self and family (realized or anticipated), and future benefits to others. (See Table 3, Appendix B) These results support the notion that personal benefits are fundamentally different than those directed towards other people, and may have differing impacts on support for GM products.

Responses to the question of whether participants agreed with the statement; "My family and I have already benefited from biotechnology." were used to create the variable "currentpersonalbenefit," while "futurepersonalbenefit" measured whether participants anticipated benefits accruing to people like them as a result of biotechnology within the next 5 years. Both variables loaded primarily on a single factor, which was subsequently called "personalbenefits" and included in the final regression analysis.

Three variables were concerned with measuring the benefits that survey takers thought would impact others (the poor, other nations and future generations). "Reducepollution" reflected whether they felt that the technology would lead to reduced levels of pollution in the next 20 years, "reducehunger" indicated whether they anticipated a reduction in world hunger over the same time period, and "conserveresources" recorded their feelings as to whether biotechnology would help conserve resources in third world countries. All of these predictors were characterized by substantial loadings on the second factor, later named "othersbenefits."

At the outset, it was anticipated that both the "personalbenefits" and the "othersbenefits" variables would be associated with an increase in respondents' support of GM foods (produce positive coefficients). While one can hardly argue with the tendency to support something from which one stands to benefit, there is also research that suggests that the public is highly concerned with this technology's propensity to alleviate burdens (such as hunger) in developing nations. (Beckwith et al., 2003)

The variable "male" was included in the analysis to determine what, if any, difference there would be in levels of support between males and females. Given the findings of previous research, the expectation was that this measure would yield a positive coefficient, reflecting the fact that males are more supportive than females.

The effect of the perceived moral acceptability of biotechnological applications in agriculture and food production on levels of support was also explored. Respondents were asked to indicate whether they agreed with the statement that "the use of biotechnology in the production of food and drinks is morally acceptable for society," responses were used to create a dummy variable ("moralacceptability").[15] Before running the model, it was expected that those who perceived GM crops to be morally acceptable would display higher levels of support.

A variable representing political party affiliation, specifically whether respondents identified themselves as republican ("republican"), was chosen to represent their ideological perspective. Since low levels of liberal ideology have already been shown to be associated with increased levels of support, it was anticipated that self-reported republicans would be more likely to support this use of biotechnology than would others.

A variable measuring whether respondents identified themselves as Catholic ("catholic") was also included in the model of support. Membership in almost any religion could arguably have an impact on one's acceptance of GM foods, however, to date the Catholic Church is the only religious body to speak out on the issue. The expected relationship between participation in the Catholic Church and levels of support for GM foods was unclear before the analysis was conducted however, because while church officials have spoken out about the technology, they have not taken a consistent position of either support or opposition. On several occasions, religious leaders have expressed disapproval of industry's use of life patents, stating that such an appropriation of life was morally and ethically wrong. Pope John Paul II however, spoke in favor of the technology based upon its potential to supply food for the needy. (Warner, 2000) To the author's knowledge, previous attempts to discern the motivating factors behind feelings of support for GM foods have not specifically considered the influence of religion, a fact which further underscored the uncertainty regarding its impacts.

Results

Due to the categorical nature of the dependent variable, and the fact that just two response categories were available ("support" and "oppose"), probit and logistic regressions were chosen as the techniques of choice for use in determining the relationship between respondents' personal characteristics and beliefs, and their support for the use of biotechnology in agriculture and food production. The analysis was run twice, once using the dummy variable "risk," and once using the instrumental variable "riskinstrument." "Riskinstrument" was associated with a statistically significant coefficient in the resulting equation, a fact which indicates that the original measure of risk suffered from some degree of endogeneity and hence, should not be included in the analysis.   The model which included "riskinstrument" was found to be statistically significant (probit chi^2= 151.79, logit chi^2=132.99), and did a fairly good job of explaining the variation in support across participants (probit r^2=0.3473, logistic r^2=.3513). (See table 5.)

Table 5. Determinants of Support for Genetically Modified Foodstuffs: Results of Probit and Logitistic Regressions

Independent Variables	Probit Coefficient	p-value (Probit)	Logistic Regression Coefficient	Odds Ratio	p-value (Logit)	Discrete Change (0→1)
riskinstrument	-3.695975	0.000	-6.791918	.0011228	0.000	N/A
othersbenefits	-0.04988003	0.669	-0.088893	0.9149435	0.676	N/A
personalbenefits	0.5617046	0.000	1.020156	2.773626	0.000	N/A
trustgov	-0.12140454	0.364	-0.2633424	0.7684787	0.274	N/A
trustnongov	0.37253306	0.039	0.6903971	1.994507	0.038	N/A
testable	0.11672854	0.091	0.1759743	1.192407	0.151	N/A
exposure	0.41990513	0.000	0.7661922	2.151558	0.000	N/A
informed	-0.05719669	0.517	-0.0911625	0.9128694	0.569	N/A
catholic	0.31799114	0.033	-0.5430434	0.5809774	0.042	-0.0903
republican	0.0796872	0.117	0.1673195	1.182132	0.069	0.0594
male	0.15169948	0.276	0.3030795	1.354022	0.224	0.0384
moralacceptability	0.36468976	0.012	0.6552792	1.92568	0.015	0.0735

Of the independent variables incorporated into the regressions, the measures of risk ("riskinstrument"), personal benefits ("personalbenefits"), trust in information provided by non-governmental sources ("trustnongov"), measures of exposure to information on the subject ("exposure"), Catholicism ("catholic"), Republicanism ("republican") and moral acceptability ("moralacceptability") were found to be significant at the p=0.05 level or greater using the most stringent (two-tailed) test of statistical significance. Of these, the coefficients associated with risk and Catholicism were negative in sign, indicating that individuals who believe the use of biotechnology in food production to be risky, as well as those who identify themselves as Catholic, are less likely to be supportive of this technological application than those who do not have these characteristics.

The relationship between risk and support is hardly surprising; it is in agreement with previous findings and arguably, with common sense. The conclusion that Catholics are less likely to support GM foods than non-Catholics is not so clear-cut, however. While it indicates that some denomination-specific reasoning is influential in reducing support in this regard, judgments do not appear to be based entirely around perceptions of morality (as evidenced by the relatively low correlation (0.0274) between "catholic" and "moralacceptability"). The effect of this religious affiliation is noteworthy, however, as indicated by the fact that, all else equal, the likelihood of supporting GM foods is nine percentage points lower among Catholics than non-Catholics, a fact which highlights the need for more focused research on the subject.

Despite previous claims that people consider benefits to humankind as a whole in deciding whether to support GM foods, the results of this analysis indicate that only benefits reaped by the individual and their families influence levels of support. The coefficient associated with “personalbenefits” is positive in sign, thus, as expectations of personal benefits increase, so to do levels of support for GM foods.

The fact that people’s expectations of benefits accruing to others as a result of the use of biotechnology were not influential over their levels of support for such applications is quite telling. It is possible that goals such as reducing world hunger and conserving natural resources are considered unimportant by the average American and therefore, did not influence their feelings of support. It may also be that, as was observed in a previous study involving Danish participants, such aims were considered in the valuation process but significant doubts existed as to whether they would ever be realized, leading people to discount their importance. (Beckwith et al., 2003) Before concluding that members of the American public are exclusively interested in improving their own wellbeing, therefore, more in-depth research on the subject is warranted.

While trust in information provided by governmental sources was not found to be a significant determining factor in respondent’s support of GM technology, their trust in information provided by non-governmental sources, including television, food manufacturers and scientists, was relevant. As was expected, the coefficient associated with trust in information was positive in sign.

It is unclear, however, why trust in information from one set of sources should be important and the other not. One possible explanation is that the varying levels of participation these groups have had in the public debate on the subject of GM crops accounts for this finding. Thus far, information on the subject has primarily been generated by industry and university scientists, and disseminated to the public via television and other forms of mass media. Regulatory agencies, on the other hand, have remained largely absent from the public debate on the subject and, as described previously, chosen to treat products created using genetic engineering as they do their conventionally-derived equivalents. These differential levels of involvement may impact respondents' perceptions. (Besely et al., 2005; Frewer et al., 1997; Nisbett et al., 2001)

The "exposure" variable was also highly significant and produced a positive coefficient, indicating that those who had heard of using biotechnology in food production, had attained a baccalaureate or post-graduate degree, and/or had read or talked with someone about biotechnology, were more likely than others to be supportive of GM foods. These findings demonstrate that members of the public who are highly educated, as well as those who are more familiar with the subject matter, tend to view biotechnology in a more positive light than do their less educated, less informed counterparts. People's judgments as to how informed they were regarding scientific and technological issues were clearly not influential on their feelings in this matter, however, their level of knowledge (as measured by the series of true/false questions related to genetics) was somewhat important, and had the effect of increasing support.[16] Taken together, these results seem to indicate that the more people know about biotechnology, the greater their support for it.

Republican respondents were about 1.18 times more likely to be supportive of the use of biotechnology in agriculture and food production than were non-Republicans. This finding is in agreement with the claim that more liberal-minded individuals are less approving of such endeavors, and although the studies consulted in preparation for the current analysis did not specifically explore the influence of political party affiliation, it appears that it is in fact, an important predictor of support.

It is not altogether clear why Republican participants viewed GM foods more positively than did others; none of the political parties appear to have adopted a definitive stance with regard to biotechnology. It may be that certain characteristics of the industry, and of its regulation in the U.S., such as the existence of minimal federal oversight and substantial reliance upon market forces, are more in-line with Republican ideology than with the views of Democrats and others.

Another important determinant in respondents' levels of support for GM foods was their feeling as to whether such technological applications were morally acceptable. Those who did not object to such process on moral grounds were nearly twice as likely (as indicated by the odds ratio of 1.93) to indicate their support for the use of biotech in food production. This finding is in agreement with previous research which indicated the importance of ethical considerations to feelings of support.

In some respects, the lack of explanatory power associated with certain variables is as enlightening as the significance of others. The high p-value (0.276 for both the logitistic regression and probit) associated with the variable "male" in the current analysis provides evidence that, contrary to previous assertions, gender has no discernable effect on people's feelings of support or opposition to GM foods. Given that this conclusion has been reached before (see James, 2003), it is somewhat surprising that some of the literature still purports such a divide to be a tangible reality and worthy of consideration, while at the same time failing to investigate the influence of such factors as political party and religious affiliation.

Conclusions

In the United States, genetically modified foods (and foods containing GM ingredients) have been deemed substantially equivalent" to products derived through traditional cross-breeding techniques, and levels of development, cultivation, sales and consumption far outpace those occurring in any other nation. Despite this, little public debate on the subject has occurred and the average citizen remains largely uninformed regarding biotechnology and the products it yields. Thus far, Americans' reactions have been far less negative than those witnessed abroad, yet it is not altogether clear how much support actually exists for this technology. Even less certain are the nature and the relative importance of factors which inspire one to adopt a position of either support or opposition to the use of biotechnology in agriculture and food production.

The analysis presented here built upon the work of previous researchers in trying to discern the role of knowledge, trust, perceptions of risks and benefits, moral acceptability, political identity and religiosity in influencing levels of support for GM foods. To facilitate the examination of a large number of independent variables, a series of three factor analyses were performed (one focused on knowledge, one on trust and one on benefits) to reduce the amount of data, thereby saving degrees of freedom, as well as to assist in discerning the underlying relationships that exist between the original measures. The issue of risk perception, although arguably quite influential in determining levels of support, shares a good deal of conceptual common ground with many of the other factors thought to be influential in this regard. To account for any correlation in the error terms across the right hand side variables, an instrumental variable measuring risk was created and incorporated into the model.

The analysis revealed that a variety of factors were important in predicting whether respondents supported or opposed GM foods. High levels of perceived risk were found to appreciably increase the likelihood that a person would oppose this technology. However, knowledge acquired through exposure to the subject matter had a significant positive effect on support, as did trust in information provided by non-governmental sources, and the expectation that the technology would yield benefits for one's self or one's family. Republicans were found to be more supportive than those professing other political party affiliations, however, Catholics were less supportive than members of other faiths and the non-religious. Finally, those who felt that GM foods were morally acceptable were more likely to indicate their support than were individuals who felt otherwise. Benefits expected to accrue to others (people other than the respondents and their families) were not significant in determining levels of support, and trust in information provided by governmental sources, knowledge as measured by a set of six true/false questions about genetics and heredity, perceptions of how informed one is regarding issues related to biotechnology and respondents' gender were similarly unimportant.

Although for the most part, this analysis acted to replicate and combine the findings of previous researchers, the unique treatment and combination of variables considered here allowed for the influence of familiar factors, such as risk perceptions and trust, to come together in new and interesting ways. In light of these findings, further research is clearly warranted, especially with regard to the role of expected benefits for others, and the influence of people's religious affiliation, on their tendency to support GM foods and biotechnology. A set of well-designed survey instruments could likely do much to further explain the influences and interconnections between the factors considered here. However, one must be careful not to lose sight of the fact that the inner workings of the human mind are infinitely complex and unique, and even the most expertly-crafted probes are likely too cumbersome to ever fully tease them apart.

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Appendix A

Below are a list of the statements used to test respondents' knowledge of genetics and biotechnology.

1) Genetically modified animals are larger than normal animals.
   False

2) Humans and chimpanzees have more than half of their genomes in common.
   True

3) Cloning produces identical offspring.
   True

4) Only GM tomatoes contain genes, ordinary tomatoes do not.
   False

5) Eating genetically modified foods can modify human genes.
   False

6) It is impossible to transfer animal genes to plants.
   False

Appendix B

Table 1: Factor Analysis of Original Independent Variables Measuring Knowledge [17]

Variables	Loadings on Factor 1 (Unrotated Solution)	Loadings on Factor 2 (Unrotated Solution)	Loadings on Factor 3 (Unrotated Solution)	Loadings on "testable" (Factor 1, Rotated Solution)	Loadings on "exposure" (Factor 2, Rotated Solution)	Loadings on "informed" (Factor 3, Rotated Solution)
readbiotech	0.35519	0.26960	0.29198	0.15205	-0.50762	-0.05738
talk	0.43715	0.26716	0.18242	0.22951	-0.46563	-0.16209
college	0.30777	0.23873	0.23566	0.13006	-0.43131	-0.06557
correctscale	0.82072	-0.30631	-0.00072	0.86092	-0.14520	-0.07167
dontknowscale	-0.75236	0.40221	0.08647	-0.85567	0.00046	0.05595
informtech	0.28347	0.32861	-0.40010	0.09724	-0.04802	-0.58022
informsci	0.36806	0.31986	-0.37302	0.17290	-0.09535	-0.58132
informag	-0.01277	0.08195	-0.08457	-0.04823	0.01176	-0.10755
heard	0.29728	0.19559	0.19946	0.14497	-0.37607	-0.06305

Table 1: Factor Analysis of Original Independent Variables Measuring Trust

Variables	Loadings on Factor 1 (Unrotated Solution)	Loadings on Factor 2 (Unrotated Solution)	Loadings on "trustgov" (Factor 1, Rotated Solution)	Loadings on "trustnongov" (Factor 2, Rotated Solution)
trusttv	0.38232	0.16234	0.22355	0.35007
trustusda	0.49578	-0.14721	0.49215	0.15890
trustmanufacturers	0.43432	0.09896	0.30228	0.32720
trustscientists	0.38296	0.10608	0.25589	0.30403
trustfda	0.51568	-0.14096	0.50503	0.17531

Table 3: Factor Analysis of Original Independent Variables Measuring Benefits

Variables	Loadings on Factor 1 (Unrotated Solution)	Loadings on Factor 2 (Unrotated Solution)	Loadings on "othersbenefits" (Factor 1, Rotated Solution)	Loadings on "personalbenefits" (Factor 2, Rotated Solution)
reducepollution	0.41440	-0.17334	0.42581	0.14304
reducehunger	0.44195	-0.25209	0.49846	0.10202
conserveresources	0.45631	-0.11388	0.41809	0.21537
futurepersonalbenefit	0.49071	0.24264	0.20879	0.50604
currentpersonalbenefit	0.35297	0.32907	0.04826	0.48015

Appendix C

Table 4: Logistic Regression on "Risk" to Create "Riskinstrument" Instrumental Variable[18]

Independent Variable	Coefficient	p-value
trusttv	-0.0115645	0.947
futurepersonalbenefit	-0.0299527	0.879
trustusda	-0.1575039	0.623
noacc	0.3975011	0.377
ntvracc	0.5322277	0.180
vryacc	0.0200978	0.957
somacc	0.1467564	0.661
somuse	1.059724	0.004
vryuse	0.5204733	0.215
ntvruse	1.491705	0.000
nouse	1.641044	0.001
trustmanufacturers	-0.0125099	0.944
trustscientists	-0.4701046	0.150
trustfda	-0.4083273	0.141
asufreg	0.0807219	0.639
currentpersonalbenefit	0.1315735	0.458
reducepollution	0.1080192	0.543
newdis	0.5142499	0.003
reducehunger	-0.3830194	0.030
conserveresources	-0.054551	0.770

Pseudo r^2= 0.0815

Wald Chi^2= 69.35

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[1] The USDA regulates GM Crops under the Plant Protection Act, the EPA under the Federal Insecticide, Fungicide and Rodenticide Act and the Toxic Substances Control Act, and the FDA under the Federal Food Drug and Cosmetics Act.

[2] This consists of a system for cultivation, storage and distribution whereby GM and non-GM products are kept separate.

[3] Cloning has been found to be the most controversial, and the application to which there is the greatest degree of opposition, genetic testing and other medical applications are the most widely supported, and GM crops are associated with fairly high levels of support among members of the public.

[4] "Dread Risk" is concerned with how controllable something is, the dread it inspires, the magnitude of the negative effects, the fairness of the distribution of costs and benefits, how catastrophic a negative outcome is expected to be,

the risk to future generations, whether the risk can be reduced and whether the risk is assumed voluntarily. In considering "unknown risk," factors such as whether or not the risk is observable, whether those who are exposed to it are aware of the danger, whether the effects are delayed or immediate, the newness of the risk, and the degree of understanding regarding the risk among scientists. (Slovic, 1987)

[5] The notion of "process" relates to whether the agency in charge of regulating a risk appear to be trustworthy and actively involve affected individuals in the decision-making process, or seems arrogant and unwilling to listen to public opinion.

[6] The most common engineered traits are herbicide tolerance and pest resistance, both of which are designed to yield benefits to farmers. (Pew Factsheet, available at: http://pewagbiotech.org/)

[7] Terrorism, for example, is more dreaded than automobile accidents, and hence may be perceived as posing a greater risk despite the fact that many more Americans die in traffic each year than are killed by suicide bombers and the like.

[8] Consequences that are concentrated in time and space appear more risky than those which are diffuse but claim the same number of victims.

[9] Answers were coded on a ten point scale ranging from "not at all informed" (1) to "very well informed" (10).

[10] Variables were created by assigning a value of one to responses of seven or higher (to indicate that the respondent felt informed regarding the subject), zero otherwise.

[11] Entered into the model as "rdbio."

[12] Entered into the models as "talk."

[13] For a list of the questions, see Appendix A.

[14] Those who answered that they "strongly agree" or "somewhat agree," were coded with a one, all others were assigned a value of zero for the variable.

[15] Affirmative answers (either "strongly" or "somewhat agree") were coded as one, zero otherwise.

[16] The p-value associated with "testable," was derived through a two-tailed test of significance, was equal to 0.151 (below the normal minimum significance value of p=0.10). Had a one-tailed test been conducted (that is, had the direction of the effect of increased knowledge been postulated in advance), the variable would have been significant at the p=0.10 level.

[17] It is interesting to note that in the unrotated solution, "talk" loads most heavily on Factor 1 (with "correctscale" and "dontknowscale"). The rotated solution, in contrast, shifts "talk" to Factor 3 (with "heard" and "rdbio"). Hence, with the exception of "informag" (which as its highest loading on Factor 4), the rotated solution depicts the relationships between the knowledge variables in the same way as they are grouped in the description on page

[18] The dependent variables included all measures that were to be input into the final logistic regression for support that were thought to be in any way correlated with risk perception, namely: the measures of trust which comprised the "trust" variable derived through factor analysis ("trsttv," "trstnih," "trstama," "trstusd," "trstsci," "trustfm," and "trstfda"), whether they believed that biotechnology would help to reduce pollution ("redpol"), lead to new diseases ("newdis"), reduce world hunger ("redhun"), or preserve natural resources in the third world ("thdwrld") over the next 20 years, whether they believed that biotechnology would benefit them personally in the future ("apersben") or was already providing them with benefits ("alrben"), whether they thought that existing regulations were sufficient to protect from the risks of biotechnology ("asufreg"), whether this use of technology was morally acceptable ("noacc," "ntvryacc," "somacc," "vryacc"), and whether or not it was useful ("vryuse," "somuse," "ntvryuse," "nouse").