PUBLIC PERCEPTIONS OF "GENETICALLY MODIFIED" FOOD IN THE UNITED STATES: THE ROLES OF KNOWLEDGE, RISK, AND TRUST

by

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Public perceptions of "genetically modified" food In the United States: The roles of knowledge, risk, and trust

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Plants and animals bred using DNA from a separate organism – a process called transgenesis that uses recombinant DNA technology – are referred to as “genetically modified” (GM) throughout the world. Certain GM plants have been widely used by farmers and have demonstrated a variety of benefits. However, concerns over the safety of GM foods have led to restrictions and bans of GM foods throughout the world. Moreover, a majority of American residents think that GM foods are unsafe to eat. This study investigates the gap between the views of the American public with mainstream scientific consensus. I propose a model of public perception of GM foods based on how knowledgeable a person is, their risk perceptions, and the amount of trust they have in different actors in the GM debate. Results suggest that perceptions of risk shape views towards and purchasing behavior of GM foods, over and above other measured factors.

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Background

In 2017 roughly 800 million people suffered from hunger and over 200 million children under five years of age were afflicted with stunting or wasting, the vast majority of whom live in poorer countries in Asia and Africa (Food Security Information Network, 2018; UNICEF / WHO / World Bank, 2018). Available food resources are likely to be further strained in the future. The global population is expected to increase to over 11 billion by the end of the century (United Nations, Department of Economic and Social Affairs, Population Division, 2017). Moreover, the negative impacts of climate change on agriculture are expected to occur predominantly in the developing world, potentially adding an additional 80-90 million to the number of hungry and malnourished by century's end (IPCC, 2001, Chapter 19 Box 19-3). Finally, as many countries have developed and grown a middle class, the additional demand for meat and other animal products has put further stress on food systems and necessitated both putting additional land into agricultural production and increased the price of grain, further contributing to food insecurity (Rosegrant, 2008; Timmer, 2008). As a result of these processes the demand for food globally will increase and, given the scale of the increase, it is likely farmers will be called upon to increase yields on currently planted acres as well as farm more acreage.

Throughout time, in order to increase yields, farmers have incorporated technological advances into their production strategies, often unbeknownst to the general public. In the last three decades, however, consumers in the United States and throughout the world have become increasingly interested in agricultural and plant breeding processes. One type of plant breeding – referred to hereafter as transgenesis – has captured the attention of consumers, private companies, and government regulators more than any other. Recombinant DNA (rDNA) technology uses enzymes to combine DNA sequences; these sequences can then be transferred into a host cell in order to express desirable characteristics (Pray, 2008). Transgenesis, which utilizes rDNA technology, is known more commonly as genetic engineering (GE) or genetic modification (GM) and has been used since the 1970s (Pray, 2008). Crops bred using GM technology have demonstrated increases in crop yields and reductions in pesticide use compared to conventional crops (Finger et al., 2011; Klumper and Qaim, 2014). Yet, the overall impact of GM crops has been relatively limited compared to what early proponents expected, due in part to public concerns over safety (Herring and Paarlberg, 2016). In the United States nearly forty percent of consumers think that GM foods are worse for their health than non-GM foods (Pew Research Center, 2016). Asked another way, just thirty-seven percent agree that GM foods are safe to eat (Pew Research Center, 2015). The negative public response to crops bred via transgenesis (i.e. GM, genetically modified, GMO, etc.) has limited the number and types of these potentially beneficial crops that have been grown throughout the world (Herring and Paarlberg, 2016). The lack of uptake has been driven either via private companies not wanting to use GM crops for fear of public outcry - as in the United States – or lack of government approval (e.g. much of the European Union, and many countries in Africa) (Herring and Paarlberg, 2016). Because attitudes towards GM foods have been used as a justification for policies or practices restricting their use, it is important to better understand the attitudes the public holds towards this technology and other methods of plant breeding. Indeed, since the introduction of this technology members of the agricultural industry, policymakers, and scientists have surveyed the public in order to better understand individuals' reactions. This study continues in that tradition and seeks to add to the conversation by gathering public preferences for a wide variety of policy outcomes as well as understanding how knowledge of GM regulation and risk perceptions of GM foods influence those policy preferences.

Sociotechnical History of Genetic Modification

Farmers have used selective breeding for centuries as a means to increase agricultural yields. It wasn't until the late 19th and early 20th century that Gregor Mendel's work on plant hybridization was appreciated and plant breeding was taken up on a large scale by governments and commercial entities (Kingsbury, 2009). Since then there have been rapid technological advances in the fields of plant and animal breeding as well as wide scale adoption of plant varieties produced in the last 100 years (Herring and Paarlberg, 2016). These advances have been driven by the desire to produce crop varieties that exhibit traits useful to farmers (e.g. resistance to pests, larger fruits/seeds) and/or consumers (e.g. more uniform end product, better taste). Advances in the fields of plant genetics and agricultural biotechnology went largely unnoticed and were even applauded by the general public in the United States until the 1990s (Mohorcich, 2018). One particular method of plant breeding discovered in 1973 and dubbed transgenesis, a process that involves the direct and intentional transfer of genetic material from one organism into another, was cause for controversy and public concern (Losey et al., 1999; Kuntz 2014; Mintz, 2017).

Since the 1980s the term "genetic modification" or "genetic engineering" or "GMO" has typically only applied, in the public mind as well as in legal definitions, to plant and animal varieties developed via rDNA technology and that involve the transfer of genetic information between organisms (Mohorcich, 2018; 7 C.F.R. § 340.1). At the time of their commercialization in the late 1980s, two thirds of Americans demonstrated approval or ambivalence towards genetically engineered products (Ezzell, 1987; Finucane and Holup, 2005; Mintz, 2017). In the 1990s, however, a study linking a transgenic variety of maize with harm to Monarch butterfly larvae ignited public outcry over "GMOs" (Losey et al., 1999; Kuntz, 2014; Mintz, 2017). Though the negative effects of the GM maize on Monarch butterflies were quickly thereafter shown to be negligible, the plight of the Monarch butterfly continues to be used in the debates over the technology (Minorski, 2001; Mintz, 2017). Indeed, one consumer advocacy NGO, *the Non-GMO Project*[1], has a Monarch butterfly on its logo and label. Since the 1990s the public's views have shifted over genetic engineering, with a 2015 study indicating that less than 40% of Americans believe that genetically modified foods are safe to eat (Pew Research Center, 2015). This puts the American people significantly at odds with members of the American Association for the Advancement of Science, 88% of whom agree that GM foods are safe for people to eat (Pew Research Center, 2015). In addition to the AAAS, the National Academy of Sciences, Engineering, and Medicine released a comprehensive report in 2016 that "could not find persuasive evidence of adverse health effects directly attributable to consumption of GE foods" but did find some evidence of benefits to human health (National Academies of Sciences, Engineering, and Medicine, 2016, p. 236). The view that GM foods pose no more risk to human health than crops bred via any other method is a view shared by hundreds of scientific bodies throughout the world.

Meanwhile, the number of acres of farmland planted with transgenic crops is at an all-time high. Over 90% of maize, soybeans, and cotton in the US are transgenic varieties (Fernandez-Cornejo, 2014). In addition, a meta-analysis of the impacts of GM crops has shown robust benefits to farmers including reduced chemical pesticide use, increased crop yields, and increased profits (Klumper and Qaim, 2014). Moreover, the meta-analysis found that the benefits were greatest for farmers in the developing world; compared to conventional farming, farmers growing GM crops experience average yield gains of about 22%. These benefits have been shown without evidence of negative human health outcomes. GM foods have been shown to pose no unique risks when compared with food grown conventionally and plants bred via transgenesis have been studied more

[1] https://www.nongmoproject.org/

than plants bred any other way. Nevertheless, most Americans believe GM foods are not safe and dozens of countries across the world have strict limits or bans on the cultivation and/or importation of GM crops or products. There is strong evidence that public perceptions have driven the lack of uptake of certain types of GM food crops. In the United States, which has a more permissive regulatory attitude towards GM crops than Europe, the only GM fruits and vegetables currently grown are Hawaiian papaya, summer squash, apples, potatoes, and sweet corn despite the fact that GM staple crop varieties have been developed (James, 2014; Herring and Paarlberg, 2016). Herring and Paarlberg (2016) assess the literature investigating the political economy of GM crops and conclude that the restriction of GM food crops is not because of scientific evidence of novel risks and several scholars point to public resistance as a primary explanation for reluctance to grow GM crops for food consumption (Mohorcich, 2018; Schurman and Munro, 2010, 111).

Regulation of Genetic Modification

As the general public has reacted to the invention and use of crops bred via transgenesis, government regulators have responded as well. This section focuses on regulations in the U.S. context, as this study focuses on public sentiment among American residents. However, much of the literature on public attitudes and consumer preferences towards GM foods has focused on countries in Europe. In the United States three different agencies, the Environmental Protection Agency (EPA), US Department of Agriculture (USDA), and the Food and Drug Administration (FDA) jointly regulate GM foods. The current US definition of “GM” includes any crop or animal that had DNA introduced from a separate organism. Though the definition doesn’t mention transgenesis by name, transgenesis is the only process by which DNA from a separate organism is introduced into crops. Therefore, the current definition of GM foods in the US makes transgenesis synonymous with GM. The requirement that DNA from a separate organism is introduced into a plant or animal is the key distinction. Older forms of plant breeding use chemical or physical agents (mutagens) to increase the rate of mutations and breed the resulting "mutants" with other cultivated plants. The mechanisms for this mutation breeding – or mutagenesis – were discovered in the 1920s and thousands of crops bred this way have been used by farmers since (Schouten and Jacobsen, 2007). Mutagenesis, though clearly a way to change the genetic makeup of an organism, is not subject to GM regulation in the US or in Europe. However, a newer form of mutagenesis is challenging that definition.

Presently, government regulators in the United States and across the world are deciding the proper regulatory protocols for several new GM foods and even newer breeding techniques. The first commercially available animal, a salmon, was introduced to Canadian consumers in 2016 after 25 years devoted to securing regulatory approval (Waltz, 2017). A recent advancement in biology dubbed the clustered regularly interspaced short palindromic repeats mutagenesis (CRISPR mutagenesis; also referred to as CRISPR-associated system [Cas]), allows genomes to be edited such that existing genes can be removed and/or new genes can be added (Jinek, et al., 2012). Researchers expect CRISPR/Cas mutagenesis to speed up and make cheaper the development of new plant and animal varieties because the technology allows for more precise changes to a plant or animal's DNA (Hefferon and Herring, 2017). An important question is how regulators will handle these gene-edited organisms. As stated above, current US regulatory definitions of GM are synonymous with transgenic, in theory exempting gene-edited products from US regulation. Indeed, a 2016 decision by the USDA exempted a gene-edited CRISPR mushroom from its GM regulatory process (Waltz, 2016). Even in Europe, generally considered to be more restrictive of GM foods, early legal rulings on CRISPR mutagenesis have suggested that at least some products will be exempt from the EU's GM foods regulations because they are a form of mutagenesis (Jansson, 2018). However, some environmental and consumer advocacy non-governmental organizations want any crop or animal created with these new technologies to be treated the same as GM foods (Greenpeace European Unit, 2018; Green America, n.d.; Non-GMO Project, 2018; Center for Food Safety, 2016). The Court of Justice of the European Union ruled in July 2018 that gene-edited organisms are not exempt from EU GM regulations (Callaway, 2018). Interestingly, the ruling subjected the new form of mutagenesis (e.g. CRISPR) to GM regulation while exempting older mutagenesis techniques (i.e. radiation and chemical mutagenesis).

Since the reaction of the public, in the United States and abroad, can be closely linked to government policy limiting the development, planting, and/or importation of transgenic crop varieties, this research investigates factors that influence public attitudes towards genetic engineering.

Literature Review

Public Perceptions of GM Foods

Recent survey results suggest that most Americans are either unsure about the safety of consuming GM foods or believe that they are unsafe to eat. For example, a recent study using a representative sample found that 64% of Americans opposed the use of GM technology in food production (Scott et al., 2016). A separate study, also using a representative sample, found that equal portion of Americans believe either that GM foods are safe to eat (34%), unsafe to eat (34%), or are unsure (32%) (McFadden and Lusk, 2016). Interestingly, the American public's views on GM technology differs dramatically from that of experts. A 2014 survey contrasted the percentage of Americans who believe GM foods are safe to eat (37%) with the views of members of the American Association for the Advancement of Science (88%), noting that this is the largest difference between scientists and the American public on any major scientific issue, including nuclear energy, climate change, vaccines, and evolution (Pew Research Center, 2015). While it perhaps isn't surprising that the views of the American public and the views of scientists differ, the fact that disharmony on this issue is so large warrants further investigation.

Much of the literature on public perceptions of GM foods has attempted to determine what factors influence general support or opposition for the technology or its application. Although this body of work has produced mixed results, several themes have emerged: risk and benefit perceptions, knowledge of GM food technology, trust in actors involved in GM debate, and moral concerns. A meta-analysis published in 2013 noted that demographic information was not often used when predicting attitudes towards GM foods, though some more recent work has suggested connections (Frewer et al 2013; Pew Research Center 2015; Pew Research Center 2016; McFadden, 2016).

Demographics

As mentioned above, there is widespread skepticism towards GM foods in the United States amongst the public, yet the demographic correlates of these views are poorly understood. While recent research suggests that Democrats are more likely to hold views consistent with scientists on GM foods (McFadden, 2016), a meta-analysis concluded that most studies find no significant relationship (Frewer et al., 2013). In addition, a recent study conducted by the Pew Research Center found that younger Americans are more skeptical of GM foods, while another study found younger Americans to be less skeptical of GM foods (Pew Research Center 2016; McFadden, 2016). Neither income nor education has consistently predicted attitudes towards GM foods one way or the other. The one demographic indicator that has consistently predicted more negative attitudes towards GM foods is gender; women are more likely to be suspicious of GM foods than men (Hallman et al, 2003; Gaskell et al., 1999, McFadden, 2016; Frewer et al, 2013; Pew Research Center, 2016).

Risk and Benefit Perceptions

Most of the research in this field has focused on identifying the perceived risks and benefits associated with GM food technology as well as testing different means of communicating risks and benefits. One way risks and benefits are conveyed to the American public is via the news media. Mintz (2017) identifies over a dozen purported risks of GM foods that were conveyed to the US public between 2011 and 2013 by major newspaper media outlets. These include risks to human health from the consumption of GM foods, the creation of super pests and weeds, additional pesticide and herbicide use, genetic drift, loss of biodiversity, international trade relations, increased farmer dependency on corporations, and ethical concerns related to people “playing God”. In addition, Mintz (2017) identifies purported benefits communicated to the public: reduced pesticide use, increased crop yields, increased farmer profits (and perhaps implicitly increased biotechnology company profits), drought/flood resistance in plants, plant disease resistance, improved nutrition, more affordable food, reduced farmer exposure to pesticides, longer food shelf-life, and potential benefits due to innovation in the medical or biofuel industries. The purported potential risks and benefits of GM foods appear to be infinite, a feature which might contribute to the difficulty of determining with precision the source of public support or antipathy. Further, many of the perceived risks of GM foods are severe and borne by consumers (e.g. cancer) while most of the perceived benefits accrue to the producers.

Trust

There are conflicting views about how best to conceptualize trust in relation to GM foods. Frewer et al. (2003) distinguishes studies that conclude trust is a factor that shapes attitudes towards GM foods with those who view trust as a consequence of previously held attitudes. Other studies get at the concept in different ways. McFadden and Lusk (2016) find that 65% of Americans prefer decisions about the regulation of GM foods to be taken out of their hands and made by experts. Meanwhile, another study reports that a minority of Americans believe that scientists have a good understanding of the health risks of GM foods even though scientists are among the most trusted groups involved in the GM debates (Pew Research Center, 2016). There is also evidence to suggest that trust interacts with knowledge; those who know more about science are more likely to trust scientists (Pew Research Center, 2016).

Knowledge

Researchers have examined the roles knowledge of genetics and GM food technology, both measured and self-reported by respondents, play in predicting support for GM foods regulation (McFadden, 2016). It is perhaps unsurprising that actual knowledge of biotechnology is low, given its highly technical nature. McFadden and Lusk (2016) contend that consumers preferences related to the labeling of foods containing GM ingredients should not be used as support for that particular policy, given how a nearly identical proportion of Americans support labeling of foods containing DNA as GM foods. Fernbach et al., (2019) found that those who think they know the most about GM foods have the lowest levels of knowledge of plant breeding and genetics.

Research Objectives and Contributions to the Existing Literature

There is currently regulatory uncertainly around new plant and animal breeding technologies - namely CRISPR - in the United States and across the world. Like GM technology before them, these new techniques are difficult to explain and understand, meaning that the success of the new technologies will depend in part on acceptance from a public that doesn’t have a deep scientific knowledge of the foods they consume. Considering that GM foods are currently available to consumers in the United States, further understanding what drives their public perceptions remains a worthwhile endeavor. This study advances the existing literature by utilizing more nuanced measures of risk perception and support for GM regulations than typically considered in the literature. Most research has focused on the relatively simple question of whether or not GM foods are safe for human consumption or have measured general attitudes towards GMOs or biotechnology in general (Pew Research Center 2015; Pew Research Center 2016; McFadden and Lusk, 2016) or focused only on policies restricting the use of GM foods (Scott et al., 2016). As the term "genetic modification" could be understood to include any human-influenced change to the genetic makeup of plants or animals (i.e. any breeding method for plants or animals) it is important to compare attitudes towards GM foods with attitudes towards other similar or earlier breeding techniques. In addition, many of the studies focusing on policy preferences related to GM foods have focused on labeling laws or country-wide bans. Frewer, et al. (2013) called for additional nuance to the range of policy outcomes and types of attitudes tested; this study heeds that call[2].

The effect of public perceptions on altering plant genes is still evolving and still influencing regulation and technology adoption. Therefore, we need to continue to track and explore the nature and drivers of these perceptions. I propose that perceptions of risk, knowledge of GM technology and regulation, and trust in actors in the GM debate influence the policies that American residents support and whether or not they avoid GM foods in their food purchasing decisions. The following research questions are the focus of this investigation:

1. How knowledgeable is the American public about what GM foods are and how GM foods are regulated?
2. What proportion of the American public makes an effort to avoid purchasing GM foods and which actors are most trusted?

[2] This suggestion is particularly timely given the rapid development of plant breeding technologies and the uncertainty related to government regulation.

3. Are there risk factors the American public cares about other than health when considering potential downsides of GM foods?

4. Which policies regulating GM foods does the American public support?

5. What demographic and psychological factors predict GM purchasing behavior and policy support?

Materials and Methods

Data Collection

The institutional review board at the University of Colorado – Boulder approved this study (protocol # 17-0366). The survey was hosted online by Qualtrics and distributed to participants via Amazon Mechanical Turk (MTurk). MTurk is a crowdsourcing online marketplace that enables ‘requesters’ to solicit ‘workers’ to complete human intelligence tasks (HITs). MTurk has been and continues to be used by social science researchers as a cost-effective way to conduct research – the sample is broadly similar to the internet-using public and subjects have been shown to pay attention to directions as much as subjects from more traditional sources (Paolacci, Chandler, and Ipeirotis, 2010). We advertised the HIT as “Answer a survey about your opinions” in order to minimize self-selection bias from those particularly interested in GM foods. The survey was completed by 310 MTurk workers on July 21 and August 2. Responses were checked to ensure that respondents answered questions fully and answered the three attention checks accurately (e.g. “What is two plus two?”). On these criteria 7 responses were removed. In addition, this study was designed to focus on the knowledge and perceptions of people living in the United States. IP addresses were cross-checked with Latitude and Longitude information as well as responses to a question on race and one asking for the respondents’ zip code; 21 responses were removed. Of the final 282 responses, 15 had missing data on questions relevant to the multiple regression analyses and were thus removed from all final analyses for a final sample size of 267. We paid participants

$2.00 for completing the HIT. Compared to a representative sample of the American public, our survey sample is slightly more male, more educated, and slightly younger. Forty-five percent of the survey sample identified as female, 39.4% held a bachelor's degree, and the average income category was $40,000 to $59,999. The median age of the sample is 35 and the average age is 37.

Twenty-five percent of the sample identified as Republican or lean-Republican, twenty-three percent as Democrat or lean-Democrat, seventeen percent as unaffiliated, and thirty-five percent as unaffiliated or "other". While many of the participants were unwilling to identify with one of the two major US political parties, sixty percent of respondents identified as liberal or very liberal, nineteen percent identified as moderate, and twenty-one percent identified as conservative or very conservative when asked about economic and social issues. I created a composite score, referred to hereafter as ideology, by averaging respondents' answers to one question about social issues and one about economic issues. This ideology variable is included in the regression analyses below.

Survey Overview

The survey consisted of six question blocks that followed the consent form. The order of blocks three through six were randomized across respondents to minimize order effects. The blocks contained the following: *1)* gathered socio-demographic information of age, race, education, gender, income, household size, and political party affiliation, *2)* three free response questions measuring the first words or images that came to mind in relation to genetically modified foods, *3)* one question asking how knowledgeable respondents were on the topic of GM foods on a five-point Likert scale from "not knowledgeable at all" to "extremely knowledgeable" and one question measuring how important the issue of GM foods was to respondents on a five-point Likert scale from "not at all important" to "extremely important" followed by six true or false questions to determine if respondents were familiar with the technical aspects of GM technology (*i.e.* if genetic modification of food crops alters fewer genes than conventional breeding techniques) as well as how GM foods are regulated in the US (*e.g.* whether or not GM foods can be labeled as USDA Organic), *4)* questions that measured support for six policies related to GM foods on a five-point scale from "strongly oppose" to "strongly support" such as whether or not GM foods should be labeled, grown, or banned in the US, *5)* one question that asks whether or not respondents make an effort to avoid GM foods and why as well as questions designed to measure how much a respondent trusts various stakeholders of GM foods (e.g. farmers, scientists, and environmental NGOs), and *6)* risk perceptions of GM technology now and in the future.

In summary, survey respondents were asked questions about their interest in the issue of GM foods, their GM food buying preferences, their perceptions of risk of GM foods, whom in the debate around GM foods they trusted, and what types of policies regulating (or not) GM foods they preferred. The survey was designed to determine whether there were relationships between public knowledge and consumer preferences of GM technology and regulations. The dependent variables were *1)* whether respondents tried to avoid GM foods and *2)* their levels of support for several different policies regulating or restricting GM foods.

Results and Discussion

In this section I will present results and discuss the implications for each of my research questions. First, I will report univariate means and distributions for variables that measure the following constructs: knowledge of GM foods, trust in target groups involved in the GM food debate, avoidance behavior of GM foods, risk perceptions, and policy support. Next, I will describe multivariate and logistic regression models that seek to predict avoidance behavior and policy support using knowledge, trust, and risk perceptions in addition to demographic information.

How Knowledgeable is the American public about GM foods?

Respondents were asked six true/false questions to assess their level of knowledge of food breeding techniques and how foods are regulated in the United States. Definitions of technical terms were not provided to respondents in order to limit the influence the questions had on respondents' answers. After data collection was completed one question was omitted due to confusing wording. The five questions used for data analysis are presented in Table 1.

Table 1. Proportion of respondents who answered T/F questions correctly (correct response in parentheses)

Question	Proportion correct	One sample t-test H_0=0.5
1. GM foods are sprayed with more pesticides than crops grown conventionally (F)	0.74	p < .001
2. Foods that have been genetically modified can be labeled as USDA Organic (F)	0.67	p < .001
3. Foods created through mutation breeding can be labeled as Organic (T)	0.46	p = 0.25
4. All fresh produce contains genes that have been altered by humans (T)	0.39	p < .001
5. Genetic modification alters fewer genes than conventional breeding (T)	0.32	p < .001

On average, across 267 respondents, the average number correct out of five was 2.59 questions (Standard Deviation [*SD*] = 1.02). A one-sample t-test comparing the mean response to chance (i.e. 2.5 out of 5) of this average score suggests that respondents did not score better or worse than chance (p = .081). Though respondents did not differ from chance on average across all questions, they did answer four of the five questions reliably different from chance. A one-sample t-test comparing the proportion of respondents who answered each question correctly was compared to the hypothesized mean (0.5) if respondents were guessing (see far right column in Table 1). These results give further evidence that, on average, respondents knew the correct answers to Questions (hereafter Qs) 1 and 2 and did not know the correct answers to Qs 4 and 5.

In general, respondents displayed a low level of technical knowledge of plant breeding and GM foods (Qs 4 and 5), a moderate level of knowledge of food labeling in the US (Qs 2 and 3), and a high level of knowledge that one benefit of some GM crops is a reduction of pesticide use

(Q 1). Only four in ten respondents answered correctly that all fresh produce contains genes that have been altered by humans (Q 4); crops grown commercially necessarily involve plant breeding and, therefore, altered genetic material. Further, just one-third of respondents answered correctly that the process of genetic modification alters fewer genes than conventional breeding techniques, such as crossing, that alter tens of thousands of genes (Q 5). On the other hand, more than three quarters of respondents answered correctly that GM crops use fewer pesticides than crops grown conventionally (Q 1); one of the most common application of GM crops involves resistance to pesticides (insecticides and/or herbicides), precluding the need to use as much pesticide as their conventional counterparts[3]. This finding suggests that consumers understand the potential benefits (or at least one potential benefit) of GM crops. Two thirds of respondents answered correctly that the terms "GM food" and "USDA Organic" are mutually exclusive in the United States (Q 2).

In addition to answering true/false questions, respondents were asked how much they think they know about GM foods and how important the issue of GM foods is to them. The rationale for these questions was to see how well actual knowledge of GM foods compared to self-assessed knowledge and perceived importance of the topic. Roughly 11% of the sample reported that they were not at all knowledgeable about GM foods, 51% reported being slightly knowledgeable, 31% described themselves as moderately knowledgeable, and a further 7% claimed to be either very or extremely knowledgeable. Though this distribution roughly approximates that of the number of T/F questions answered correctly out of five, the correlation between self-assessed knowledge and the number of correct answers to the five true/false questions was small and not statistically significant (Pearson correlation coefficient [r] = 0.10, p =.101). There is also no correlation

[3] Note to reader: this is not necessarily true and I learned this after distributing the survey. It is generally true that herbicide-tolerant crops – the most widely known being Roundup Ready varieties – preclude the use of more toxic herbicides but it is not clear the overall volume of herbicides sprayed has decreased. This point is further discussed in the Limitations section below.

between self-assessed knowledge and four of the five true/false questions (results in Appendix A). This may suggest that perceived knowledge about GM foods is not actually grounded in mainstream scientific knowledge, or that the things respondents are knowledgeable about related to GM foods were not captured by the true/false questions in this survey instrument. In addition, there was no correlation between actual knowledge and perceived importance (r = -0.07, p = .260). This too may suggest that those who thought they know a lot about GM foods and to whom the issue was very important did not possess mainstream scientific knowledge. On the other hand, there was a moderate correlation between self-assessed knowledge and how personally important this issue is to respondents (r = 0.41, p <.001), those who rated GM foods as important tended to also perceive themselves as more knowledge about the technology. Additionally, there was a significant weak correlation between two true/false questions and personal importance; those who considered the issue of GM foods to be more important were more likely to correctly believe that USDA Organic foods are not genetically modified and more likely to incorrectly believe that the process of genetic modification alters more genes than conventional plant breeding (r = 0.16 p = .007; r = -0.15, p =.014). This result is consistent with the idea that people believe non-GM foods (including USDA Organic) to be more natural or genetically pure than GM foods, and concerns about unnaturalness may be a driving force behind the strong concerns that many American residents have towards GM foods.

What Proportion of the American Public Avoid GM Foods and Which Actors in the GM Debate do they Trust?

The intent of the following survey measure was to examine to what extent respondents trusted the following groups who influence the public availability of GM crops: the biotechnology industry, environmental NGOs, farmers, government regulators, and scientists. Respondents were first asked whether or not and to what extent they tried to avoid purchasing GM foods. Then, as a proxy for trust, respondents were asked whether or not they would be more likely to buy GM foods if different groups agreed that GM foods are safe to eat.

Forty-nine percent reported that they make no effort to avoid GM foods; of those who do avoid GM foods, 46% made a little effort, 36% made a moderate effort, and 18% made a strong effort. Tables 2 and 3 summarize the average level of trust of different groups; average scores above 2.5 indicate the average respondent generally trusts the target group, and scores below 2.5 indicate that the average respondent generally distrusts the target group. As shown below in Table 2, those who made no effort to avoid GM foods had higher levels of trust for each of the various target groups on average than those who avoided GM foods. I ran a series of five t-tests to confirm the difference in average levels of trust between those who avoid GM foods and those who don't; each of the t-tests was significant at the $p < .001$ level. The results of those tests are presented in Appendix B. To assist with interpretation both within and across groups, I include the 95% confidence intervals (CIs) around each mean estimate. If, when comparing two means, the CI around one mean excludes the point estimate of the other mean, it is suggestive of a statistically significant difference.

Table 2. Trust in actors in GM debate based on avoidance of GM foods

	Does not avoid GM foods		Avoids GM foods	
Target	Mean	95% CI	Mean	95% CI
Scientists	3.44	3.31-3.56	2.52	2.37-2.68
Environmentalists	3.18	3.05-3.32	2.55	2.40-2.71
Government	3.11	2.99-3.24	2.05	1.91-2.20
Farmers	3.02	2.89-3.15	2.18	2.04-2.32
Biotechnology	2.65	2.50-2.80	1.69	1.55-1.83

Note: Question reads "Would you be more likely to buy GM foods if the majority of (target group) agreed that GM foods are safe for humans to eat?"

Response scale 1-4 1 = Definitely not 2 = Probably not 3 = Probably yes 4 = Definitely yes

On average, those who avoid GM foods reported being unwilling to change their avoidance behavior, regardless of which target group vouches for the safety of GM foods. This is indicated based on the average level of trust of each target group being at or below 2.5. For those who don't avoid GM foods, the average level of trust for each group is at or above the 2.5 threshold. However, the hierarchy of trust in the target groups is very similar for avoiders and non-avoiders alike. Scientists are the most trusted, followed by environmentalists, government regulators, farmers, and the biotechnology industry. For avoiders, scientists and environmentalists are equally trusted. Furthermore, the difference in trust between avoiders and non-avoiders was similar across all target groups, ranging from a difference of 0.63 to 1.06. This suggests two things: that avoiders are more distrusting of all targets to a similar extent and that those who avoid GM foods have made up their minds and are unwilling to change their behavior in light of new evidence. In order to examine whether or not the extent to which one avoids GM foods is related to levels of trust in the target group, Table 3 presents levels of trust in the target groups based on the degree to which those who avoid GMs do so.

Table 3. Trust in actors in GM debate based on extremity of avoidance of GM foods

	Little effort to avoid (n = 62)		Moderate effort to avoid (n=49)		Strong effort to avoid (n=23)	
Target	Mean	95% CI	Mean	95% CI	Mean	95% CI
Scientists	2.98	2.80-3.17	2.37	2.14-2.60	1.61	1.36-1.86
Environmentalists	2.98	2.78-3.19	2.35	2.09-2.60	1.83	1.49-2.16
Government	2.45	2.24-2.67	1.88	1.68-2.08	1.35	1.14-1.56
Farmers	2.61	2.45-2.77	2.00	1.79-2.21	1.39	1.18-1.61
Biotechnology	2.08	1.84-2.32	1.45	1.29-1.60	1.13	0.98-1.28

Note: Question reads "Would you be more likely to buy GM foods if the majority of (target group) agreed that GM foods are safe for humans to eat?"

Response scale 1-4 1 = Definitely not 2 = Probably not 3 = Probably yes 4 = Definitely yes

Overall, those who made a stronger effort to avoid GM foods had relatively lower levels of trust on average than those who made less of an effort to avoid GM foods. This is shown by lower levels of trust in each group from left to right as effort to avoid GM foods increases. However, there is some evidence that a portion of avoiders would be willing to change their avoidance behavior. On average, those who made a little effort to avoid GM foods reported being more likely to purchase GM foods if a majority of scientists and environmentalists agreed that GM foods are safe. There is good evidence that the vast majority of scientists do agree that GM foods are safe to eat (Pew Research, 2015). This suggests support for the idea that there is a segment of the population whose avoidance behavior could change based on exposure to scientific knowledge, if their avoidance behavior is based on fears about safety. In addition, Table 3 shows that some who avoided GM foods could be swayed by farmers and the federal government, as the average answer is very near the 2.5 threshold.

The hierarchy of trust among avoiders is different from those who don’t avoid GM foods. For those who avoid GM foods, scientists and environmentalists jointly were the most trusted, though at moderate and strong levels of avoidance overall trust was still very low. From there, the government and farmers were similarly trusted, and the biotechnology industry had by far the lowest levels of trust. Table 3 gives further evidence to the idea that the major difference between those who avoid GM foods and those who don’t is that those who avoid GM foods trusted environmentalists much more. This could suggest that those who avoid GM foods are doing so based on information received from environmentalists, though of course these results do not prove causality. Of the five target groups, many environmentalists oppose the cultivation of GM crops and at a minimum often support mandatory labeling of foods containing GM ingredients (Greenpeace European Unit, 2018; Green America, n.d.).

Are there Risk Factors American Residents Care about other than Health when Considering Potential Downsides of GM Foods?

Claims of the riskiness of GM foods have been raised since the very beginning of their commercialization. The following analyses explore the extent to which GM foods are viewed as risky and attempt to identify differences in rationales for the source of risk perceptions. Objections to GM foods are generally made based on three general categories: environmental concerns, health concerns, and social or political concerns. Examples of arguments that Mintz (2017) found in their review of major print media outlets' coverage of GM foods include environmental harm, contamination of GM-crops, distrust of biotechnology industry, harmful to human health, and negative impacts on trade. I've grouped those concerns into three categories: environmental concerns, health concerns, and social or political concerns. In addition to answering questions about different sources of concern, respondents answered questions about what they thought the future impact of GM foods would be. Those results are presented below in Table 4.

Table 4. Risk perceptions

Variable	Scale	Mean	95% CI
Future Impact	1 (extremely negative) - 7 (extremely positive)	4.49	-
Riskiness	1 (definitely not) - 5 (definitely yes)	3.02	-
Personal Worry	1 (not at all) - 5 (extremely worried)		
Environmental		2.31	2.17-2.46
Health		2.15	2.01-2.28
Social/Political		1.97	1.85-2.10

Surprisingly, respondents expressed a relatively positive view of the future impact of GM foods and low to moderate perceptions of risk. One possible explanation is that respondents were imaging a future in which GM foods have positive impacts, regardless of their present views on the subject. Another possible explanation is that risk perceptions were not as important as many scholars think, though results presented below indicate that risk perceptions were a powerful predictor of avoidance behavior and policy preference.

Of the three categories of specific risk measured, respondents were most concerned about environmental risks and more concerned about health risks than social or political risks. While the differences between risk type were small, the CIs indicate that differences are suggestive of statistical significance. That respondents were most concerned about the environmental impact of GM foods is distinct from past research. Food safety and health concerns are typically thought of as the most prominent source of public concern (Pew Research Center, 2016). Fernbach and colleagues (2019) found that respondents were more than four times as likely to list health concerns as their primary source of opposition to GM foods, though they forced respondents to choose only one concern and only asked the question to those who opposed GM foods. It is also possible that framing questions in terms of a particular concern suggests to survey respondents that there is a cause for alarm. Scott et al. (2016) argue that risk perceptions are less important than moral or emotional factors, particularly perceptions of naturalness and disgust among consumers. It is possible my result that environmental concerns are the most prominent source of concern includes concerns about naturalness, though I have no way of disentangling those constructs in this study.

Which Policies Regulating GM foods does the American Public Support?

Respondents were asked to rate their support towards a variety of policies promoting, regulating, or restricting GM foods. The full results are presented below in Table 5. Table 5 also contains the results of a one-sample t-test comparing the group means of policy support to 3.0: a value indicating neutrality on that particular policy. As can be seen in Table 5, the average respondent indicated statistically significant support for four policies (mandatory labeling of mutagenesis foods, mandatory labeling of GM foods, growing GM crops in developing countries, and the use of public funding to develop GM foods) neutrality for one policy (growing GM crops in the US), and opposition to one policy (banning GM crops in the US). Several noteworthy trends emerged from Table 5. First, two questions were designed to understand whether or not there were differences between consumers' desire to label GM crops and crops whose seeds were exposed to radiation (a conventional breeding practice and type of mutagenesis that is currently excluded from GM regulation in the United States and European Union). On average, respondents supported the labeling of GM crops and crops created via mutagenesis, and they supported labeling mutagenesis more than GM crops (4.26 vs. 4.04). On the one hand this is unsurprising given that most respondents were likely even less familiar with mutagenesis than they were with GM foods. On the other hand this is an important finding because thousands of crops bred via chemical or radiation mutagenesis have been used for decades with little to no government intervention (Ahloowalia et al., 2004) and newer plants bred via CRISPR mutagenesis appear to be even less likely to be labeled in the US than GM foods. Second, although respondents were slightly supportive of growing GM crops in both the developing world and the US, they were significantly more supportive of growing GM crops in the developing world relative to the US. This may suggest that American residents want to reduce perceived risk to themselves but are relatively more supportive of exposing poorer people to the risk. It is also possible that respondents were aware of the potential benefits on GM foods to food-insecure nations but didn't perceive as many benefits of GM foods in the US. Additionally, respondents were on average ambivalent about using public funding to develop GM crops but were slightly opposed to banning GM crop cultivation in the United States.

Table 5. Support for policies regulating GM foods			
Policy	Mean	95% CI	T-test H_0= 3
1. Mandatory labeling of foods created by mutagenesis	4.26	4.14-4.38	p = .000
2. Mandatory labeling of GM foods	4.04	3.90-4.18	p = .001
3. Growing GM crops in developing countries	3.46	3.31-3.61	p = .000
4. State or federal funding to develop GM foods	3.19	3.03-3.36	p = .082
5. Growing GM crops in the United States	3.14	2.98-3.30	p = .020
6. Banning cultivation of GM crops in the US	2.67	2.49-2.83	p = .000

Note: Question reads "Do you support or oppose the (policy)?"

Response scale 1-5 1 = Strongly oppose 2 = Moderately oppose 3 = Neither 4 = Moderately support 5 = strongly support

	Does not avoid		Little effort		Moderate effort		Strong effort	
Policy	Mean	95% CI	Mean	95% CI	Mean	95% CI	Mean	95% CI
1	3.87	3.69-4.05	4.63	4.47-4.78	4.65	4.39-4.92	4.65	4.21-5.10
2	3.53	3.33-3.74	4.48	4.30-4.67	4.57	4.29-4.85	4.65	4.21-5.10
3	4.21	4.05-4.34	3.16	2.92-3.40	2.55	2.24-2.86	1.87	1.45-2.29
4	3.92	3.72-4.11	3.05	2.80-3.30	2.12	1.83-2.42	1.70	1.18-2.21
5	4.08	3.93-4.24	2.82	2.60-3.04	1.84	1.61-2.06	1.35	1.10-1.60
6	2.04	1.82-2.25	2.65	2.38-2.91	3.61	3.25-3.97	4.26	3.77-4.75

What Demographic and Psychological Factors Predict GM Policy Support and Purchasing Behavior?

Multiple regression models predicting policy support

I next conducted a series of multiple linear regression models in order to explain variation among the six policy preference variables described in the previous section. The objective of these analyses was to explore the relative importance of the knowledge, perceived risk, trust, and demographic variables described above in the extent to which they predict support for policies surrounding GM foods. Across all of the following regression analyses I examined correlations among my predictor variables in order to check for multi-collinearity; the correlations were below thresholds for concern. Table 7 displays the results of a series of multiple linear regression models predicting each of the six policy support measures, with the most supported policies on the left and the least supported policies on the right. All predictor variables were standardized such that a one-unit increase corresponds to a one standard deviation increase in that variable. As a result, the Constant value for each model is the average level of support for that policy, in addition to being the y-intercept. “Risk” is an index of risk perceptions across five questions; raw scores were divided by the length of the scale (5 or 7) and then added together; higher values indicate higher risk perceptions. The variables “Genetics”, “Regulation”, and “Self-assessed” refer to those types of knowledge. “Genetics” is a composite of Qs 4 and 5 and “Regulation” is a composite of Qs. 2 and 3 (shown below in Table 8); respondents either answered zero, one, or two of these questions correctly. “Ideology” is a composite of respondents’ political ideology across fiscal and social issues; higher values indicate more liberal views on social and fiscal issues. Coefficients are reported for statistically significant and statistically suggestive ($p < 0.10$) results.

Table 7. Results of Multiple Linear Regression Models Predicting Support for Different Policies						
	(1) Label Mutagenesis	(2) Label GM foods	(3) Grow in Dev. World	(4) Gov't Funding	(5) Grow in the US	(6) Ban GM foods
Variable						
Risk	0.29**	0.39**	-1.03**	-0.91**	-1.15**	0.81**
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
Genetics	-0.19**	-0.22**		0.14*	0.12**	
	(.002)	(.001)		(.039)	(.006)	
Regulation				-0.12^	-0.09*	
				(.066)	(.036)	
Self-assessed	-0.19**	-0.22**				
	(.004)	(.002)				
Importance	0.15*	0.19*				
	(.046)	(.019)				
Liberal ideology				0.14*		
				(.028)		
T/F Q1						
Education						
Income						
Age						
Constant	4.26**	4.04**	3.46**	3.19**	3.14**	2.67**
Observations	267	267	267	267	267	267
R-squared	0.23	0.28	0.60	0.46	0.77	0.39

Notes. Standardized regression coefficients are reported with their associated p values in parentheses. ^p < .10, *p < .05 **p < .01

Table 8. True/False questions asked to respondents
1. GM foods are sprayed with more pesticides than crops grown conventionally
2. Foods that have been genetically modified can be labeled as USDA Organic
3. Foods that have been created through mutation breeding can be labeled Organic
4. All fresh produce contains genes that have been altered by humans
5. Genetic modification of food crops alters fewer genes than conventional breeding

In general, no sociodemographic information reliably predicted support for any of the policies, controlling for the other variables. Over and above sociodemographic information, perceived and actual knowledge personal importance of GMs, and risk perceptions reliably predicted support or opposition to all six policies, and all estimates are highly significant. For growing GM foods in the developing world (3) and banning GM foods (6) risk perceptions was the only variable that predicted support, over and above other measured constructs. A one standard deviation increase in risk perceptions corresponds to a one-unit decrease in support of growing GM foods in the developing world and four-fifths of a unit increase in banning the growth of GM foods in the US.

The models predicting support for labeling of GM foods (2) and mutagenesis (1) performed very similarly to one another. Higher risk perceptions predicted more support for labeling and the effect was slightly larger for GM foods (*adjusted r-square* = 0.39 for GM vs 0.29 for mutagenesis). A lower knowledge of genetics predicted more support for both labeling policies, as did lower self-assessed knowledge. This suggests that those with more knowledge of genetics want labeling less, over and above how much they think they know about GM foods. Additionally, it suggests that those who think they know more about GM foods are also less supportive of labeling, regardless of how much they actually know. Finally, perceiving the issue of GM foods to be more important predicted higher support for labeling in general, and the effect was again slightly higher for GM foods than for mutagenesis (0.19 vs. 0.15). Given that, on average, it appears that respondents guessed on the mutation breeding question (3) it is plausible that respondents answered questions about mutagenesis similarly to questions about GM foods and, therefore, the models behaved similarly.

Three variables other than risk perceptions predicted support towards government funding of GM foods. Higher levels of genetics knowledge was associated with increasing support for government funding. In addition, a more liberal political ideology predicted support for government funding, controlling for all other variables. This finding is perhaps unsurprising given that liberals are viewed as more willing to support government funding in general. Finally, higher levels of knowledge of GM regulation was associated with lower levels of support for government funding, though the result is not statistically significant at the $p < .05$ threshold. Two of the same variables that predicted support for government funding also predicted support for growing GM crops in the United States. Again, higher levels of genetics knowledge were associated with increasing support for growing these crops and higher levels of knowledge of GM regulation predicted lower levels of support for this policy. This could be explained if having more knowledge of regulation was associated with restrictions to GM foods in general; however, it doesn't have that association nor does more knowledge of regulation predict avoidance of GM foods, as described below.

Logistic regression model predicting avoidance behavior

Table 9. Results of Binary Logistic Regression Predicting Self-reported avoidance of GM foods

	Avoid GM Foods
Variable	Odds Ratio
Risk	22.34**
	(.000)
Genetics	0.49**
	(.002)
Regulation	
Self-assessed Importance	
Liberal Ideology	1.77**
	(.009)
T/F Q1	
Education	
Income	1.52^
	(.057)
Age	
Constant	
Observations	267
Pseudo R-squared	0.57

Notes. All predictor variables were standardized; ^p < 0.10, **p < 0.01

In addition to the multiple linear regression models predicting policy support, I sought to estimate relationships between the predictor variables described in the previous section and whether or not respondents avoided GM foods. Avoidance of GM foods was a simple binary variable coded as 1 if the respondent self-reported making any effort to avoid GM foods when purchasing food (n = 134) and 0 if they do not try to avoid GM foods (n = 133). Instead of coefficients, Odds Ratios (ORs) are presented in Table 9. Respondents who view GM foods as risky were much more likely to avoid GM foods (OR = 22.34). Respondents with a higher level of knowledge of genetics were less likely to avoid GM foods (OR = 0.49). This suggests that efforts to increase science (or at least genetics) literacy could be effective in lessening the gap between the general public and mainstream scientists on this issue. In addition, more liberal respondents were more likely to avoid purchasing GM foods (OR = 1.77). Lastly, these results tentatively suggest that wealthier respondents are more likely to avoid GM foods (OR = 1.52), though the associated p value exceeds the .05 threshold for significance ($p = .057$). In practice, the simplest way to avoid GM foods in the US is to buy food labeled USDA Organic, which is typically more expensive than food that isn't USDA Organic. This suggests wealthier consumers can access food that they consider to be safer and choose to do so.

Conclusions

Discussion

Together these results point to several interesting and important conclusions. First, respondents have a moderate amount of knowledge of GM foods; they know most about the regulation of GM foods and the least about scientific (i.e., genetic) underpinnings of the technology. The majority of respondents assessed themselves as being either slightly (51%) or moderately (31%) knowledgeable about GM foods; yet, there was no significant correlation between self-assessed and actual knowledge. However, those who viewed the issue as more important were more likely to believe that they were in fact knowledgeable about GM foods. Interestingly, those who assess themselves as knowledgeable were relatively well-informed that the USDA Organic label precludes GM foods but were less informed the process of genetic modification results in fewer alterations in genes than conventional plant breeding. This could suggest that a certain group of respondents view GM foods as less natural and avoids them based on this criterion. This could give further weight to the view of Scott, et al (2016) that much of individual's opposition to GM foods stems from views of unnaturalness and related moral concerns. This also squares with a large proportion of the American public's belief that USDA Organic foods are healthier than conventionally grown food, which in turn are healthier than GM foods (Pew Research Center, 2016). In some ways, it is not surprising to find that these beliefs about GM foods correspond with self-assessed knowledge. Media representations of GM foods have been persistently negative (Mintz, 2017) and much of the information that is most accessible is not grounded in scientific knowledge. Even the term "genetically modified" implies that some foods have been altered by humans while others have been left alone and are more natural, when in reality nearly all plants and animals eaten by humans have been carefully bred and thus modified throughout human history.

The most popular policies presented to respondents were the mandatory labeling of GM foods and foods created by mutagenesis. This is unsurprising given that McFadden and Lusk (2016) found similar levels of support for labeling crops containing DNA and GM foods. They suggest that respondents could be substituting the question “Do you want free information about a topic about which you know very little?” when presented with the option to label foods. While the question of whether to label foods containing DNA is clearly ridiculous, labeling crops bred via mutagenesis seems plausible. The first report of radiation inducing mutations for plant breeding was reported more than 90 years ago on a strain of barley (Stadler, 1928). Since then more than 2000 plant varieties bred via mutagenesis have been developed and released as commercial crops (Ahloowalia et al., 2004). Presently, the CRISPR/Cas9 system of plant breeding is a form of mutagenesis heralded as a way to breed crops resistant to environmental stressors and is being rapidly adopted (Abdelrahman et al., 2018). McFadden and Lusk (2016) argue that “consumer polls may not be a proximate cause for policy” given that consumers have low levels of knowledge about genetics and that consumers want these decisions to be made by experts. Currently there is no explicit regulation of mutagenesis in the United States while transgenic crop varieties are subject to lengthy and costly regulatory processes. My results suggest that consumers do not understand the difference between mutagenesis and transgenesis and may even want more restrictions on mutagenic crop varieties than their GM counterparts.

Half of respondents reported that they make an effort to avoid GM foods. Of the half that do make an effort to avoid GM foods, 46% of them reported that they would, on average, probably be more likely to buy GM foods if a majority of scientists and environmentalists agreed that GM foods are safe to consume. This suggests that there is a large fraction of consumers who avoid GM foods who would, at least in principle, be willing to buy GM foods if they felt confident that scientists and environmentalists vouched for the safety of GM foods. On the other hand, this also means that 27% of the total sample (i.e. 72/267) would either definitely or probably not be more likely to change their purchasing behavior, regardless of evidence of the safety of GM foods. In a nationally representative survey sample, Scott et al., (2016) found evidence that 45% of Americans displayed “absolutist” views and would not be willing to change their minds in the face of new evidence. I have suggested that a broader range of policy outcomes are worth considering the in context of GM foods. Because the term “genetically modified” is so broad it is difficult to interpret what “absolute” moral opposition to GM foods means practically. It is possible that some Americans are absolutely opposed to GM foods being grown in the US or while others simply prefer not to buy them. This could have important implications for policymakers, science communicators, and food retailers. If there truly is just a small fraction of people who are anti-GM and a larger group without strong beliefs, then there is room to focus on the moveable middle.

Interestingly, these data suggest a relationship between political ideology and views on GM foods. Prior work that has considered political views in relation to this issue has generated inconsistent results. For example, Scott et al., (2016) found that political ideology was not associated with attitudes towards GM foods, and McFadden (2016), in a separate nationally representative survey, found that Democrats were more likely than Republicans to agree that GM foods are safe. My results suggest that a more liberal ideology is associated with making an effort to *avoid* GM foods in purchasing behavior. Given that my results also suggest that those who avoid GM foods consider environmental NGOs – which are generally opposed to GM foods – to be relatively more trustworthy, further study may be warranted into the relationships between environmentalism, political ideology, and GM foods more specifically than I have considered here.

Looking to the future, it is worth remembering that what citizens and what regulators or scientists consider to be a "GMO" are likely not the same things. Hefferon and Herring (2017) claim that gene-edited crops have a higher chance of global acceptance than transgenic varieties. On the one hand this is a reasonable claim but only because there is so much evidence of transgenic crops being restricted and a very small body of evidence that government regulators have been more permissive of gene-edited crops. On the other hand, it is reasonable to think that gene-edited crops will experience a very similar amount of public backlash that transgenic crops have experienced. The term "GMO" or "genetic engineering" or GM has in a way framed the debate. The term is broad enough that it can refer to any crop that has undergone plant breeding; all genetic modification means on its face is that genes were changed. Given the very low levels of knowledge people have about genetics, I suspect that it has also taught consumers that if something is outside the GM regulatory protocols in that country than it has not had its genetic material changed by humans.

One result of this research worth considering is how supportive members of the developed world are of employing GM or gene-edited crop varieties in the developing world. My results suggest that some Americans are more supportive of other countries growing GM crops than they are of GM crops being grown in the US. Currently the vast majority of undernourished and malnourished people live in the developing world and therefore most of the potential benefits of GM and gene-edited crops accrue to food-insecure people. However, Herring and Paarlberg (2016) make a strong case that market penetration of agricultural technologies in the developing world are driven by regulation and consumer preferences in the developed world, though this seems especially likely for export crops. If the crop being grown in a developing country is intended for export, then it matters how receptive foreign governments and consumers are to eating the final

GM or gene-edited product. Many of the same actors that have raised the alarm about transgenic crops are raising the alarm about gene-edited crops. Because of this dynamic it seems likely that global production of both GM and gene-edited crops will largely depend on regulatory decisions, consumer preferences, and activism of global NGOs (not necessarily in that order) from the world's wealthiest countries and that those decisions will trickle down throughout the globe.

Limitations

This study has several limitations. First of all, the sample of participants I surveyed is not representative of the American public and therefore undesirable. This impacts my ability to generalize results to a broad population of the American public. It is a potential explanation for some of the differences from past literature that I discussed in my results. Ideally my sample would be a random sample of the American public. Secondly, my sample size (n=267) is relatively low. This results in my analyses being underpowered and limits my ability to notice potential meaningful relationships between my predictor and outcome variables. Also, it should be reinforced that all of the participants in this study are residents of the United States and, since I did not ask about respondents' nationality, it is hard to say whether the results can generalize to contexts outside of the United States.

In addition to the limitation of my sample, I have concerns with how I measured the construct of trust. I operationalized trust by asking respondents whether or not they avoided GM foods and then to what extent certain groups might influence them to change their minds. If a respondent didn't avoid GM foods in the first place, it is plausible that they would score very low on trust because they don't see themselves as being more likely to buy GM foods than they already are. Given the relatively higher scores non-avoiders reported on these measures it appears that they interpreted the question as I expected; however, this possibility still exists. Further, one possible explanation for the low levels of trust between those who avoid GM foods and those who don't is that the avoiders could be more likely to know which groups support or oppose GM foods. For example, those who both avoid GM foods and trust environmentalist organizations likely know that these NGOs oppose GM foods. Since the question was asked in terms of whether or not a respondent would be more likely to buy GM foods, it is possible that they couldn't imagine most environmentalists changing their minds and agreeing that GM foods are safe. It is also reasonable to assume that those who avoid GM foods are more likely to know which of the target groups supports and opposes GM foods based on a greater familiarity with the debate.

Thirdly, I chose not to provide a definition of GM to respondents prior to asking them the six T/F questions. The definition of GM I had in mind was anything created using rDNA technology or via transgenesis. It is unlikely most respondents knew this particular definition. As I have noted, "genetically modified" on its face is open to interpretation and can encompass virtually all foods that we eat based on the history of agriculture and selective breeding. As a result, several of the questions I asked are ambiguous and may be mutually exclusive. In future work I would provide a definition of GM if asking questions the way I did in this study. This is also a potential explanation for why levels of knowledge didn't reliably predict outcome variables in the regression analyses above.

Finally, there are additional constructs that I failed to take note of when designing the study. Though I included one question about the future impact of GM foods, I failed to account for perceived benefits of GM foods. Including benefit perceptions could help determine whether a cost-benefit framework of GM foods helps explain public attitudes. Moral and emotional factors have also been shown to influence public perceptions of GM foods. I am particularly interested in how perceptions of naturalness impact policy preferences and behavior towards new food technologies. I discuss ways to incorporate these constructs into future research in the final section.

Future Directions

The results of the regression analyses predicting policy support raises questions that warrant further research. First, self-assessed knowledge and actual knowledge of genetics both predicted less support for labeling, over and above all other variables. It is possible that this is an expression of the terms "genetically modified" and "knowledge" being amorphous and open to interpretation. One direction of future research would be to attempt to understand what facts or opinions about GM foods are the most relevant to residents of the United States. This could potentially explain the findings of Fernbach, et al. (2019) who claim that those who claim to know the most about GM foods actually know the least. It is possible that certain opposers of GM foods claim to know the most but what they "know" is not considered scientific knowledge by researchers.

Scott et al, (2016) found that the emotion disgust and moral values predicted support for legal restrictions on GM foods, over and above risk-benefit measurements. Moreover, they found a strong majority of respondents opposed to GM displaying "evidence insensitivity." Part of this could be explained by some Americans' belief that scientists aren't as sure as they claim to be about the science of GM food safety or that biotechnology companies have an inappropriate influence on the scientific process and government regulation (Pew Research Center, 2016). I found some evidence of a willingness among people who avoid GM foods to change their behavior in response to a trusted group vouching for the food's safety, suggesting that they are in fact sensitive to evidence. A possible next step would be to design an experiment manipulating the degree to which a trusted source of information is supportive of GM foods.

Finally, Rozin (2005) found that Americans perceive that the process of genetic modification reduces the “naturalness” of foods more than major changes to an organism accomplished by conventional breeding through artificial selection. In that study respondents were most concerned that genetic information from another species was being inserted into a separate organism. The threshold of whether or not genetic information is exchanged between organisms has also been used as an important distinction by government regulators. The CRISPR/Cas system allows scientists to alter genetic material of organisms within that same organism, therefore leading regulators in Sweden, Canada, and the United States to rule that genome-edited crops do not meet current definitions of GM crops and are thus excluded from special regulation (Hefferon and Herring, 2017). I have presented evidence that many people do not understand the distinctions between different types of plant breeding methods. This was most obviously shown by even more respondents supporting labeling of plants bred via mutagenesis than by transgenesis. A future research direction is to probe into the parameters of what Americans think genetic modification is not. Do Americans think that USDA Organic food has genes that were manipulated by humans? If other forms of plant breeding – not considered to be GM - were described in abstract terms would Americans be supportive? How people answer these questions is likely similar to how they interpret other interventions involving nature that are highly technical and require scientific knowledge to fully understand (e.g. geoengineering, carbon capture and storage).

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Appendices

A. Correlations of self-assessed knowledge and each T/F question

1. GM foods are sprayed with more pesticides than crops grown conventionally
2. Foods that have been genetically modified can be labeled as USDA Organic
3. Foods that have been created through mutation breeding (mutagenesis) can be labeled Organic
4. All fresh produce contains genes that have been altered by humans
5. Genetic modification of food crops alters fewer genes than conventional breeding techniques

Self-assessed knowledge and 1 r = -.062, p = .315

Self-assessed knowledge and 2 r = .006, p = .918

Self-assessed knowledge and 3 r = .041, p = .502

Self-assessed knowledge and 4 r = .150, p = .015*

Self-assessed knowledge and 5 r = .072, p = .241

B. T-tests of trust levels based on whether or not respondents avoid GM foods

Two sample t-test with equal variances

Scientists t = 9.21, p = .000

Environmentalists t = 5.96, p = .000

Farmers t = 8.80, p = .000

Government t = 10.95, p = .000

Biotechnology t = 9.14, p = .000

	Does not avoid	Avoids
Target	Mean	Mean
Scientists	3.44	2.52
Environmentalists	3.18	2.55
Government	3.11	2.05
Farmers	3.02	2.18
Biotechnology	2.65	1.69