U.S. CONSUMERS' ACCEPTANCE AND WILLINGNESS TO PAY FOR GENETICALLY MODIFIED AND GENOME-EDITED FOODS

BY

BINDU PAUDEL

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THESIS ACCEPTANCE PAGE

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This thesis is approved as a creditable and independent investigation by a candidate for the master's degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Deepthi Kolady
Advisor Date

Eluned Jones
Department Head Date

Nicole Lounsbery, PhD
Director, Graduate School Date

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ABSTRACT

U.S. CONSUMERS' ACCEPTANCE AND WILLINGNESS TO PAY FOR GENETICALLY MODIFIED AND GENOME-EDITED FOODS

BINDU PAUDEL

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Even though genetically modified (GM) crops have a lot of economic potential for producers and consumers, they have not been widely accepted due to increasing concerns related to food safety, human, animal, and environmental health. Unlike GM technology, genome-editing technology does not involve the transfer of genetic materials. It is simpler, cheaper, more precise, and faster relative to GM technology and has immense potential for incorporating producer and consumer traits. Genome-editing technology, as a novel process, not has been explored much from the consumer's side. This study uses a nationally representative survey of 1,573 U.S. consumers to examine their acceptance and willingness to pay for genome-edited foods and GM foods. We used discrete choice experiments to estimate consumers' willingness to pay for genome-edited foods and GM foods. To evaluate the effects of information, we included a control and two versions of information treatments. In treatment 1 (T1) we provided information on technological details, whereas in treatment 2 (T2) we provided the information on both technological details and their health and environmental benefits. We employed a random parameter logit model to estimate consumers' willingness to pay (WTP) for genome-edited food products. We used cluster analysis to identify consumer segments based on their attitudinal indices. The consumer characteristics and willingness to consume GM and genome edited foods are assessed within the identified clusters. Further, we used multivariate probit model to examine differences between and similarities among the determinants of the current consumption of GM foods and the future consumption of GM and genome-edited foods. Findings from the study show that consumers' WTP for GM and genome-edited foods are similar, but lower than the WTP for conventionally bred food. WTP for genome-edited foods differ based on food types. Provision of information with specific health and environmental benefits has a significant effect on WTP for genome-edited foods. Consumers' perceptions and acceptance of GM and genome-edited foods are similar to one another. Consumer were divided in three categories: uncertainty-loving, uncertainty-neutral and uncertainty-averse. Uncertainty-loving consumers were found to have positive attitudes toward future consumption of GM and genome-edited foods. Unlike WTP, willingness to consume for GM and genome-edited foods do not vary by food type. Information provision has no effect on the likelihood of acceptance of genome-edited foods, it reduces the likelihood of accepting GM foods. Consumers trust domestic start-ups and universities more than multinational firms as technology developers.

CHAPTER I

INTRODUCTION

Unlike genetically modified (GM) crops that are produced by mixing genes from two distinct species, genome-edited crops do not involve the transfer of genes between species (Doudna and Charpentier 2014, Feng et al. 2013). Consequently, genome editing is simpler, cheaper, and faster than creating GM crops. Further, unlike GM crops that mainly focus on traits important to producers, genome-edited crops have the potential to solve problems in the agricultural production system and to address consumer concerns such as allergens, food quality, and food safety (Shew et al. 2018). Producers' decisions on the use of production practices and technologies are increasingly being influenced by consumer preferences and trade potential. For the commercial success of genome-edited foods, widespread consumer acceptance of genome-editing technologies is essential (Araki and Ishii 2015, Bredahl 2001). However, there are still number of unanswered questions regarding genome-edited foods. Do consumers recognize genome-edited foods different from GM foods? What is the effect of information on consumer acceptance and willingness to pay (WTP) for GM and genome-edited foods? What is the role of product benefits and for the developer of technology in determining acceptance and WTP for genome-edited foods? Are there any consumer segments based on attitudinal preferences in food markets? What are the determinants of consumer acceptance of GM and genome-edited foods? Our study tries to address these questions. Results from the study provides insights for technology developers and industries that will facilitate full integration of this new technology into the marketplace and society.

Chapter II focuses on examining U.S. consumers' WTP for GM and genome-edited foods using discrete choice experiments. This chapter also seeks to evaluate the effect of information on consumer' WTP. To evaluate the effect of information, a control and two versions of information treatments were provided to the respondents. In information treatment 1, respondents were provided with information on technological details, whereas in information treatment 2, respondents were provided with the information on both technological details and their health and environmental benefits. The results from this chapter provide insights on U.S. consumers' WTP for GM and genome-edited foods and helps evaluate the effect of information on consumers' WTP for GM and genome-edited foods.

Chapter III focuses on examining U.S. consumer responses towards GM and genome-edited foods. Consumer segments based on their attitudinal indices are identified via cluster analysis in this chapter. The socio-economic characteristics, awareness and knowledge, opinion towards biotechnology, and willingness to consume GM and genome-edited foods are assessed in these identified consumer segments. Further, a multivariate probit model is used to examine differences between and similarities among the determinants of the current consumption of GM foods and the future consumption of GM and genome-edited foods. The results from this chapter provide insights on the impacts of consumer beliefs, attitudes, knowledge, and information on consumer acceptance of GM and genome-edited foods.

Chapter IV summarizes results, conclusions and implications from Chapter II and Chapter III.

CHAPTER II

U.S. CONSUMER'S PREFERENCE AND WILLINGNESS TO PAY FOR GENETICALLY MODIFIED AND GENOME-EDITED FOODS: A DISCRETE CHOICE EXPERIMENT APPROACH[1]

[1] This paper is under the review of Journal of Agricultural and Resource Economics (JARE).

Abstract

This study uses a nationally representative survey of 1,573 U.S. consumers to estimate U.S. consumers' willingness to pay (WTP) for genome-edited foods relative to foods produced using genetically modified (GM) technology and conventional breeding. The study finds that (i) consumers' WTP for GM and genome-edited foods are similar but, lower than the WTP for conventionally bred food; (ii) WTP for genome-edited foods differ based on food types; (iii) provision of information with specific health and environmental benefits have a significant effect on WTP for genome-edited foods, and (iv) consumers trust domestic start-ups and universities more than multinational firms as technology developers.

Introduction

Genome-editing is an emerging biotechnological technique that can be used across crops and livestock in both developed and developing countries to create a farming and food system that is environmentally sustainable, economically viable, and that ensures food safety and nutritional security (Gates 2018, Dance 2015). Unlike its predecessor technology, GM crops, which are produced by mixing genes from two distinct species, genome-edited crops do not involve the transfer of genes between species (Doudna and Charpentier 2014, Feng et al. 2013). Consequently, genome editing is simpler, cheaper, and faster than creating GM crops. Further, unlike GM technology that focused on traits important for agricultural producers, genome-editing has the potential to address biotic and abiotic stresses affecting agricultural production while also addressing consumer concerns such as allergens, food quality, nutrition, and food safety

(Shew et al. 2018). Despite the scientific consensus on the potential economic benefits and food safety of GM crops, consumers worldwide have misconceptions regarding, and even unfamiliarity with, GM crops limiting its diffusion to 29 countries that currently grow GM crops (Graff, Hochman, and Zilberman 2009, Baker and Burnham 2001, Lusk, McFadden, and Wilson 2018, NAS 2016, Rousu et al. 2004, Wunderlich and Gatto 2015, ISAAA 2018). Lack of an effective science-based communication strategy that promotes public awareness of GM crops is one of the reasons for the polarization of public perceptions towards GM crops (Capalbo et al. 2015, Frewer, Scholderer, and Bredahl 2003, Blancke, Grunewald, and De Jaeger 2017, Blancke et al. 2015).

Like GM crops, genome editing makes permanent changes in a plant's genome that are passed on through genes which raise concerns related to food safety, human, animal, and environmental health (Cotter and Perls 2018, Cox, Platt, and Zhang 2015, Ishii and Araki 2016). Like GM technology, commercial success, and social integration of the genome-editing will depend on consumer acceptance and willingness to pay (WTP) for the technology. Based on available evidence on the consumer acceptance of GM crops, consumer acceptance of the technology will rely on factors such as whether consumers perceive genome-editing as an improved technology over GM, their trust in the institutions that develop the technology, and the effect of sharing science-based communication/information. Some prior studies compared consumers' acceptance and WTP for genome-edited foods to that of GM foods finding higher acceptance for genome-edited foods (Shew et al. 2017, Shew et al. 2018, Muringai, Fan, and Goddard 2020a, Caputo, Lusk, and Kilders 2020b). However, our current understanding of the effect of information, the developer of the technology, and food types on consumers' acceptance of genome-edited foods is limited.

The objectives of this study are three-fold: (i) estimate WTP for two genome-edited foods in relation to GM, and conventional foods; and (ii) analyze the effect of general and specific information on WTP for GM and genome-edited foods; and (iii) determine the effect of the developer of technology on WTP for GM and genome-edited foods. This study uses a nationally representative survey of 1,573 U.S. consumers and employs a discrete choice experiment (DCE) to estimate WTP. The study includes two food products with different processing levels: soybean oil and apples, as focus food products.

The study contributes to the emerging literature on consumers' acceptance and WTP for genome-edited foods relative to GM foods (Araki and Ishii 2015, Shew et al. 2018, Muringai, Fan, and Goddard 2020a, Caputo, Lusk, and Kilders 2020b, Marette, Disdier, and Beghin 2020). This study differs from the previous studies by focusing on two different food products each with commercial GM products already available in the market. Consumers' familiarity with GM soybean oil and GM apple might help consumers to better understand the risks and benefits of genome-edited soybean oil and apple and better answer related DCE questions. The study's findings on the differential effect of information on consumers' WTP between GM and genome-edited foods provide insights for technology developers and policymakers to develop an effective science-based communication strategy to scale up the consumer acceptance of the technology.

Literature Review

Conventional plant breeding, GM, and genome-editing technologies

Scientific advancements in fields such as genetics paved the way for the use of modern plant breeding techniques such as hybridization for crop trait improvements. Traditional plant breeding techniques allowed plant breeders to incorporate desirable traits such as increased yield, and disease and pest resistance. Although advancements in genomics reduced the time elapsed from the selection of a desirable trait to the successful breeding and development of a new variety substantially, the traditional process is still time-consuming and has limits in incorporating consumer traits such as food quality, reduced allergenicity, etc. (Pacher and Puchta 2017).

Technological advancements in agricultural biotechnology led to the development of GM crops that are produced using either transgenic or cisgenic genetic modification (Aghaee et al. 2015, NAS 2016, Shew et al. 2016, Baker and Burnham 2001, Huffman 2003). In the case of transgenic GM crops, genetic modification introduces foreign DNA from a different species whereas, in the case of cisgenic, foreign DNA is introduced from another cultivar of the same species (Ishii and Araki 2016, Huang et al. 2016, Shew et al. 2016). Most GM crops grown currently across the world are products of transgenic modification (Huang et al. 2016, ISAAA 2018). Although there is a scientific consensus that overall GM crops had favorable outcomes for adopters of all scales, and foods from GM crops are as safe as the foods from non-GM crops (NAS 2016) the technology is very controversial. The concerns over GM crops include environmental concerns such as the potential for the development of resistant weeds and pests, health concerns related to food safety, social and economic concerns related to monopolistic power of technology and seed companies, high seed prices, and the technologies' impact on farm structure (Chern et al. 2002, Han and Harrison 2007, Sprink et al. 2016, Kolady and Herring 2014, Kolady and Srivastava 2018).

Recent advancements in genome engineering using tools such as clustered regularly interspaced short palindromic repeats-Cas9 (CRISPR-Cas9) allow site-specific modifications in the genomes of cells and organisms (Zhang et al. 2016, Zong et al. 2017, Feng et al. 2013, Doudna and Charpentier 2014, Dance 2015, Araki and Ishii 2015). Unlike GM, the genome-editing technology solely deals with the alteration of genes that already exist within the crop/organism and more closely mimics nature. Consequently, genome editing has the potential to address concerns such as the human health impacts of transgenic GM crops.

Status of genome-editing technology in the U.S.

Anti-browning white button mushroom is the first CRISPR-Cas9 genome-edited crop developed in the U.S. by researchers in Penn State. Calyxt, a Minnesota based company in the U.S., announced its first sale of genome-edited soybean oil with high oleic acid for commercial use in 2019. Genome-edited soybean oil with improved nutrition, high-fiber gluten wheat, alfalfa with improved digestibility, and pulses with improved protein profile are some of the products in Calyxt's pipeline (Calyxt 2019, 2020). Cibus, a pioneer of precision genome editing in agriculture has developed genome-edited herbicide-resistant canola that is being cultivated in Montana and North Dakota as of 2019. Herbicide and disease tolerant rice, flax, potato, wheat, corn, and soybean are the products in Cibus's pipeline (Cibus 2020). In addition, the companies such as Yield10Bioscience, Pairwise, and Corteva Agri-science (Waxy corn) are also working on the rapid development of genome-edited foods like waxy corn hybrids, flaxseed with increased omega-3 content, cacao with resistance to fungal and viral diseases, sweeter strawberries with better shelf storage, etc. (Yield10BioScience 2020, Pairwise 2018, Corteva 2019). In addition to the firms listed above, there are many private firms, public land grant universities, and research organizations investing in the research and development of genome-edited crops and livestock.

Consumers' acceptance and willingness to pay for GM foods

Unlike genome-edited foods, there is an extensive body of research that focuses on drivers of consumers' acceptance and willingness to pay for GM foods. Previous studies on consumer acceptance of GM foods identify familiarity (Baker and Burnham 2001); food quality and safety (Baker and Burnham 2001); quality and trustworthiness of products (Bredahl 2001), and consumers' perception of risks and benefits (Han and Harrison 2007) as important factors in decision making. Studies on WTP for GM foods shows that consumers that perceive additional risk require a discount to purchase GM foods and that perceived benefits reduce the discount required to purchase GM foods (Moon, Balasubramanian, and Rimal 2007, Huffman 2003, Huffman et al. 2003). A meta-analysis of consumer WTP for GM foods shows that on average consumers placed 23%-42% higher value for non-GM foods than GM foods and European consumers have a higher premium for non-GM foods than U.S. consumers (Lusk et al. 2005). Studies that examined the role of information or labeling on consumer WTP for GM foods showed that information shared with the public domain has an important role in determining consumer acceptance and has a significant effect on consumer preferences (Colson and Huffman 2011, Wunderlich and Gatto 2015, Han and Harrison 2007). Previous research also showed that third party information is a moderating force against the extreme views of the agricultural biotech industry and environmental groups. Public provision of such third-party information could greatly improve social welfare of adoption and diffusion of GM crops (Huffman et al. 2003, Huffman 2003). Information on the positive environmental effects of GM foods has the greatest value for consumers compared to information on health impacts and impacts on developing countries (Rousu and Lusk 2009). Overall, these studies suggest that educating consumers about GM foods might be a viable strategy to mitigate their concerns about unknown health risks and adverse environmental effects and to increase their acceptance.

Consumers' acceptance and willingness to pay for genome-edited foods

Araki and Ishii (2015) and Ishii and Araki (2016) conducted studies on consumer acceptance of food crops developed by genome editing to explore the bottlenecks of consumer acceptance of genome-edited crops and recommended that developers should focus initially on traits that are of interest to consumers. A multi-country assessment of consumers' willingness to consume and WTP for CRISPR-produced foods compared to GM foods showed that consumer acceptance is lower in countries such as Belgium and France relative to the USA and Canada (Shew et al. 2018). Shew et al. (2018) also found a positive impact of information on consumer acceptance of genome-edited foods. A recent study compared Canadian consumers' acceptance of GM and genome-edited potatoes and found higher acceptance and WTP for genome-edited potatoes compared to

GM potatoes (Muringai, Fan, and Goddard 2020). Caputo et al. (2020) compared U.S. consumers' acceptance of genome-edited, GM, conventional, organic, and non-GM foods using both fresh and processed products as focus products and found a positive impact of information on consumer willingness to pay for genome-edited foods. Marette et al. (2020) compared U.S. and French consumers' WTP for genome-edited apples relative to GM and conventionally bred apples. The study found that consumers' WTP for genome-edited and GM apples are lower than the WTP for conventionally bred apples. Marette et al. (2020) also reported that price discounts for genome-edited apples were lower than that for GM apples and information condition consumers' preferences towards GM and genome-editing technologies.

Methods

Design of the study

The study received Institutional Review Board approval from omitted for review University. We used an online opt-in internet panel maintained by Qualtrics to select participants for this study. The online survey was implemented in April 2020. Qualtrics ^{XM} prescreened the survey respondents by age, sex, ethnicity, and income using quotas that helped to ensure that the sample was representative of U.S. consumers. The target population of the study was U.S. consumers who are aged 18 years or older and the primary grocery shoppers who contribute at least 50% of the total household purchases. Previous studies have shown that the consumer acceptance and willingness to pay for novel food products are influenced by the information presented to the respondents (Lusk et al. 2004, McFadden and Huffman 2017, Rousu et al. 2007). We employed a split design survey with a control and two versions of information treatments in our study. In the information treatment 1 version of the survey questionnaire (T1), respondents were provided with details on the similarities and differences between GM and genome-edited food technologies in terms of technology use. In the information treatment 2 version of the survey questionnaire (T2), the details on both technology and their potential health and environmental impacts were provided to the respondents (Appendix 1, 2 and 3). Every other question in the survey remained the same across all the treatments. All the respondents who participated in the survey were randomly assigned to an information or control treatment of the survey. The survey instrument of each treatment versions had a section on choice questions to estimate consumers' willingness to pay for GM and genome-edited foods. The study had a sample size of 1,573 respondents in total, out of which 527 received the control treatment, 523 received T1, and the remaining 523 received T2. Table 1 displays the sample characteristics.

Table 1. Summary statistics of survey sample (N=1573)

Demographics	**All sample (n=1573)**	**Control (n=527)**	**Treatment 1 (n=523)**	**Treatment 2 (n=523)**	**U.S. Census**
Sex					
Male	49.27%	49.72%	49.14%	48.95%	49.2%
Female	50.73%	50.28%	50.86%	51.05%	50.8%
Age					
18-24 years old	13.22%	12.90%	13.19%	13.58%	9.6%
25-34 years old	16.91%	17.65%	15.68%	17.40%	13.8%
35-44 years old	16.34%	16.32%	17.02%	15.68%	12.6%
45-54 years old	17.86%	17.27%	18.74%	17.59%	13.2%
55-64 years old	16.72%	16.51%	16.63%	17.02%	12.8%
65 years or older	18.94%	19.35%	18.74%	18.74%	15.2%

Ethnicity					
White	60.52%	60.53%	60.61%	60.42%	61.1%
Hispanic or Latino	18.05%	18.03%	17.97%	18.16%	17.8%
Black or African American	12.59%	12.52%	12.62%	12.62%	12.3%
Native American/Alaska Native	0.57%	0.76%	0.57%	0.38%	0.7%
Asian	5.59%	5.50%	5.54%	5.74%	5.4%
Other	2.67%	2.66%	2.68%	2.68%	2.7%
Household Annual Income					
< $10,000 to 24, 999	22.95%	27.13%	23.52%	18.16%	20.2%
$25,000 to $49,999	28.35%	30.55%	28.30%	26.20%	21.9%
$50,000 to $ 74,999	16.72%	17.27%	18.16%	14.72%	17.5%
$75,000 to $99,999	11.82%	13.66%	9.94%	11.85%	12.5%
$100,000 or more	20.15%	11.39%	20.08%	29.06%	27.9%
Education					
College degree or higher	32.23%	31.88%	32.89%	31.93%	31.5%
Marital Status					
Married	47.43%	44.21%	45.51%	52.58%	48.3%
Unmarried	52.57%	55.79%	54.49%	47.42%	51.7%
Employment Status					
Employed	60.39%	58.25%	60.80%	62.14%	63.3%
Unemployed	39.61%	41.75%	39.20%	37.86%	36.7%
Average number of children per household (0-18 years old)	0.65	0.68	0.61	0.66	0.58
Residence					
Urban	73.05%	72.30%	69.79%	77.06%	80.7%
Rural	26.95%	27.70%	30.21%	22.94%	19.3%

As per Table 1, there is no significant difference between key socio-demographic characteristics of control and information treatments except for a few socio-demographic characteristics i.e., household income, marital status, and place of residence. Similarly, the socio-demographic characteristics of sample respondents across all the treatment were found to be in line with the 2010 U. S. population census (Bureau 2010, 2018a).

Choice experiment

We used a discrete choice experiment (DCE) to collect data on consumers' WTP towards various attributes and attribute levels. DCE presents an attractive way to simulate real-market decision-making settings. The choice structure provides an option for respondents to opt-out from purchasing decision and, has often been used to analyze attitudes toward new attributes and levels that may not be found in the market (Lusk, Roosen, and Fox 2003, Van Loo et al. 2011, Syrengelas et al. 2017, Muringai, Fan, and Goddard 2020, Caputo, Lusk, and Kilders 2020).

Food products, attributes, and attribute levels

In this study we focus on soybean oil and apples as focus food products for the following reasons: (i) GM soybean oil and GM apple are already available in the market (Erickson 2015, Rosenblum 2017); (ii) Genome-edited soybean is commercially available in the U.S., while genome-edited apple is in the research pipeline of some private firms and public research organizations (Synthego 2019); and (iii) soybean oil is highly processed while apple is fresh produce. The inclusion of these food products in the study enables us to examine whether there is any difference in consumers' WTP based on food types.

Since one of the objectives of this study is to examine consumers' WTP for genome-edited foods relative to the existing plant breeding technologies, we included conventional breeding, GM, and genome-editing, and no-information as technology attributes. However, the technology used in food production is not the only factor in driving consumer acceptance and WTP for food products. Consumers are also driven by the associated health and environmental benefits of the technology used in food production. Studies have found that consumers are willing to pay more for enhanced nutrition (Steur et al. 2013, González, Johnson, and Qaim 2009, Colson and Huffman 2011), agronomic traits such as pest resistance, herbicide tolerance(Costa-Font, Gill, and Trail 2008) and improved shelf life or reduced food wastage (Moon and Balasubramanian 2002). Furthermore, corporate trust in developers of technology is also identified as a key factor in driving consumers' WTP for novel technologies (Lusk, McFadden, and Wilson 2018). Therefore, we included the health and environmental benefits of technology and the developer of the technology as important attributes in the choice experiment.

The attributes and levels selected for soybean oil are prices per 48 fl. oz ($1.99, $3.49, $4.99, $6.49), health/nutritional attribute of the product (high oleic acid content and normal oleic acid content), the environmental attribute of the product (reduction in pesticide use and no reduction in pesticide use), the technology used in food production (conventional, GM, genome-editing, and no information), and developer of technology (domestic-start up, a multinational firm, university, and no information).

Similarly, the attributes and levels identified for apple are prices per lb ($0.99, $1.49, $1.99, $2.49), health/nutritional attribute of the product (high vitamin C and antioxidants and normal vitamin C and antioxidants), the environmental attribute of the product (resistant to browning and susceptible to browning), the technology used in food production (conventional, GM, genome-editing, and no information), and developer of technology (domestic-start up, a multinational firm, university, and no information) (Table 2).

Table 2. Soybean oil and apple attributes and levels in discrete choice experiment design

Soybean oil attributes	**Levels**	**Apple attributes**	**Levels**
Price ($/48 fl. oz.)	$1.99	Price ($/lb)	$0.99
	$3.49		$1.49
	$4.99		$1.99
	$6.49		$2.49
Nutritional content	High	Nutritional content	High
(Oleic acid)	Normal	(Vitamin C & antioxidants)	Normal
Use of pesticide	Reduced use	Resistance to browning	Resistant to browning
	No reduction		Susceptible to browning
Technology	Conventional breeding	Technology	Conventional breeding
	Genetically modified (GM)		Genetically modified (GM)
	Genome-editing		Genome-editing
	No Information		No Information
Developer	University	Developer	University
	A multinational firm		A multinational firm
	Domestic start up		Domestic start up
	No Information		No Information

The price levels for soybean oil and apple were selected based on market observations and the national retail report of USDA from Jan 25, 2020, to February 6, 2020 (AMS 2020). The average price for soybean oil from Jan 25, 2020, to February 6, 2020, was $3.54 per 48 fl. oz whereas the average price for an apple during the period was $1.61 per pound (AMS 2020). The inclusion of the ‘No information’ attribute level as a base attribute level allows the estimation of coefficients for other attribute levels of interest for technology and developer attributes. The definition of attributes and attribute levels were presented to respondents across all treatments.

Designing choice sets

We used NGene software to generate choice scenarios for the choice experiment. Separate choice scenarios were generated for soybean oil and apple using different NGene models and Bayesian priors. Bayesian priors of each attribute level were coded in NGene to derive a D-efficient design for both products. The use of Bayesian priors decreases the standard error of the estimates and increases the efficiency of choice scenarios (SÁndor and Wedel 2001). NGene software calculates the D-error value for each combination of choice scenarios and subsequently improves the combination of choices by reducing the D-error value in each iteration (ChoiceMetrics 2012, Syrengelas et al. 2017). D-error values for the choice scenarios of soybean oil and apple were 0.50 and 0.52, respectively. DCE design always faces a trade-off between the number of choice scenarios and the number of effective responses. Increasing the number of choices in the DCE facilitates an increase in efficiency of the model (Vanniyasingam et al. 2016, Vermeulen, Goos, and Vandebroek 2010), however, this leads to response fatigue among the respondents (Hensher, Rose, and Greene 2015). To address the issue of inefficient responses resulting from the response fatigue of the respondents, we developed a total of 24 choice scenarios for each product in 4 blocks. Each respondent who participated in the survey were randomly assigned to one of the four blocks for soybean oil and one of the four blocks for apple. This meant each respondent faced 6 choice scenarios for soybean oil and another 6 choice scenarios for apple. Each choice scenario had 3 alternatives, Option A, Option B, and Neither. Option A and Option B represented soybean oil or apple with varying attribute levels and "Neither" represented the opt-out alternative.

Table 3. Sample choice set for soybean oil

Attributes	**Option A**	**Option B**	
Price ($/48 fl. oz)	3.49	6.49	**Neither**
Nutrition (Oleic acid)	High	Normal	
Level of pesticide use	Reduced use	No reduction	
Technology	Genome-editing	Conventional	
Developer	No information	University	
	☐	☐	☐

Table 4. Sample choice set for apple

Attributes	**Option A**	**Option B**	
Price ($/lb)	1.49	1.49	**Neither**
Nutrition (Vitamin C & antioxidants)	High	Normal	
Food wastage (Browning)	Resistant to browning	Susceptible to browning	
Technology	Genetically modified	Conventional	
Developer	University	A multinational firm	
	☐	☐	☐

The presence of hypothetical choice situations in a stated preference study usually leads to an issue of hypothetical bias where respondents are likely to report unrealistic behaviors or values in the surveys. To address the issue of hypothetical bias, cheap talk scripts were provided prior to each choice situation across all the treatments of the study. Previous studies suggest that the cheap talk strategy is an effective approach to address the hypothetical bias in stated preference methods and significantly reduces biases in WTP (Cummings and Taylor 1999, Champ, Moore, and Richard 2009).

Empirical framework and model

As mentioned above, DCE is a multi-attribute, stated preference method where individuals make trade-offs between utilities obtained from different choice situations of a particular product. Further, each choice situation in DCE is composed of multiple attributes and attribute levels. Therefore, the utility yielded by a particular choice situation depends on its combination of attributes and attribute levels. Simply, the utility of an individual for a particular choice situation in DCE is a function of its attributes and attribute levels (Louviere and Hensher 1983, Revelt and Train 1998, Train 2009). Underpinned by the theoretical framework of random utility in DCE, it is important to address heterogeneity in consumers while eliciting consumer preference and their choice behavior. The random parameter logit (RPL) model allows heterogeneity among the individual responses which thereby results a variation in parameter estimation among the consumers (Train 2009). We used a random parameter logit model for eliciting U.S. consumers' willingness to pay for genome-edited foods. The random utility (U_{ijt}) of the individual consumer *i* for alternative *j* in choice set *t* that underlies the RPL model is represented by a deterministic and a stochastic component as given below (Revelt and Train 1998, Train 2009).

$$U_{ijt} = V_{(ijt)} + \lfloor u_{ij} + \varepsilon_{ijt} \rfloor \quad (1)$$

Where U_{ijt} is the latent unobservable utility of individual consumer i for alternative *j* in choice situation *t*, V_{ijt} is the systematic portion of the utility determined by the product attributes x_{ijt}, u_{ij} is an error term which is distributed normally over consumers and alternatives, and ε_{ijt} is the stochastic error, independently and identically distributed overall consumers, alternatives, and choice sets.

The probability of individual consumer *i* choosing alternative *j* in choice set *t* is $P(U_{ijt} \geq U_{ikt})$, over all possible *k* alternatives, where $k \in T_i$, $j=1, \ldots, k$; and $T_i = \{t_1, t_2, \ldots, t_T\}$ represents the choice scenarios faced by individual consumer *i*.

Following equation (1) and assuming V_{ijt} to be a linear additive function of several attributes with corresponding weights, the linear utility (U_{ijt}) of individual consumer *i*, from each alternative *j* within the choice situation is estimated using the following empirical models for soybean oil and apple:

$$U_{ijt}(\text{Soybean Oil}) = \beta_p Price_{ijt} + \beta_1(\text{High oleic acid})_{ijt} + \beta_2(\text{Reduced use of pesticide})_{ijt} + \beta_3(\text{Conventional breeding})_{ijt} + \beta_4(\text{GM})_{ijt} + \beta_5(\text{Genome-editing})_{ijt} + \beta_6(\text{Domestic-start up})_{ijt} + \beta_7(\text{A multinational firm})_{ijt} + \beta_8(\text{University})_{ijt} + \beta_9(\text{Neither})_{ijt} + u_{ij} + \varepsilon_{ijt} \quad (2)$$

$$U_{ijt}(\text{Apple}) = \beta_p Price_{ijt} + \beta_1(\text{High antioxidants \& vitamin C})_{ijt} + \beta_2(\text{Resistance to browning})_{ijt} + \beta_3(\text{Conventional breeding})_{ijt} + \beta_4(\text{GM})_{ijt} + \beta_5(\text{Genome-editing})_{ijt} + \beta_6(\text{Domestic-start up})_{ijt} + \beta_7(\text{A multinational firm})_{ijt} + \beta_8(\text{University})_{ijt} + \beta_9(\text{Neither})_{ijt} + u_{ij} + \varepsilon_{ijt} \quad (3)$$

where βs, u_{ij}, and ε_{ijt} are explained before, price variable represents the price of the given product, and other attributes are dummy variables that take the value of one if the product was labeled with that specific attribute, and zero otherwise. In equations 2 and 3, all the attributes except price are considered as random variables.

Consumer WTP was calculated by dividing the j[th] attribute level parameter, β_j, by the negative of the price coefficient, βp, such that

$$WTP = \beta_j / -\beta p, \text{ where } j \text{ is 1 to 8.} \tag{4}$$

The disutility in terms of dollars of walking away from the purchase of a soybean oil or apple (Neither) is calculated as:

$$WTP = \beta_9 / -\beta p \tag{5}$$

The 95% confidence intervals of the WTP estimates are calculated using Krinsky and Robb method of parametric bootstrapping to determine the statistical significance of WTP estimates (Krinsky and Robb 1986).

Results

Utility coefficients for soybean oil attributes

Table 5 reports the RPL results for the control and information treatments for soybean oil. The statistically significant standard deviation estimates of most of the attributes in the models imply the presence of heterogeneity in consumers' preferences and justify the use of RPL model. As expected, the price has a significant and negative impact on consumers' utility. Genome-editing attribute has a positive and statistically significant influence on consumers' utility in T2 while GM attribute does not have a statistically significant influence on consumers' utility in any treatments. Unlike GM and genome-editing, the conventional breeding attribute has a positive and statistically significant influence on consumers' utility across all treatments. Among the other attributes, consumers' utility was positively impacted by the following attributes in control and information treatments; reduced use of pesticide, developed by domestic-startup companies, and developed by the university. While consumers' utility in control and T1 treatments were positively influenced by multinational firm attribute, no such statistically significant effect was present in T2.

Table 5. Random parameters logit estimates of soybean oil

Variables	**Control (n=527)**	**Treatment 1 (n=523)**	**Treatment 2 (n=523)**
Price	-0.34*** (0.03)	-0.33*** (0.03)	-0.22*** (0.03)
Conventional	0.37*** (0.14)	0.57*** (0.15)	0.50*** (0.13)
Genetically Modified	0.02 (0.16)	-0.02 (0.16)	0.22 (0.15)
Genome-editing	0.04 (0.14)	0.23 (0.15)	0.44*** (0.14)
High oleic Acid	-0.20 (0.11)	-0.01 (0.11)	0.17 (0.11)
Reduced pesticide use	0.69*** (0.11)	0.57*** (0.11)	0.27** (0.11)
Domestic start up	0.53*** (0.09)	0.50*** (0.09)	0.28*** (0.09)
A Multinational firm	0.33*** (0.10)	0.35*** (0.11)	0.12 (0.09)
University	0.47*** (0.10)	0.47*** (0.10)	0.27*** (0.09)
Neither	-1.68*** (0.20)	-1.82*** (0.22)	-1.92*** (0.22)
Std. dev. of random parameters			
Conventional breeding	1.07*** (0.17)	1.48*** (0.26)	0.59** (0.26)
Genetically modified (GM)	0.78*** (0.22)	0.63** (0.25)	0.47 (0.28)
Genome-editing	0.77*** (0.22)	0.91*** (0.19)	0.41 (0.22)
High oleic acid	0.63*** (0.15)	0.82*** (0.17)	0.92*** (0.12)
Reduced pesticide use	0.84*** (0.16)	0.73*** (0.19)	0.75*** (0.13)
Domestic start up	0.21 (0.18)	0.15 (0.19)	0.53*** (0.15)
A Multinational firm	0.59** (0.24)	0.30 (0.20)	0.40 (0.28)
University	0.76*** (0.15)	0.61*** (0.15)	0.34 (0.18)
Neither	2.52*** (0.16)	2.96*** (0.20)	2.91*** (0.20)
Observations	9486	9414	9414
Log-likelihood	-2853.16	-2742.61	-2811.04

*** and ** indicate statistical significance at 1% and 5%, respectively

Figures in parentheses represent standard error.

Utility coefficients for apple attributes

The results of the RPL model of apple are reported in Table 6. Like soybean oil, the price has a significant and negative impact on consumers' utility. Unlike soybean oil for which the genome-editing attribute has a positive and statistically significant influence on consumers' utility in T2, no such effects are present for genome-editing in apple across any treatments. However, GM attribute has a negative and statistically significant effect on consumers' utility in the control treatment. Similar to soybean oil, the conventional breeding attribute has a positive and statistically significant influence on consumers' utility across all treatments. Among the other attributes, consumers' utility was positively impacted by the following attributes in control and information treatments: developed by domestic-startup companies, developed by the multinational firm, and developed by the university. Health benefit attribute (high vitamin C & antioxidants) has a positive and statistically significant effect in control and T2, while no such effect is present in T1. The environmental benefit attribute (resistance to browning) has a positive and statistically significant influence on consumers' utility in control and T1 treatments while no such effect was present in T2.

Table 6. Random parameters logit estimates of apple

Parameters	**Control (n=527)**	**Treatment 1 (n=523)**	**Treatment 2 (n=523)**
Price	-0.72*** (0.06)	-0.74*** (0.06)	-0.59*** (0.05)
Conventional	0.85*** (0.13)	0.84*** (0.13)	0.71*** (0.12)
Genetically modified (GM)	-0.37*** (0.14)	0.01 (0.16)	-0.02 (0.15)
Genome-editing	-0.17 (0.13)	0.06 (0.13)	0.10 (0.13)
High vitamin C & antioxidants	0.26** (0.12)	0.15 (0.13)	0.27** (0.11)
Resistant to browning	0.51*** (0.13)	0.26** (0.13)	0.06 (0.12)

Domestic start up	0.50*** (0.10)	0.40*** (0.10)	0.43*** (0.10)
A Multinational firm	0.20 (0.10)	0.18 (0.10)	0.24** (0.10)
University	0.32*** (0.10)	0.37*** (0.10)	0.52*** (0.10)
Neither	-2.03*** (0.20)	-2.43*** (0.21)	-2.55*** (0.23)
Std. dev. of random parameters			
Conventional	0.63*** (0.24)	0.82*** (0.20)	0.74*** (0.23)
Genetically modified (GM)	0.63*** (0.23)	1.13*** (0.23)	1.14*** (0.19)
Genome-editing	0.72*** (0.22)	0.93*** (0.19)	0.91*** (0.18)
High vitamin C & antioxidants	0.89*** (0.15)	0.94*** (0.14)	0.53*** (0.21)
Resistant to browning	1.69*** (0.14)	1.64*** (0.14)	1.45*** (0.14)
Domestic start up	0.26 (0.21)	0.16 (0.38)	0.32 (0.17)
A Multinational firm	0.84*** (0.16)	0.32 (0.27)	0.43*** (0.16)
University	0.15 (0.24)	0.26 (0.22)	0.58*** (0.13)
Neither	2.04*** (0.16)	2.21*** (0.16)	2.71*** (0.21)
Observations	9486	9414	9414
Log-likelihood	-2793.76	-2716.40	-2737.24

Note: ***, and ** represent significance at 1% and 5% levels.

Figures in parentheses represent standard error.

Willingness to pay for soybean oil attributes

Table 7 reports the willingness to pay estimates of soybean oil computed using RPL coefficients shown in Table 5. Regarding the use of agricultural technologies in soybean oil production, consumers in control treatment are willing to pay $1.10/48 fl. oz ($p<0.01$) more for the soybean oil labeled as produced with conventional breeding compared to no information option. Although the WTP estimate for genome-editing technology is higher than that for GM technology, both are not statistically significant in the control treatment. The confidence intervals for the WTP estimate of conventional breeding do not overlap with those of GM and genome-editing technologies in the control treatment. For the developers of the technology, consumers in the control treatment are willing to pay $1.58/48 fl. oz (p<0.01), $0.97/48 fl. oz (p<0.01), and $1.40/48 fl. oz (p<0.01) more for domestic start-up label, multinational firm label, and university label, respectively compared to the no information option. Confidence intervals of WTP estimates for three technology developers overlap. On average, consumers in the control treatment are willing to pay $2.06/48 fl. oz (p<0.01) more for reduced pesticide use attribute compared to no-reduction in pesticide use attribute.

Table 7. Willingness to pay estimates of soybean oil with 95% confidence interval

Variables	**Control (n=527)**	**Treatment 1 (n=523)**	**Treatment 2 (n=523)**
Conventional breeding	$1.10*** [0.30, 1.88]	$1.73*** [0.86, 2.60]	$2.31*** [1.22, 3.46]
Genetically modified (GM)	$0.05 [-0.82, 1.01]	$-0.07 [-0.96, 0.93]	$1.03 [-0.28, 2.71]
Genome-editing	$0.13 [-0.69, 1.04]	$0.71 [-1.19, 1.75]	$2.02*** [0.72, 3.82]
High oleic Acid	$-0.60 [-1.34, 0.05]	$-0.03 [-0.75, 0.62]	$0.78 [-0.24, 1.76]
Reduced pesticide use	$2.06*** [1.44, 2.75]	$1.75*** [1.14, 2.43]	$1.24** [0.29, 2.23]
Domestic start up	$1.58*** [1.05, 2.20]	$1.54*** [0.97, 2.19]	$1.31*** [0.52, 2.22]
A Multinational firm	$0.97*** [0.36, 1.68]	$1.07*** [0.42, 1.82]	$0.56 [-0.28, 1.58]
University	$1.40*** [0.83, 2.00]	$1.45*** [0.86, 2.09]	$1.23*** [0.44, 2.06]
Neither	$-4.97*** [-6.16, -3.92]	$-5.57*** [-7.00, -4.34]	$-8.86*** [-11.85, -6.74]

***, and ** indicate statistical significance at 1%, and 5%, respectively.

Figures in parentheses represent Krinsky and Robb 95% confidence intervals of willingness to pay.

Although the sign and significance of WTP estimates of soybean oil attributes in T1 treatment are similar to the control treatment, there are some differences in the value of WTP estimates. Consumers in T1 treatment are willing to pay $1.73/48 fl. oz (p<0.01) more for the soybean oil labeled as produced with conventional breeding compared to no information option. Similar to control treatment, WTP estimate genome-editing technology is higher than that for GM technology, and both are not statistically significant in T1 treatment. Unlike the control treatment, confidence intervals of WTP estimates for conventional breeding, GM, and genome-editing technology overlap. For the developers of the technology, consumers in T1 treatment are willing to pay \$1.54/48 fl. oz ($p<0.01$), \$1.07/48 fl. oz ($p<0.01$), and \$1.45/48 fl. oz ($p<0.01$) more for domestic start-up label, multinational firm label, and university label, respectively compared to the no information option. Similar to control treatment, confidence intervals of WTP estimates for technology developers overlap in T1 treatment. On average, consumers in T1 treatment are willing to pay \$1.75/48 fl. oz ($p<0.01$) more for reduced pesticide use attribute compared to no-reduction in pesticide use attribute.

Unlike control and T1 treatments, genome-editing attribute in T2 treatment has a positive and statistically significant coefficient. Consumers in T2 treatment are willing to pay \$2.02/48 fl. oz ($p<0.01$) more for the genome-editing attribute compared to the no information option. Consumers in T2 treatment are willing to pay \$2.31/48 fl. oz ($p<0.01$) more for the soybean oil labeled as produced with conventional breeding compared to no information option. Similar to T1, confidence intervals of WTP estimates for conventional breeding, GM, and genome-editing technologies overlap in T2. Another key difference in T2 is the statistical non-significance of the WTP estimate of the multinational firm label. For the developers of the technology, consumers in T2 treatment are willing to pay \$1.31/48 fl. oz ($p<0.01$), and \$1.23/48 fl. oz ($p<0.01$ more for domestic start-up label, and university label, respectively compared to the no information option.

Similar to control and T1 treatments, confidence intervals of technology developers overlap in T2. On average, consumers in T2 treatment are willing to pay $1.24/48 fl. oz ($p<0.05$) more for reduced pesticide use attribute compared to no-reduction in pesticide use attribute.

Willingness to pay for apple attributes

Table 8 reports the willingness to pay estimates for apple computed using RPL coefficients shown in Table 6. Regarding the use of agricultural technologies in apple production, consumers in control treatment are willing to pay $1.18/lb ($p<0.01$) more for apples labeled as produced with conventional breeding compared to no information option. However, consumers in the control treatment are willing to pay $0.52/lb ($p<0.01$) less for an apple labeled as GM. As per Table 8, WTP estimates for genome-editing technology in control treatment is not statistically significant. The confidence intervals for WTP estimates of the conventional breeding attribute does not overlap with those of GM and genome-editing technologies. For the developers of the technology, consumers in control treatment are willing to pay $0.69/lb ($p<0.01$), and $0.44/lb ($p<0.01$) more for domestic start-up label and university label, respectively compared to the no information option. On average, consumers in control treatment are willing to pay $0.36/lb ($p<0.05$) more for health attribute (high vitamin C and antioxidants) and $0.71/lb ($p<0.01$) more for environmental benefit attribute (resistant to browning). Similar to the control treatment for soybean oil, confidence intervals of WTP estimates for three technology developers overlap.

Table 8. Willingness to pay estimates of apple with 95% confidence interval

Variables	**Control (n=527)**	**Treatment 1 (n=523)**	**Treatment 2 (n=523)**
Conventional	$1.18*** [0.83, 1.58]	$1.13*** [0.78, 1.51]	$1.21*** [0.79, 1.67]
Genetically modified (GM)	$-0.52*** [-0.88, -0.14]	$0.01 [-0.39, 0.44]	$-0.03 [-0.50, 0.48]
Genome-editing	$-0.24 [-0.57, 0.12]	$0.08 [-0.27, 0.45]	$0.16 [-0.26, 0.64]
High vitamin C & antioxidants	$0.36** [0.04, 0.69]	$0.20 [-0.13, 0.53]	$0.46** [0.09, 0.84]
Resistant to browning	$0.71*** [0.35, 1.09]	$0.36** [0.01, 0.72]	$0.11 [-0.30, 0.52]
Domestic start up	$0.69*** [0.42, 0.99]	$0.54*** [0.28, 0.83]	$0.73*** [0.41, 1.09]
A Multinational firm	$0.28 [-0.01, 0.58]	$0.24 [-0.02, 0.52]	$0.40** [0.08, 0.75]
University	$0.44*** [0.18, 0.69]	$0.50*** [0.24, 0.76]	$0.88*** [0.56, 1.21]
Neither	$-2.82*** [-3.39, -2.32]	$-3.28*** [-3.89, -2.75]	$-4.33*** [-5.30, -3.54]

***, **, * indicate statistical significance at 1%, 5%, and 10% respectively

Figures in parentheses represents Krinsky and Robb 95% confidence intervals of willingness to pay

Consumers in T1 treatment are willing to pay $1.13/lb ($p<0.01$) more for apple labeled as produced with conventional breeding compared to no information option. However, the provision of information changes WTP estimates of some attributes in T1. For example, the WTP estimate for GM attribute turns positive and becomes statistically non-significant in T1 treatment. Although statistically non-significant, the WTP estimate for genome-editing technology increases by 133% in T1. Similar to control treatment, confidence intervals of WTP estimates do not overlap for conventional breeding, GM, and genome-edited technologies. Consumers in T1 treatment are willing to pay $0.54/lb ($p<0.01$), and $0.50/lb ($p<0.01$) more for domestic start-up label and university label, respectively compared to the no information option and their confidence intervals overlap. The WTP estimates for health attributes become non-significant in T1 treatment. On average, consumers in T1 treatment are willing to pay 0.36/lb ($p<0.05$) more for the resistant to browning attribute.

Consumers in T2 treatment are willing to pay $1.21/lb ($p<0.01$) more for apple labeled as produced with conventional breeding compared to no information option. Although statistically non-significant, the WTP estimate for genome-editing technology increases by 100% (from 0.08 to 0.16) in T2, while the WTP estimate decreases for GM technology. While the confidence intervals of GM and genome-editing technologies overlap, the confidence interval of conventional breeding technology does not overlap with the former two. For the developers of the technology, consumers in T2 treatment are willing to pay $0.73/lb ($p<0.01$), $0.40/lb ($p<0.05$), and $0.88/lb ($p<0.01$) more for domestic start-up label, a multinational firm, and university label, respectively compared to the no information option. On average, consumers in T2 treatment are willing to pay $0.46 ($p<0.05$) more for health attribute (high vitamin C and antioxidants).

Discussion

Because of the difference in focus, products and attributes, a direct comparison of our results with previous studies is not possible. However, results from this study are comparable to previous studies that reported that consumers' WTP for genome-edited and GM foods are lower than that of conventionally bred agricultural products (Marette, Disdier, and Beghin 2020, Muringai, Fan, and Goddard 2020, Caputo, Lusk, and Kilders 2020, Shew et al. 2018). Unlike previous studies that found statistically significant price discounts for genome-edited and GM foods, we find statistically significant price discount (WTP) only for GM apple in the control treatment. Although WTP estimates for GM and genome-edited foods are not statistically significant, findings from this study show that consumers' WTP is the highest for a conventionally bred food product, followed by genome-edited food, and then GM food. However, overlapping of confidence intervals of WTP estimates of genome-edited and GM foods suggest that WTP estimates of these two technologies are not statistically significantly different from each other.

Similar to previous studies, we also find that consumers' WTP for GM and genome-edited technologies vary based on food types and processing levels (Caputo, Lusk, and Kilders 2020). Although not statistically significant, findings from the study show that without the provision of any information, consumers' WTP for GM and genome-edited soybean oil are higher than that of apple. This relatively higher WTP for soybean oil suggests that consumers' acceptance of GM and genome-editing technologies in processed foods is higher than that of fresh produce like an apple.

The increase in WTP estimates of genome-edited foods in information treatments T1 and T2 relative to the control treatment suggest that provision of information condition consumer preferences (Marette, Disdier, and Beghin 2020, Caputo, Lusk, and Kilders 2020, Shew et al. 2018). Although the provision of technology details increases WTP estimates for genome-edited apple and soybean oil, the increase in WTP is higher when technology information is combined with more specific information on the benefits of the technologies. As per our study, the effect of information that combines objective details on technology with health and environmental benefits have the most effect on WTP for genome-edited soybean oil (T2). The relatively less effect of information (T1 and T2 treatments) on GM apple and soybean oil may be because consumers' have already made up their preferences towards GM technology and foods which are available since the mid-1990s. Compared to GM foods, genome-edited foods are new. Results from the study imply that science-based communication and public engagement from the private and public sectors can influence consumers' attitudes, perceptions, and behavior towards genome-edited foods.

Ishii and Araki (2016) argued that the development of crop cultivars with traits that meet consumer demands are more likely to be accepted by consumers. Caputo et al. (2020) showed that specific information on the health and environmental benefits of genome-edited foods increases consumers' WTP and acceptance of genome-edited foods. Results from our study show mixed evidence on the effect of consumer health benefit and environmental benefit attributes on consumers' WTP for genome-edited foods. Reduced pesticide use attribute (environmental benefit) has a positive and statistically significant effect on WTP for genome-edited soybean oil across all treatments, while resistant to browning attribute (environmental benefit) for genome-edited apple has a positive and statistically significant coefficient in control and T1 treatments. The overlapping of confidence intervals of WTP estimates between treatments suggests that WTP estimates are not statistically different across treatments that differ based on the type and extent of information provided. Compared to the environmental attribute, WTP estimates for health-related attributes with direct consumer benefits such as high oleic acid in soybean oil and high vitamin C and antioxidants in apple are valued less by consumers in our study sample. This is an aspect that needs to be investigated in future research and will have implications for labeling.

Similar to previous studies (Muringai, Fan, and Goddard 2020, Ishii and Araki 2016, Lusk, McFadden, and Wilson 2018), findings from our study show that consumers trust domestic start-up firms and universities more than multinational firms as developers of GM and genome-editing technologies. Most of the commercially available GM technologies are developed by multi-national firms that exert significant market power in agricultural biotechnology and seed industries (Kolady and Srivastava 2018). Relative to GM technology, genome-editing is cheap and faster and that facilitates R&D investments from start-up firms and universities at a higher rate than for GM technologies (Martin-Laffon, Kuntz, and Ricroch 2019). Results from our study imply that leveraging consumer trust in start-up firms and universities by encouraging their active public engagement has the potential to condition consumer preferences towards genome-edited technologies and foods.

Conclusions

In this study, we use a nationally representative survey of U.S. consumers to estimate consumers' WTP for genome-edited foods relative to foods produced from crops using GM technology and conventional breeding. The study shows that consumers' WTP for GM and genome-edited foods are similar and lower than the WTP for a conventionally bred food product. As per the study, consumers' WTP for genome-edited foods differ based on food types and processing levels, with higher consumer valuation for genome-edited processed foods (e.g., soybean oil) than fresh produce (apple). The study finds that the provision of information that combines technology-related information with specific health and environmental benefits have a statistically significant effect on consumers' WTP genome-edited foods than providing only general technology-related information. While no such statistically significant effect of information is evident for GM foods. The study's findings show that consumers exhibit preference order towards developers of the technology with the greatest trust in domestic start-ups followed by university. The consumers have the least preference for multinational firms as a technology developer.

The commercial success of the application of genome-editing in the agricultural sector will depend on consumers' acceptance of genome-edited foods. Findings from the study show that although consumers' valuation of GM and genome-edited foods are similar, science-based communication and public engagement that communicate various health, environmental, and economic benefits of genome-edited foods have the potential to condition consumer preferences towards genome-edited foods. Consumer trusted sources such as domestic start-up firms and universities may want to lead such public engagement effort to avoid the fate of GM foods.

CHAPTER III

DETERMINANTS OF CONSUMER ACCEPTANCE OF GENETICALLY MODIFIED AND GENOME-EDITED FOODS: MARKET AND POLICY IMPLICATIONS[2]

[2] This paper is selected for presentation at the 2021 Agricultural & Applied Economics Association and Western Agricultural Economics Association Joint Annual Meeting, Austin, TX, August 1-3.

Abstract

Genome-editing is a breakthrough technology for crop improvement, but its commercial success depends on public acceptance of its foods. Using data from a national survey, we classified respondents into three clusters. Uncertainty-loving individuals were more aware and knowledgeable of genetically modified (GM) and genome-edited foods and more likely to consume both foods in the future than neutral and uncertainty-averse individuals. Past GM food consumption determinants differ from those of future GM and genome-edited food consumption. Information provision left genome-edited food acceptance unchanged but had unintended consequences for GM foods. Consumers trust domestic start-ups more than multinational firms as technology developers.

Introduction

Since their introduction in the 1990s, genetically modified (GM) foods have generated strong debates over the costs and benefits of GM technology for various stakeholders including farmers, consumers, technology developers, and seed companies (Anderson 2010, Graff, Hochman, and Zilberman 2009, Kolady and Herring 2014, NAS 2016). GM technology – which includes the transfer of genes between (transgenic) and/or within (cisgenic) species – raises human and environmental health concerns. This leads more and more countries to strengthen their regulations of GM foods, which increases regulatory costs and results in regulatory divergence between countries and may cause trade disruptions (Rousu et al. 2004, Runge, Bagnara, and Jackson 2001, Blancke, Grunewald, and De Jaeger 2017, Delwaide et al. 2015, Shew et al. 2016).

Newly emerging genome-editing technologies – which solely deal with changing genes that already exist within a crop, animal, or bacteria, and closely mimic processes observed in nature – can address health and environmental concerns associated with the transgenic and cisgenic aspects of GM technology. Also, compared to GM technology, genome-editing is faster and cheaper (Cox, Platt, and Zhang 2015, Dance 2015, Doudna and Charpentier 2014, Feng et al. 2013). As a result, more and more start-up firms seek to invest in genome-editing research and development. This has the potential to increase innovation and competition in the agricultural biotechnology sector, with potentially positive implications for technology access and price. However, there are questions about consumer acceptance of genome-edited foods and consumer responses to genome-edited foods relative to GM foods.

Most existing studies on consumer acceptance of GM foods tend to focus on socio-economic determinants such as age, education, ethnicity, gender, income, the presence of children in the household, and consumer concerns about food safety risks (Baker and Burnham 2001, James and Burton 2003, Rousu et al. 2004, Costa-Font, Gil, and Traill 2008, Delwaide et al. 2015). Due to the emergent nature of the technology, the number of studies focusing on consumer acceptance of genome-edited foods is limited, particularly studies considering the role of consumer attitudes, beliefs, and information. Science education programs, science-based communication and outreach efforts, and differentiating foods based on beneficial characteristics of technology via labelling all can influence consumers' attitudes, beliefs, and ultimately purchasing and consumption behavior (Baker and Burnham 2001, Hingston and Noseworthy 2018). In this study we seek to extend the current understanding of the impact of consumer beliefs and attitudes on the acceptance of GM and genome-edited foods and examine the effect of information regarding technologies on consumer acceptance of such foods.

The specific objectives of this study are to: (i) segment consumers based on attitudinal preferences and examine segment-specific consumer characteristics and consumption behavior toward GM and genome-edited foods; (ii) investigate the effect of information about the technology and its benefits on consumers' acceptance of GM and genome-edited foods, and (iii) compare the determinants of consumer acceptance of GM and genome-edited foods.

This study used a national representative survey of U.S. consumers to collect the necessary data for the analysis and used soybean oil and apple as focus products. We developed attitudinal indices on food technology neophobia, the new ecology paradigm, and the corporate distrust scales to assess the effects of attitudes on consumer acceptance of GM and genome-edited foods. We employed cluster analysis and multivariate probit models to address study objectives. Consumers were categorized into three clusters based on their attitudes: Cluster 1 (comprising of individuals willing to try new food technologies and who have trust in food industry uncertainty-loving); Cluster 2 (neutral group), and Cluster 3 (not willing to try new food technologies and who have less trust in the food industry – uncertainty-averse). Findings show that uncertainty-loving consumers are more likely to consume GM and genome-edited foods than uncertainty-averse consumers. Further, determinants of past consumption of GM foods differ from those of future consumption of GM and genome-edited foods. Consumers who indicated being likely to consume GM foods in the future are also more likely to consume genome-edited foods in the future, even with the provision of information describing similarities among and differences between the technologies and their benefits. Although largely similar, there are some differences in the determinants of genome-edited foods based between food types. Further, consumers have more trust in domestic start-up firms as technology developers than when this role is played by multinational firms.

Our work contributes to the existing literature on consumer acceptance of GM and genome-edited foods. To a large extent, consumer acceptance of genome-editing technology may depend on whether consumers perceive genome-editing as an improvement over GM technology in terms of the former's health and environmental impacts. A comprehensive understanding of drivers of consumer acceptance of genome-edited foods is necessary for the private and public sector to develop valuable communication and outreach efforts and for the effective integration of the technology in the global marketplace. Findings from this study provide insights on role of knowledge, attitudes, and beliefs about consumer acceptance of GM and genome-edited foods. These findings will be of help in designing reasonable regulations that reflect consumer perceptions, in formulating informative and appropriate labels for genome-edited foods that enhance consumer trust in food production methods, and in developing science-based communication efforts that are essential for avoiding a repeat of the consumer backlash faced by GM crops and foods.

Literature Review

Determinants of consumer acceptance of GM foods

Socio-economic factors such as age, education, ethnicity, gender, income, and the presence of children in the household are shown to influence consumer acceptance of GM foods (Baker and Burnham 2001, Han and Harrison 2007). An attitude is an individual's disposition to respond favorably or unfavorably to an object, person, institution, or any other discriminable aspect of the individual's world (Ajzen 1989). Given that attitudinal processes are related to socio-economic and demographic attributes such as age, ethnicity, residence and income level, attitude is also an important predictor of GM food acceptance. In particular, consumer attitudes toward a product do not depend on a single judgment but may involve multiple beliefs (Costa-Font, Gil, and Traill 2008). Likewise, consumer attitudes regarding GM foods may not just be determined by knowledge, but also by beliefs. There is a limited number of studies that show that consumer attitudes toward a food product depend on the overall perceived risks and benefits associated with the product itself and process in which it was produced (Baker and Burnham 2001, Lusk et al. 2005, Costa-Font, Gil, and Traill 2008).

Some studies classify consumers into groups according whether they are optimistic or pessimistic about, whether they are undecided or against, or have complex reservations about GM foods (Costa-Font, Gil, and Traill 2008). Classifying individuals according to their attitudes towards GM foods is useful for conducting market segment analyses and provides insights for developing marketing and outreach programs associated with technology innovations. Available evidence suggests that cross-country differences exist in relation to consumers' risks and benefits perceptions related to GM food. Risk averse people are less likely to accept GM foods, implying strong regulations are important to increase consumer confidence (Baker and Burnham 2001, Lusk et al.

2005). In general, European consumers tend to have more negative attitudes towards GM foods than do U.S. consumers (Runge, Bagnara, and Jackson 2001, Sprink et al. 2016, Wunderlich and Gatto 2015, Delwaide et al. 2015).

Some studies show that consumers are favorably disposed to GM foods that have tangible benefits, including GM foods that have improved nutritional contents, have environmental benefits, or improve food security in developing countries (Lusk, McFadden, and Rickard 2015, Delwaide et al. 2015, Rousu and Lusk 2009, Blancke, Grunewald, and De Jaeger 2017, Hingston and Noseworthy 2018). Other studies show that the provision of positive information about the technology and consumer perceptions about their potential benefits increase consumer acceptance and willingness to pay (WTP) for GM foods (Huffman et al. 2003, McFadden and Lusk 2017, Wunderlich and Gatto 2015).

Consumers tend to draw distinctions between breeding techniques, and they are primarily interested in the outcomes from breeding rather than the techniques themselves (Lusk, McFadden, and Wilson 2018, Shew et al. 2017). Further, consumers prefer cisgenic over transgenic GM foods and are willing to pay more for the former than the latter (Shew et al. 2016, Colson and Huffman 2011). Lusk et al. (2018) showed that support for or opposition to GM food depends on consumers' perceptions of who created the technology. Consumer organizations, environmental groups, and scientists are generally perceived to be more trustworthy than the biotech industry and government (Costa-Font, Gil, and Traill 2008, Hunt and Wald. 2018).

Determinants of consumer acceptance of genome-edited foods

Because genome-editing is a relatively new technology, the number of empirical studies on consumer acceptance of genome-edited foods is limited. Available evidence suggests that similar to GM foods, cross-country differences exist in relation to consumer acceptance and willingness to pay for genome-edited foods. Shew et al. (2018) showed that consumer acceptance rates in European countries such as Belgium and France are lower than in the United States and Canada. There are studies that showed that consumers prefer GM foods over genome-edited foods (Muringai, Fan, and Goddard 2020, Caputo, Lusk, and Kilders 2020, Marette, Disdier, and Beghin 2020). There are also studies that found that consumers perceive genome-editing to be similar to genetic modification and may exert similar discounts on GM and genome-edited foods (McFadden et al. 2021, Shew et al. 2018).

Except for Caputo et al. (2020), the limited number of studies available on consumer acceptance of genome-edited foods focus on a single product and do not take into consideration how consumer acceptance varies between products. Additionally, studies focusing on the role of attitudes, beliefs, and perceptions about consumer acceptance of genome-edited foods, and whether determinants of consumer acceptance vary between GM and genome-edited foods are lacking.

Methods

Design of the study

The study received Institutional Review Board approval from omitted for review University. The study used an online opt-in internet panel maintained by Qualtrics to select a nationally representative sample of U.S. consumers. The target population was U.S. consumers aged 18 years or older, who are the primary grocery shoppers and contribute at least 50% of the total household purchases (please refer to Chapter II Methods for details).

The survey instrument had several sections with questions related to purchasing behavior and consumption; perceptions of the ecological paradigm, food technology neophobia, and corporate distrust; awareness, knowledge, beliefs, and attribute preference towards GM and genome-edited foods; willingness to consume genome-edited foods, and socio-demographic information. Questions regarding the attitudinal scale, as well as about awareness and knowledge about GM and genome-edited foods were asked prior to the information treatments. However, questions about consumer beliefs concerning safety, benefits, labelling, and future willingness to consume GM and genome-edited foods were asked after the provision of information treatments. This approach was followed to capture the effects, if any, of the prior perceptions and knowledge vs. perceptions and beliefs post information treatments.

Attitudinal indices

Consumer concerns about GM technology and foods include those involving food safety, human and environmental health, corporate monopoly, and corporate distrust aspects (Thompson 2000, Wunderlich and Gatto 2015, Costa-Font, Gil, and Traill 2008, Frewer, Scholderer, and Bredahl 2003, Lusk, McFadden, and Wilson 2018). Attitudes influence consumer behavior, so gaining an improved understanding of consumer attitudes toward a mix of factors – including those relating to new or controversial food technologies, to environmental or ecological aspects, and to corporate distrust – and how these attitudes are related to consumer acceptance of GM and genome-edited foods will provide insights on the effective development of market outreach, communication, education efforts, and regulations that influence consumer behavior. A brief description of attitudinal indices used in the study is given below.

Abbreviated Food Technology Neophobia Scale

The Abbreviated Food Technology Neophobia Scale (AFTNS) is an abbreviated form of the Food Technology Neophobia Scale (FTNS), which predicts willingness to consume food produced by novel and controversial food technologies (Schnettler et al. 2017). Unlike FTNS, which has 13 components grouped into four factors (Cox and Evans 2008), AFTNS has nine factors grouped into one factor. Allocations along the AFTNS scale capture consumers' views on whether they consider new food technologies as unnecessary or not as well as their risk perceptions toward new food technologies. The components included in the AFTNS scale are shown in Appendix 4. Survey respondents were asked to indicate their level of agreement with the statement using a 7-points Likert scale where 1=strongly disagree, 2=disagree, 3=somewhat disagree, 4=neutral, 5=somewhat agree, 6=agree, and 7=strongly agree. High AFNS values are associated with high levels of food technology neophobia and vice versa.

Corporate distrust scale

Consumers' trust in innovators of food technology is an important factor in their acceptance of GM foods. Generally, consumer distrust levels toward corporations exceed those regarding university and non-governmental organizations (Costa-Font, Gil, and Traill 2008, Lusk, McFadden, and Rickard 2015, Lusk, McFadden, and Wilson 2018). Most currently available GM technologies were developed by large corporations, whereas small start-up firms and universities tend to play a disproportionately large role in the development of genome-editing technologies (Doudna and Charpentier 2014, Calyxt 2019, Dance 2015, Zhang et al. 2016). Because consumer acceptance of GM and genome-edited foods may vary based on their attitudes toward corporate distrust, it is imperative to assess consumers' general attitudes toward corporations.

Allocations along a corporate distrust scale captures people's attitudes toward corporations as institutions in general. (Adams, Highhouse, and Zickar 2010) showed that corporate distrust is negatively correlated with having interpersonal trust, positive attitudes toward human nature, and a belief in a just world. The 13 statements used in constructing the corporate distrust scale are presented in Appendix 5. Each survey respondent was asked to choose the answer that best describes their agreement or disagreement with each statement using a 5-point Likert scale where 1=strongly disagree, 2=disagree, 3=neither agree or disagree, 4=agree, and 5=strongly agree. High values along the corporate distrust scale are associated with high levels of corporate distrust.

New Ecology Paradigm

Allocations along the New Ecological Paradigm (NEP) scale reflect individuals' environmental concerns (Dunlap et al. 2000). An NEP score provides an indicator of the degree to which an individual endorses a pro-ecological worldview. Given that many consumers are concerned about the ecological and environmental impacts of technologies such as GM and genome-editing, we use the NEP scale to examine whether consumer attitudes toward and acceptance of GM and genome-edited foods can be explained by their underlying values toward the environment. The scale is constructed from individual responses to 15 statements that measure agreement or disagreement on a 5-point Likert scale where 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree (Appendix 6). High values along the NEP scale reflect high levels of endorsement of a pro-ecological worldview.

Cluster analysis

Cluster analysis facilitates the development of groups of consumers with similar needs and wants. Socio-economic (age, education, income, etc.) and psychographic (lifestyle, interests, opinion, beliefs, etc.) variables are often used to develop consumer segments with similar preferences (Baker and Burnham 2001). We performed hierarchical clustering using Ward's linkage method for cluster analysis. We used cluster analysis to identify groups of respondents with similar attitudinal preferences and then examined their socio-demographic characteristics, awareness, knowledge, and beliefs towards GM and genome-edited foods in each cluster. This segmentation enables gaining an improved understanding about the relationship between attitudinal preferences and consumer acceptance of GM and genome-edited foods. Additionally, this facilitates the development of marketing, educational, and communication plans to influence consumer behavior.

Multivariate Probit model

In this study, we are also interested in examining differences between and similarities among the determinants of the current consumption of GM foods and the future consumption of GM and genome-edited foods. Utility theory suggests that a consumer is willing to consume a food developed with the use of a new technology if their net utility from consuming the food exceeds their utility associated with the status-quo. However, a consumer's willingness to consume genome-edited foods in the future may be related to their current and future decision to consume GM foods. To model these decisions, we focus on three binary consumption decisions involving food technology, such that the respondent: (i) currently consumes GM foods (yes = 1; zero otherwise), (ii) indicates willingness to consume GM foods in the future (yes = 1; zero otherwise), and (iii) indicates willingness to consume genome-edited foods in the future (yes = 1; zero otherwise).

The M-equation multivariate probit model where M=3 is given below:

$$Y^*_{im=}\beta'_m X_{im} + \in_{im,} \quad m = 1, \ldots, M \tag{6}$$

$$Y_{im=} \text{ 1 if } Y^*_{im} > 0 \tag{7}$$

Where Y^*_{im} is the latent variable representing each of the three consumption decisions, X_{im} are the explanatory variable influencing consumption decisions (which can be different between decisions), $\in_{im}$, $m = 1, 2, and$ 3 are error terms distributed as multivariate normal, each with a mean of zero, and variance-covariance matrix V, where V has values of 1 on the leading diagonal and correlations $\rho_{jk} = \rho_{kj}$ as off-diagonal elements. Because we only observe the binary outcome Y_{im}(whether the respondent currently consumes GM or willingness to consume GM and/or genome-edited foods in the future), we estimate the following equation:

$$Y_{im} = \beta_m' X_{im} + \epsilon_{im,} \quad m = 1, \dots, M \qquad (8)$$

The log-likelihood function for a sample of N independent observations when M=3, is given by

$$L = \sum_{i=1}^{N} W_i log\emptyset_3 \, (\mu_i; \Omega) \qquad (9)$$

where W_i is an optional weight for observations and $\emptyset_3$ is the trivariate standard normal distribution with arguments μ_i and Ω (Cappellari and Jenkins 2003). Equation (9) is estimated using the Geweke-Hajivassiliou-Keane (GHK) smooth recursive conditioning simulator, such that the tri-variate normal distribution function is expressed as the product of sequentially conditioned univariate normal distribution functions.

Results

Awareness and knowledge towards GM and genome-edited foods

Table 9 shows that 89% of survey respondents indicated having heard of GM foods, of whom about one-half (43%) noted having heard of genome-edited foods. Compared to the high level of general awareness about GM technologies, only 70% indicated being knowledge (with 20% who noted being very knowledgeable and 50% who stated being somewhat knowledgeable) about GM foods. An even smaller share of respondents (45%) indicated being knowledgeable (19% of the respondents considered themselves very knowledgeable and 26% considered themselves somewhat knowledgeable) about genome-edited foods. Regarding consumer perceptions of agricultural biotechnology, 38% of the respondents indicated having positive (19% each for very positive and positive) views, 34% regarded it as neutral, and 28% as negative (18% held somewhat negative and 10% had very negative views about agricultural biotechnology). Columns 3 and 4 in Table 9 show that awareness and knowledge of GM and genome-edited foods and agricultural biotechnology are substantially higher among current consumers of GM foods than non-consumers of GM foods. About 35% of the respondents indicated having neutral views about agricultural biotechnology.

Table 9. Consumer awareness, knowledge and opinion on GM and genome-edited foods

Category	**Total Sample**	**Current GM Consumers** [a]	
	(n=1573)	**Yes (n=747)**	**No (n=826)**
Heard of GM			
Yes	89.32%	99.20%	80.39%
No	10.68%	0.80%	19.61%
Heard of genome-edited			
Yes	42.59%	59.30%	27.48%
No	57.41%	40.70%	72.52%
Knowledgeable about GM			
Knowledgeable	69.80%	87.01%	54.24%
Not at all	30.20%	12.99%	45.76%
Knowledgeable about genome-edited			
Knowledgeable	44.25%	61.45%	28.69%
Not at all	55.75%	38.55%	71.31%
Perception about agricultural biotechnology			
Positive	37.95%	58.77%	19.13%
Neutral	34.39%	25.44%	42.49%
Negative	27.65%	15.80%	38.38%

[a] *Significant difference between current GM and non-GM consumers for all the variables*

Clusters based on attitudinal indices

The attitudinal scale values for the whole sample were 41.8, 49.6, and 50.7 for AFTNS, corporate distrust, and NEP, respectively. The attitudinal scale values for respondents in Cluster 1 were 35.6, 38.1, and 47.6, for AFTNS, corporate distrust, and

NEP, respectively; the corresponding values were 43.1, 55.2, and 54.8 for respondents in Cluster 2, and 54.5, 62.2, and 45.9 for respondents in Cluster 3. Respondents in Clusters 1 and 3 had the lowest and the highest values, respectively, for AFTNS and corporate distrust. Based on these results, respondents in Cluster 1 were characterized as being willing to try new food technologies and having trust in the food industry (uncertainty-loving), Cluster 2 as a neutral group, and Cluster 3 as not willing to try new food technologies and having relatively less trust in the food industry (uncertainty-averse).

Table 10 provides the cluster-wise summary statistics of selected demographics attributes of the survey respondents. In particular, Cluster 3 differs considerably from Cluster 1 with regard to several characteristics. For example, 71% of Cluster 3 respondents are female compared to 42% and 52% in Clusters 1 and 2, respectively. Also, 36% of Cluster 3 respondents are in the 25-34 age group and only 10% are in the 65+ age category, compared to a more even distribution among age categories for Clusters 1 and 2. Regarding ethnicity, Cluster 3 has the largest share identifying as white (78%) and the smallest shares of individuals of Hispanic or Latino descent (10%) and those who are Black or African (9%). Among other ethnicities, individuals of Asian descent account for only 1% in Cluster 3 compared to 6% and 7% in Clusters 1 and 2, respectively.

In addition to having demographic differences, the clusters differ in terms of socio-economic characteristics. For example, Cluster 1 has the largest percentage of college-educated respondents (36%), and Cluster 3 has the smallest percentage (26%). Also, 56% of Cluster 3 respondents have annual income levels of at least $100,000, compared to 14% and 15% of individuals in Clusters 1 and 2, respectively. In addition, 90% of Cluster 3 respondents live in urban areas, whereas only about 70% of Clusters 1 and 2 respondents do so. Finally, 75% of Cluster 3 respondents have children, but only 37% and 35% of Clusters 1 and 2 do so, respectively.

Table 10. Cluster-wise summary statistics of survey respondents' key socio-demographics [b]

Category	**Category**	**Total Sample (n=1573)**	**Cluster 1 (n=608)**	**Cluster 2 (n=740)**	**Cluster 3 (n=225)**
Sex	Female	50.73%	41.94%	51.76%	71.11%
Age	18-24	13.22%	14.80%	12.30%	12.00%
	25-34	16.91%	14.97%	12.84%	35.56%
	35-44	16.34%	16.45%	14.32%	22.67%
	45-54	17.86%	17.43%	19.73%	12.89%
	55-64	16.72%	16.94%	19.46%	7.11%
	65+	18.94%	19.41%	21.35%	9.78%
Ethnicity	White	60.52%	61.68%	54.32%	77.78%
	Hispanic or Latino	18.05%	16.94%	21.35%	10.22%
	Black or African American	12.59%	12.66%	13.65%	8.89%
	Native American/ Alaska Native	0.57%	0.33%	0.68%	0.89%
	Asian	5.59%	6.09%	6.62%	0.89%
	Other	2.67%	2.30%	3.38%	1.33%
Education	College or higher	32.23%	35.69%	31.35%	25.78%
Annual income	< $10,000 to $24,999	22.95%	22.70%	25.54%	15.11%
	$25,000 to $49,999	28.35%	30.76%	30.95%	13.33%
	$50,000 to $74,999	16.72%	19.24%	17.30%	8.00%
	$75,000 to $99,999	11.82%	13.82%	11.49%	7.56%
	$100,000 or more	20.15%	13.49%	14.73%	56.00%
Place of residence	Urban	73.05%	69.57%	70.81%	89.78%
Have children	Yes	41.26%	37.34%	34.46%	74.22%

[b] *Significant difference between clusters for all the variables*

Table 11 shows there are also statistically significant differences between clusters regarding the respondents' awareness and knowledge of GM and genome-edited foods. In particular, 59% of Cluster 3 respondents indicated having heard of genome-edited foods compared to 39% and 40% in Clusters 1 and 2, respectively. Similarly, the respondents' perceived knowledge of GM foods is highest in Cluster 3 – 77% of this cluster's respondents indicated being very or somewhat knowledgeable of GM foods – compared to 67% and 70% in Clusters 1 and 2. Perceived knowledge about genome-edited foods is also highest in Cluster 3, where 66% stated being very or somewhat knowledgeable of genome-edited foods, compared to 42% and 40% for Clusters 1 and 2, respectively. With regards to the individuals' perceptions of agricultural biotechnology, Cluster 3 has the largest percentage of respondents (55%) who indicated having positive views (either very positive or somewhat positive) of agricultural biotechnology, and also the largest percentage of individuals (36%) with negative beliefs (either somewhat negative or very negative) about agricultural biotechnology. Overall, the responses reported in Table 11 show that among the three clusters, Cluster 3 – the uncertainty-averse group – has the greatest share of individuals who indicated being aware of and knowledgeable about GM and genome-edited foods, and also the largest share of respondents who stated having positive views toward agriculture biotechnology. Table 11 also shows that the percentage of respondents who indicated being willing to consume GM apple, GM soybean oil, genome-edited apple, and genome-edited soybean oil is substantially higher in Cluster 1 (uncertainty-loving) than in Cluster 3 (uncertainty-averse), whereas that of Cluster 2 is in between the values of Clusters 1 and 3.

Table 11. Cluster-wise summary of consumers' awareness, knowledge, opinion towards GM and genome-edited foods [c]

Category	**Total sample (n=1573)**	**Cluster 1 (n=608)**	**Cluster 2 (n=740)**	**Cluster 3 (n=225)**
Heard of GM				
Yes	89.32%	88.65%	92.03%	82.22%
No	10.68%	11.35%	7.97%	17.78%
Heard of genome-edited				
Yes	42.59%	39.31%	40.27%	59.11%
No	57.41%	60.69%	59.73%	40.89%
Knowledgeable about GM				
Knowledgeable	69.80%	66.61%	70.41%	76.44%
Not at all	30.20%	33.39%	29.59%	23.56%
Knowledgeable about genome-edited				
Knowledgeable	44.25%	42.11%	39.59%	65.33%
Not at all	55.75%	57.89%	60.41%	34.67%
Perception about agricultural biotechnology				
Positive	37.95%	44.24%	27.70%	54.67%
Neutral	34.39%	40.63%	36.89%	9.33%
Negative	27.65%	15.13%	35.41%	36.00%

[c] *Significant difference between clusters for all the variables*

Table 12 also shows that the percentage of respondents who indicated being willing to consume GM apple, GM soybean oil, genome-edited apple, and genome-edited soybean oil is substantially higher in Cluster 1 (uncertainty-loving) than in Cluster 3 (uncertainty-averse), whereas that of Cluster 2 is in between the values of Clusters 1 and 3.

Table 12. Cluster-wise willingness to consume GM and genome-edited foods

	Total Sample (n=1573)	**Cluster 1 (n=608)**	**Cluster 2 (n=740)**	**Cluster 3 (n=225)**
Consume GM				
Yes	47.49%	49.67%	41.62%	60.89%
No	52.51%	50.33%	58.38%	39.11%
Willingness to consume GM apple				
Yes	59.69%	68.26%	56.49%	47.11%
No	40.31%	31.74%	43.51%	52.89%
Willingness to consume GM soybean oil				
Yes	62.75%	72.86%	58.65%	48.89%
No	37.25%	27.14%	41.35%	51.11%
Willingness to consume genome-edited apple				
Yes	59.82%	66.28%	57.03%	51.56%
No	40.18%	33.72%	42.97%	48.44%
Willingness to consume genome-edited soybean oil				
Yes	60.58%	68.59%	57.03%	50.67%
No	39.42%	31.41%	42.97%	49.33%

Past consumption of GM foods and future willingness to consume GM and genome-edited foods

A description and summary statistics of the variables included in the multivariate probit model are presented in Appendix 7 and 8, respectively. We used two multivariate probit models to analyze soybean oil and apple separately. The results of multivariate probit models are listed in Appendix 9 and 10. Tables 13 and 14 list the marginal effects of the coefficients of the multivariate probit models for soybean oil and apple, respectively. The significance of the correlation coefficients of multivariate probit models (Appendix 9 and 10) and the likelihood ratio test supports the use of a multivariate probit model instead of three separate probit models.

Table 13. Marginal effects from the multivariate probit model for soybean oil

Variables	**Consume GM**	**Willingness to consume GM Soybean oil**	**Willingness to consume Genome-edited Soybean oil**
	dy/dx (SE)	dy/dx (SE)	dy/dx (SE)
AFTNS	0.00 (0.00)	-0.00 (0.00)	-0.00** (0.00)
Corporate Scale	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
NEP Scale	-0.00 (0.00)	0.00 (0.00)	0.01*** (0.00)
Treatment 1		-0.01 (0.02)	0.02 (0.02)
Treatment 2		-0.06*** (0.02)	-0.02 (0.03)
Knowledge about GM foods	0.26*** (0.02)	0.03 (0.02)	0.01 (0.02)
Knowledge about Genome-edited foods			0.06*** (0.02)
Feel about use of agricultural biotech	0.14*** (0.02)	0.09*** (0.01)	0.08*** (0.01)
GM safe	0.01 (0.02)	0.05 *** (0.01)	-0.04** (0.02)
Genome-editing safe			0.10*** (0.01)
GM benefits	0.02 (0.02)	0.08*** (0.01)	0.03** (0.02)
Genome-editing benefits			0.06***(0.01)
GM labelling	-0.02** (0.01)	-0.00 (0.01)	-0.01 (0.01)
Genome-editing labelling			-0.00 (0.01)
University	-0.02** (0.01)	-0.00 (0.01)	0.01 (0.01)
Domestic start-up	0.04*** (0.01)	0.05*** (0.01)	0.03**(0.01)
Cluster 1	0.03 (0.04)	0.06* (0.03)	0.08** (0.04)
Cluster 3	0.01 (0.04)	-0.18*** (0.04)	-0.12*** (0.04)
Sex	-0.02 (0.02)	-0.08*** (0.02)	-0.07*** (0.02)
Age	-0.04*** (0.01)	-0.02*** (0.01)	-0.01 (0.01)
Education	0.02 (0.02)	0.07 ***(0.02)	0.06*** (0.02)
Annual Income	0.01* (0.01)	-0.03**** (0.01)	-0.03*** (0.01)

Standard errors in parentheses. *** p<0.01, ** p<0.05

Table 14. Marginal effects from multivariate probit model for apple

Variables	**Consume GM**	**Willingness to consume GM Apple**	**Willingness to consume Genome-edited Apple**
	dy/dx (SE)	dy/dx (SE)	dy/dx (SE)
AFTNS	0.00 (0.00)	-0.01*** (0.00)	-0.00 (0.00)
Corporate Scale	0.00 (0.00)	-0.00 (0.00)	0.00 (0.00)
NEP Scale	-0.00 (0.00)	0.00 (0.00)	0.01*** (0.00)
Treatment 1		-0.02 (0.02)	-0.03 (0.02)
Treatment 2		-0.05 (0.03)	-0.04 (0.02)
Knowledge about GM foods	0.26*** (0.02)	0.02 (0.02)	0.03 (0.02)
Knowledge about Genome-edited foods			0.04 (0.02)
Feel about use of agricultural biotech	0.14*** (0.02)	0.08*** (0.01)	0.08*** (0.01)
GM safe	0.01 (0.02)	0.07*** (0.01)	-0.00 (0.02)
Genome-editing safe			0.10*** (0.01)
GM benefits	0.02 (0.02)	0.06*** (0.01)	-0.01 (0.01)
Genome-editing benefits			0.07***(0.01)
GM labelling	-0.02** (0.01)	-0.01 (0.01)	-0.01 (0.01)
Genome-editing labelling			-0.00 (0.01)
University	-0.03* (0.01)	0.02 (0.01)	0.03** (0.01)
Domestic start-up	0.04*** (0.01)	0.05*** (0.01)	0.03** (0.01)
Cluster 1	0.03 (0.04)	-0.00 (0.03)	0.03 (0.03)
Cluster 3	0.01 (0.04)	-0.15*** (0.04)	-0.14*** (0.04)
Sex	-0.02 (0.02)	-0.06*** (0.02)	-0.07*** (0.02)
Age	-0.04*** (0.01)	-0.00 (0.01)	0.00 (0.01)
Education	0.02 (0.02)	0.04** (0.02)	0.03 (0.02)
Annual Income	0.01* (0.01)	-0.03*** (0.01)	-0.02*** (0.01)

Standard errors in parentheses. *** p<0.01, ** p<0.05

Past consumption of GM foods

The question of whether respondents had consumed GM foods in the past three months was asked prior to presenting any information treatments, so the “Consume GM” model does not include treatment variables. Given that past consumption of GM foods is not likely to be influenced by perceptions about the safety and benefits of genome-edited soybean oil, variables related to genome-editing were not included in the “Consume GM” and “Willingness to consume soybean oil” models.

Tables 13 and 14 show that respondents who consider themselves knowledgeable of GM foods, those having strongly positive feelings about the use of agricultural biotechnology, and those wanting the technology developed by domestic start-ups were more likely to consume GM foods in the past than their counterparts. In contrast, consumers who indicated having strong feelings toward labelling GM soybean oil and GM apple, and older respondents were less likely to have consumed GM foods than their counterparts.

Willingness to consume GM and genome-edited soybean oil

As per Table 13, the determinants of consumer decisions on future consumption of GM and genome-edited soybean oil are largely similar to one another. Among the attitudinal variables, NEP has positive and statistically significant coefficients for willingness to consume GM and genome-edited soybean oil. Similar to the results of the “Consume GM” model, having a positive perception of agricultural biotechnology increases the likelihood of future consumption of GM and genome-edited soybean oil. In addition, if the innovator is a domestic start-up, being in Cluster 1 (uncertainty-loving group) and having higher levels of education each increases the likelihood of consuming GM and genome-edited soybean oil in the future. However, being in Cluster 3 (uncertainty-averse group), being female, and having higher levels of annual income each decreases the likelihood of future consumption of GM and genome-edited soybean oil. Some of the variables have differing influences on consumers' future consumption of GM and genome-edited soybean oil. In particular, among the attitudinal variables, a high value along the AFTNS scale decreases the likelihood of willingness to consume genome-edited soybean oil in the future, while no such effect is present for willingness to consume GM soybean oil. Also, among the treatment variables (using the control as the base case), Information Treatment 2 – which provides both technical information along with health and environmental benefits – decreases the likelihood of a willingness to consume GM soybean oil, while no such effect is evident for genome-edited soybean oil. Further, as the degree of consumers' beliefs in the safety of GM soybean oil increases, the likelihood of future consumption of genome-edited soybean oil decreases. Finally, among the socio-demographic variables, older people are less likely to consume GM soybean oil than younger individuals, while no such effect is present for genome-edited soybean oil.

Willingness to consume GM and genome-edited apple

The multivariate regression results for apple reported in Table 14 are very similar to those for soybean oil, listed in Table 13. For example, similar to the soybean oil results, consumers having positive perceptions towards agricultural biotechnology, positive beliefs about GM apple safety, positive beliefs about GM apple's benefits, and higher levels of education are more likely to consume GM apple than their counterparts. As in the case of GM soybean oil, having a domestic start-up firm as the developer of the technology is associated with a higher likelihood to consume GM apple in the future than if the technology would be developed by multinational firms. Similar to willingness to consume GM soybean oil, consumers who are female, are assigned to Information Treatment 2, and have high incomes are less likely to consume GM apple in the future than their counterparts. A notable difference is the negative effect of AFTNS on willingness to consume GM apple while no such effect was present for willingness to consume GM soybean oil. Unlike in the case of willingness to consume GM soybean oil, neither being in Cluster 2 nor age influences the likelihood of willingness to consume GM apple in the future.

Many factors influencing willingness to consume genome-edited apples are similar to those influencing willingness to consume genome-edited soybean oil. For example, as in the case of genome-edited soybean oil, scoring high on the NEP scale, holding positive perceptions about agricultural biotechnology, having positive perceptions about the safety of genome-edited apple, having domestic start-up firms as technology developers, and having a high income each positively influences the likelihood of the respondents' willingness to consume genome-edited apples. Similar to willingness to consume genome-edited soybean oil, being classified in Cluster 3, being female, and having a high income each reduces the likelihood of willingness to consume genome-edited apples in the future. A comparison of results of the willingness to consume GM and genome-edited apple shows some differences as well. For example, unlike in the case of genome-edited soybean oil, none of the attitudinal variables are statistically significant in the willingness to consume decision of genome-edited apples. While belonging to Cluster 1 and having a high level of education increases the likelihood of willingness to consume genome-edited soybean oil, no such effects are present for willingness to consume genome-edited apple.

Discussion

Although consumers' concerns about the safety of GM foods have stayed fairly stable in recent years, their awareness of GM foods has been increasing (Lusk, McFadden, and Rickard 2015). The results of our study indicate that consumer awareness and knowledge of GM foods are substantially higher than concerning genome-edited foods. Also, those with relatively high levels of self-expressed awareness and knowledge indicated consuming more GM foods in the past than their counterparts (Table 9). The results in Tables 11-14 show various systematic components of consumer behavior towards GM and genome-edited foods.

Tables 13 and 14 show that there are more differences than similarities between past consumption of GM foods and future consumption decisions of GM and genome-edited foods. Although past consumption of GM foods is not a good predictor of a consumer's willingness to consume genome-edited foods in future, a consumer who is willing to consume GM foods in future is also more likely to consume genome-edited foods in future. Unlike in the case of past consumption of GM foods, consumers' attitudes, knowledge, and beliefs are important for their future consumption decisions of GM and genome-edited foods. Previous studies showed that consumers who score high on the AFTNS scale are shown to be less likely to consume GM foods (Schnettler et al.

2017). Our finding that consumers with high AFTNS scores and with strong beliefs that GM and genome-edited foods should be labeled as such are relatively less likely to consume GM and genome-edited foods in the future suggest the importance of building consumer trust in new food technologies by way of developing an appropriate policy and regulatory framework, science-based labeling information, and sound education and outreach efforts.

Contrary to the current opposition to GM foods based on potential environmental impacts among some individuals and groups, the existence of distinguishable attitudinal factors – as measured along the NEP scale – that have a positive impact on future willingness to consume GM and genome-edited foods suggest that as consumers' awareness about the environmental impacts of food production increases, increasing numbers of consumers may be willing to consume GM and genome-edited foods. Therefore, highlighting the environmental benefits associated with new food technologies in their market outreach efforts, may provide technology developers and food manufacturers an avenue for scaling up the acceptance of these novel foods in the marketplace.

The importance of attitudes in future willingness to consume is further underlined by the statistically significant effect of cluster dummies generated based on attitudinal variables on willingness to consume GM and genome-edited foods (Table 13 and 14). Baker and Burnham 2001 and Lusk et al. (2005) reported that risk-averse people are less likely to accept GM foods than risk-loving individuals. Overall, findings from our study imply that consumers grouped in uncertainty-loving and uncertainty-averse clusters based on their attitudes toward new food technologies, the ecological paradigm, and corporate distrust exert opposing influence on their willingness to consume GM and genome-edited foods. Although the proportion of uncertainty-averse consumers in our sample is low (14%) compared to the uncertainty-loving (39%) and neutral (47%) groups, findings from our study show higher proportions of uncertainty-loving and neutral consumers are willing to consume GM and genome-edited foods than in the uncertainty-averse group (Table 13).

Subjective and objective knowledge is shown to be important in consumers' attitudes towards GM foods. Previous studies have shown that individuals with a high level of subjective knowledge are less influenced by information than those with low subjective knowledge levels (Costa-Font, Gil, and Traill 2008). In our study, the provision of information about the technologies and their benefits exerts a negative influence on future willingness to consume GM foods while no such effect on future willingness to consume genome-edited foods is identified. In a recent study on consumers' perception of the safety of genome-edited citrus, McFadden et al. (2021) found that providing scientific information and narrative have a negative effect on consumer perceptions of the safety of genome-edited citrus. Although not directly comparable due to differences in the variables used in the models in these studies, overall, these results suggest that the effect of information provision about the technologies and their benefits may not lead to similar outcomes for consumer acceptance of GM and genome-edited foods and may produce unintended consequences such as negative effect. In addition to providing science-based communication and information, attitudes, values, beliefs, and existing knowledge levels (subjective and objective) are at play, and their mutual interaction may lead to unintended consequences such as a negative effect on consumer willingness to consume GM foods observed in this study. Trust allows decision making in the presence of incomplete knowledge on the consequences of a decision and replaces missing information to tolerate perceived uncertainty of the situation (Gutteling et al. 2006). Empirical results from our study shows that consumers who trust domestic start-up firms and universities as technology developers over multinational firms are more likely to consume GM and genome-edited foods in the future. This finding is encouraging for start-up firms who actively invest in the R&D of genome-edited foods which has the potential to increase consumers' food choices and producers' access to technology through a broad portfolio of technologies, increased competition, and competitive pricing.

Given that female and older consumers and those with higher income are less likely to consume GM and genome-edited foods, communication and market outreach efforts targeted at these groups may lead to higher overall acceptance of GM and genome-edited foods in future. Overall, findings from the study show that determinants of future acceptance of GM and genome-edited foods are more or less similar between technologies and food types. This may be because, as reported previously, consumers are more interested in the outcomes from breeding than the technique themselves (Lusk, McFadden, and Wilson 2018, Shew et al. 2017).

Conclusions

Genetic modification of plants has been used since the mid-1990s to address agricultural production challenges and to mitigate the harmful effects of pests, diseases, and weeds. Due to rising consumer concerns about the safety and environmental impacts of genetic modification – particularly involving the transfer of genes between species and or between organisms within a species – GM food regulations and acceptance vary across the globe. Genome-editing is a relatively new technique that modifies genes within an organism and thus avoids concerns associated with the transfer of genes between or within species. In recent years, genome-editing has become faster and cheaper than genetic modification, and it has the potential to become an important tool for addressing producer and consumer concerns in the farming and food sectors.

Our study shows that consumer awareness and knowledge of genome-edited foods is almost half those of GM foods. Classification of respondents into clusters rank-ordered along attitudinal scales facilitates dividing the respondents into three distinct groups: uncertainty-loving, neutral, and uncertainty-averse individuals. Respondents in the uncertainty-loving group had higher levels of awareness and knowledge of GM and genome-edited foods and agricultural biotechnology and are more likely to consume GM and genome-edited foods in the future than those in the other two groups.

Findings identified differences between the determinants of past consumption of GM foods and those of future consumption of GM and genome-edited foods. Although largely similar, there are some differences between the determinants of genome-edited foods based on food type. Respondents who are likely to consume GM foods in the future are also more likely to consume genome-edited foods in the future, suggesting these two decisions are linked.

Attitudinal factors, prior perceptions of agricultural biotechnology, beliefs about safety, benefits, and labeling are important determinants of future consumption of GM and genome-edited foods. The provision of science-based information on conventional, GM, and genome-editing breeding techniques, and highlighting the health and environmental benefits of each technique using soybean oil and apple as examples may negative affect consumers' future willingness to consume GM foods, while no such effect is evident for genome-edited foods. The involvement of domestic start-up firms as technology developers increases consumers' willingness to accept GM and genome-edited foods. Among the socio-demographic factors, age, income, and being female exert negative influences, while education exerts a positive influence on future consumption decisions on GM and genome-edited foods.

Overall, respondents' support for and consumer acceptance of GM and genome-edited foods do not vary based on food types. Consumers are heterogeneous and their attitudes can change as new food technologies and food traits are introduced. Findings from our study underscore the importance of developing appropriate regulations, labeling policies, education, outreach, and communication efforts to inform consumers about GM and genome-edited foods and their critical importance for improving outcomes through the entire food systems. The study also shows that improving consumer acceptance of GM foods will likely also improve the acceptance of genome-edited foods.

CHAPTER IV

CONCLUSIONS

In this study, we first examined U.S. consumers WTP for GM and genome-edited foods and evaluated the effect of information on consumers' WTP. Second, we examined determinants of consumers acceptance of GM and genome-edited foods. Results from Chapter II show that consumers' WTP for GM and genome-edited foods are similar and lower than the WTP for a conventionally bred food. WTP for GM and genome-edited foods varies based on food type, such that consumers have a higher WTP for processed food than for fresh produce. Though consumers' valuations of GM and genome-edited foods are similar, the provision of information, market outreach efforts and public engagement that communicates various health, environmental, and economic benefits of genome-edited foods can influence consumers' attitudes, perceptions, and behavior toward genome-edited foods. Institutions associated with relatively high level of trust among consumers, such as domestic start-up firms and universities, are better placed to lead such public engagement efforts for the integration of genome-edited foods in the market than organizations that are associated with lower levels of trust in the minds of consumers.

Results of Chapter III show that consumers' perceptions about and acceptance of GM and genome-edited foods are similar. Unlike WTP, willingness to consume GM and genome-edited foods do not vary based on food type. Attitudinal factors, prior perceptions of agricultural biotechnology, beliefs about safety, benefits, and labelling are important determinants of future consumption of GM and genome-edited foods. Uncertainty-loving consumers were found to have positive attitudes toward future consumption of GM and genome-edited foods. Improvement in consumer acceptance of GM foods will likely also improve the acceptance of genome-edited foods.

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APPENDIX

Appendix 1. Control treatment

Soybean oil attributes

Nutritional Content (Oleic Acid):

(Oleic acid is a monounsaturated fatty acid which facilitates improved health and oxidative stability for oil shelf life, flavor, and durability)**

High refers to high level of oleic acid and is considered nutritious for human health and heart.

Normal refers to regular level of oleic acid.

Use of pesticide level

Reduced use refers to minimal application of toxic pesticides (e.g., weedicides, insecticides etc.) with positive environmental benefits and improved food safety.

No reduction refers to regular application of toxic pesticides.

Technology

Conventional breeding refers to traditional plant breeding practices in U.S.

Genetic Modification (GM) refers to agricultural biotechnology that involves insertion of foreign genetic material into the genome of an organism to develop new traits.

Genome-editing refers to an advancement in biotechnology that involves addition, deletion, or modification of genetic material in the genome of an organism to develop new trait.

No information on technology

Developer

Domestic start-up refers to a local firm/company in the first stage of its operations.

A multinational firm refers to a global company that develops food products.

University refers to an academic institution involved in education and research.

No information on developer of technology

Now, please take time to read the following instructions before proceeding with the survey carefully. Imagine you are in your usual grocery store and considering the purchase of soybean oil. In the following, you will see **6 choices/decision scenarios for soybean oil.** Each choice scenario includes a description of different soybean oil attributes. All features of the product in each choice scenario are identical in quality except that they vary in their price, nutritional content, use of pesticide level, type of technology used in production and developer of the technology. In each choice scenario, please indicate the decision you would make based on your own preferences.

Alternatively, you may choose NOT TO PURCHASE either product. When you are faced with a choice scenario, assume that is the only option you have and select one of the options (Option 1, Option 2, Neither). Please do not compare options between questions.

Before answering, note that prior research shows that people often overstate the amount they are willing to pay when answering survey questions like this. I ask that you think carefully and respond to each of the following purchase questions exactly as you would if you were actually in a grocery store, and you were going to face the consequences of your decision: which is to pay money if you decide to buy food.

Appendix 2. Information on technologies used in production of food products (Information treatment 1)

Conventional breeding:

Conventional breeding is the traditional plant breeding technique that involves the crossing of two different species together with relevant characteristics and selecting the offspring with the desired combination of characteristics. The process is lengthy and there are limitations to introduce new traits such as pesticide/disease resistance, reduced allergenicity, and high nutrition content that are of interest to producers and consumers. Overall, there are no known negative environmental or health effects of conventional plant breeding.

Genetic Modification (GM) technology:

Genetic modification (GM) technology involves the transfer of genetic material (genes) within and beyond the species boundaries, resulting in modification or alteration of organism to provide an organism with a new trait. This technology allows incorporation of new traits such as pesticide/disease resistance, reduced allergenicity, and high nutrition content that are of interest to producers and consumers. U.S. National Academy of Sciences, Engineering, and Medicine (NAS) recently concluded that GM foods are as safe as conventional foods for human consumption, the technology still remains controversial due to environmental and health concerns.

Genome-editing technology:

Unlike GM technology that involves transfer of genes within and beyond species boundaries, genome editing technology solely with altering the genes that already exist within the crop/organism and more closely mimics nature. Like GM, this technology allows incorporation of new traits such as pesticide/disease resistance, reduced allergenicity, and high nutrition content that are of interest to producers and consumers. Genome-editing is more advanced, precise, faster, cheaper, and cost-effective relative to GM technology. Genome-editing technology is controversial due to the involvement of genetic manipulation and many countries are still undecided on how to regulate this new technology.

Soybean oil attributes

Nutritional Content (Oleic Acid):

(Oleic acid is a monounsaturated fatty acid which facilitates improved health and oxidative stability for oil shelf life, flavor, and durability)**

High refers to high level of oleic acid and is considered nutritious for human health and heart.

Normal refers to regular level of oleic acid.

Use of pesticide level

Reduced use refers to minimal application of toxic pesticides (e.g., weedicides, insecticides etc.) with positive environmental benefits and improved food safety.

No reduction refers to regular application of toxic pesticides.

Technology

Conventional breeding refers to traditional plant breeding practices in U.S.

Genetic Modification (GM) refers to agricultural biotechnology that involves insertion of foreign genetic material into the genome of an organism to develop new traits.

Genome-editing refers to an advancement in biotechnology that involves addition, deletion, or modification of genetic material in the genome of an organism to develop new trait.

No information on technology

Developer

Domestic start-up refers to a local firm/company in the first stage of its operations.

A multinational firm refers to a global company that develops food products.

University refers to an academic institution involved in education and research.

No information on developer of technology

Now, please take time to read the following instructions before proceeding with the survey carefully. Imagine you are in your usual grocery store and considering the purchase of soybean oil. In the following, you will see **6 choices/decision scenarios for soybean oil.** Each choice scenario includes a description of different soybean oil attributes. All features of the product in each choice scenario are identical in quality except that they vary in their price, nutritional content, use of pesticide level, type of technology used in production and developer of the technology. In each choice scenario, please indicate the decision you would make based on your own preferences.

Alternatively, you may choose NOT TO PURCHASE either product. When you are faced with a choice scenario, assume that is the only option you have and select one of the options (Option 1, Option 2, Neither). Please do not compare options between questions.

Before answering, note that prior research shows that people often overstate the amount they are willing to pay when answering survey questions like this. I ask that you think carefully and respond to each of the following purchase questions exactly as you would if you were actually in a grocery store, and you were going to face the consequences of your decision: which is to pay money if you decide to buy food.

Appendix 3. Information on health and environmental benefits related to technology (Information treatment 2)

Information on technologies used in production of food products

Conventional breeding:

Conventional breeding is the traditional plant breeding technique that involves the crossing of two different species together with relevant characteristics and selecting the offspring with the desired combination of characteristics. The process is lengthy and there are limitations to introduce new traits such as pesticide/disease resistance, reduced allergenicity, and high nutrition content that are of interest to producers and consumers. Overall, there are no known negative environmental or health effects of conventional plant breeding.

Genetic Modification (GM) technology:

Genetic modification (GM) technology involves the transfer of genetic material (genes) within and beyond the species boundaries, resulting in modification or alteration of organism to provide an organism with a new trait. This technology allows incorporation of new traits such as pesticide/disease resistance, reduced allergenicity, and high nutrition content that are of interest to producers and consumers. U.S. National Academy of Sciences, Engineering, and Medicine (NAS) recently concluded that GM foods are as safe as conventional foods for human consumption, the technology still remains controversial due to environmental and health concerns.

Genome-editing technology:

Unlike GM technology that involves transfer of genes within and beyond species boundaries, gene editing technology solely with altering the genes that already exist within the crop/organism and more closely mimics nature. Like GM, this technology allows incorporation of new traits such as pesticide/disease resistance, reduced allergenicity, and high nutrition content that are of interest to producers and consumers. Genome-editing is more advanced, precise, faster, cheaper, and cost-effective relative to GM technology. Genome-editing technology is controversial due to the involvement of genetic manipulation and many countries are still undecided on how to regulate this new technology.

Information on health and environmental benefits related to technology

GM and genome-edited apples have enhanced antioxidants and vitamin C and are more nutritious compared to conventionally produced apples. Furthermore, GM and genome-edited apples have been engineered to produce less polyphenol oxidase, or PPO, the enzyme that causes the flesh to turn brown. Because of this, slices of genetically modified and genome-edited apples can stay free of browning for a longer period of time and reduce food wastage.

GM and genome-edited soybean have been engineered to produce high oleic acid, that is more nutritious as compared to conventionally produced soybean oil. Furthermore, GM and genome-edited soybean presented here are herbicide tolerant implying positive environmental benefits in terms of reduced use of many toxic weedicides by farmers.

Soybean oil attributes

Nutritional Content (Oleic Acid):

(Oleic acid is a monounsaturated fatty acid which facilitates improved health and oxidative stability for oil shelf life, flavor, and durability)**

High refers to high level of oleic acid and is considered nutritious for human health and heart.

Normal refers to regular level of oleic acid.

Use of pesticide level

Reduced use refers to minimal application of toxic pesticides (e.g., weedicides, insecticides etc.) with positive environmental benefits and improved food safety.

No reduction refers to regular application of toxic pesticides.

Technology

Conventional breeding refers to traditional plant breeding practices in U.S.

Genetic Modification (GM) refers to agricultural biotechnology that involves insertion of foreign genetic material into the genome of an organism to develop new traits.

Genome-editing refers to an advancement in biotechnology that involves addition, deletion or modification of genetic material in the genome of an organism to develop new trait.

No information on technology

Developer

Domestic start-up refers to a local firm/company in the first stage of its operations.

A multinational firm refers to a global company that develops food products.

University refers to an academic institution involved in education and research.

No information on developer of technology

Now, please take time to read the following instructions before proceeding with the survey carefully. Imagine you are in your usual grocery store and considering the purchase of soybean oil. In the following, you will see **6 choices/decision scenarios for soybean oil.** Each choice scenario includes a description of different soybean oil attributes. All features of the product in each choice scenario are identical in quality except that they vary in their price, nutritional content, use of pesticide level, type of technology used in production and developer of the technology. In each choice scenario, please indicate the decision you would make based on your own preferences.

Alternatively, you may choose NOT TO PURCHASE either product. When you are faced with a choice scenario, assume that is the only option you have and select one of the options (Option 1, Option 2, Neither). Please do not compare options between questions.

Before answering, note that prior research shows that people often overstate the amount they are willing to pay when answering survey questions like this. I ask that you think carefully and respond to each of the following purchase questions exactly as you would if you were actually in a grocery store, and you were going to face the consequences of your decision: which is to pay money if you decide to buy food.

Appendix 4. Statements included for developing abbreviated food technology neophobia scale (AFTNS)

Please indicate your level of agreement with the statement below by using the numbers 1-7 from the rating scale below**.** (Rating Scale: 1= Strongly Disagree, 2=Disagree, 3=Somewhat Disagree, 4=Neutral, 5= Somewhat Agree, 6= Agree, 7= Strongly Agree) When responding we ask you to think about new food technologies in general rather than one specific technology.

S.N.	**Statement**	**Scale (1-7)**
1	New foods are not healthier than traditional foods	
2	The benefits of new food technologies are often grossly overstated	
3	There are plenty of tasty foods around, so we do not need to use new food technologies to produce more	
4	New food technologies decrease the natural quality of food	
5	New food technologies are unlikely to have long term negative health effects*	
6	New food technologies may have long term negative environmental effects	
7	It can be risky to switch to new food technologies too quickly	
8	Society should not depend heavily on technologies to solve its food problems	
9	There is no sense trying out high-tech food products because the ones I eat are already good enough	

*Among the nine components, component 5 has score value reversed in order.

Appendix 5. Statements included for developing corporate distrust scale

Please indicate your level of agreement with the statement below by using the numbers 1-5 from the rating scale below**. (**Rating Scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree)

S.N.	**Statement**	**Scales (1-5)**
1	Corporations are not respectful of laws.	
2	Corporations do not accept accountability for their actions.	
3	People who run corporations will lie if doing so will increase company profits.	
4	Corporations do not care about acting ethically.	
5	Corporations will break laws if they can make more money from it.	
6	Corporations put their own interests above the public's interests.	
7	Corporations are driven by greed.	
8	Corporations care only about money.	
9	Corporations want power at any cost.	
10	Corporations take a lot more than they give.	
11	Corporations intentionally deceive the public.	
12	Corporations do not consider the needs of their employees when making business decisions.	
13	Corporations exploit their workers.	

Appendix 6. Statements included for developing new ecological paradigm (NEP) scale

Please indicate your level of agreement with the following statements by using the numbers 1-5 from the rating scale below. **(**Rating Scale: 1= Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5= Strongly Agree)

S.N.	**Statement**	**Scale (1-5)**
1	We are approaching the limit of the number of people the Earth can support.	
2	Humans have the right to modify the natural environment to suit their needs.	
3	When humans interfere with nature it often produces disastrous consequences.	
4	Human ingenuity will ensure that we do not make the Earth unlivable.	
5	Humans are severely abusing the environment.	
6	The Earth has plenty of natural resources if we just learn how to develop them.	
7	Plants and animals have as much right as humans to exist.	
8	The balance of nature is strong enough to cope with the impacts of modern industrial nations.	
9	Despite our special abilities, humans are still subject to the laws of nature.	
10	The so-called "ecological crisis" facing humankind has been greatly exaggerated.	
11	The Earth is like a spaceship with very limited room and resources.	
12	Humans were meant to rule over the rest of nature.	
13	The balance of nature is very delicate and easily upset.	
14	Humans will eventually learn enough about how nature works to be able to control it.	
15	If things continue on their present course, we will soon experience a major ecological catastrophe.	

Appendix 7: Description of variable used in multivariate probit model

Variables	Description
Dependent Variables	
Consume GM	1 if the respondent currently consumes GM products, 0 otherwise
Willingness to consume GM soybean oil/ Willingness to consume GM apple	1 if the respondent expressed willingness to consume GM apple or soybean oil, 0 otherwise
Willingness to consume genome-edited soybean oil/ Willingness to consume genome-edited apple	1 if the respondent expressed willingness to consume genome-edited soybean oil or apple, 0 otherwise
Independent Variables	
Attitudinal indices	
AFTNS	1= strongly disagree, 2=disagree, 3=somewhat disagree, 4=neutral, 5= somewhat agree, 6= agree, and 7= strongly agree
corporate scale	1= strongly disagree, 2= disagree, 3=neutral, 4=agree, and 5= strongly agree
NEP scale	1= strongly disagree, 2=disagree, 3=neutral, 4=agree, 5= strongly agree
Treatments	
treatment 1	1 if the respondent was assigned to treatment 1, 0 otherwise
treatment 2	1 if the respondent was assigned to treatment 2, 0 otherwise
Knowledge and opinion variables	
Knowledge about GM	0= not at all knowledgeable about GM; and 1= knowledgeable about GM
Knowledge about genome-edited	0= not at all knowledgeable about genome-edited foods; and 1= knowledgeable about genome-edited foods
Feel about use of agricultural biotech	0= negative, 1= neutral, 2= positive
Consumer beliefs	
GM Safe	1= strongly disagree, 2= disagree, 3= Unsure, 4= agree, and 5= strongly agree

Genome-editing safe	1= strongly disagree, 2= disagree, 3= Unsure, 4= agree, and 5= strongly agree
GM benefits	1= strongly disagree, 2= disagree, 3= Unsure, 4= agree, and 5= strongly agree
Genome-editing benefits	1= strongly disagree, 2= disagree, 3= Unsure, 4= agree, and 5= strongly agree
GM Labelling	1= strongly disagree, 2= disagree, 3= Unsure, 4= agree, and 5= strongly agree
Genome-editing Labelling	1= strongly disagree, 2= disagree, 3= Unsure, 4= agree, and 5= strongly agree
Preference for developer	
University	1= strongly disagree, 2= disagree, 3= Unsure, 4= agree, and 5= strongly agree
Domestic-start-up	1= strongly disagree, 2= disagree, 3= Unsure, 4= agree, and 5= strongly agree
Multinational firm	1= strongly disagree, 2= disagree, 3= Unsure, 4= agree, and 5= strongly agree
Consumer segments	
Cluster 1	1 if the respondent was grouped into cluster 1, and 0 otherwise
Cluster 2	1 if the respondent was grouped into cluster 2, and 0 otherwise
Cluster 3	1 if the respondent was grouped into cluster 3, and 0 otherwise
Demographics	
Sex	1 if the respondent is a female and 0 otherwise.
Age	1= 18-24 years of age, 2= 25-34, 3= 35-44, 4=45-54, 5=55-64, and 6=65+.
Education	1= below high school, 2= high school graduate/associate degree, and 3= college degree or high
Annual Income	1= < $10,000 to $24,999, 2= $25,000 to $49,999, 3=$50,000 to $74,999, 4= $75,000 to $99,999, and 5=$100,000 or more

Appendix 8. Summary statistics of key variables used in multivariate probit model

Variable	Consume GM		Willingness to consume GM Soybean oil		Willingness to consume GM Apple		Willingness to consume Genome-edited Soybean oil		Willingness to consume Genome-edited Apple	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Attitudinal indices										
AFTNS	42.04	41.60	44.97	39.97	44.83	39.81	44.52	40.08	44.17	40.26
	(9.75)	(10.38)	(9.67)	(9.81)	(9.38)	(9.99)	(9.57)	(9.97)	(9.71)	(9.98)
Corporate Scale	49.58	49.67	51.73	48.37	51.49	48.36	50.97	48.74	50.90	48.76
	(11.92)	(11.92)	(11.90)	(11.76)	(11.68)	(11.92)	(11.72)	(11.97)	(11.52)	(12.11)
NEP Scale	51.55	49.77	51.02	50.52	50.97	50.52	50.39	50.91	50.57	50.80
	(8.60)	(7.63)	(8.67)	(7.91)	(8.61)	(7.91)	(8.24)	(8.17)	(8.23)	(8.19)
Treatments										
Control	-	-	0.32	0.34	0.32	0.34	0.35	0.33	0.33	0.34
			(0.47)	(0.48)	(0.47)	(0.47)	(0.48)	(0.47)	(0.47)	(0.47)
Treatment 1	-	-	0.32	0.34	0.33	0.33	0.32	0.34	0.34	0.33
			(0.47)	(0.47)	(0.47)	(0.47)	(0.47)	(0.47)	(0.47)	(0.47)
Treatment 2	-	-	0.36	0.32	0.35	0.32	0.33	0.33	0.33	0.33
			(0.48)	(0.47)	(0.48)	(0.47)	(0.47)	(0.47)	(0.47)	(0.47)
Knowledge and opinion about food technology										
Knowledge about GM	0.62	1.22	0.78	0.97	0.83	0.95	0.78	0.98	0.80	0.97
	(0.62)	(0.66)	(0.70)	(0.70)	(0.71)	(0.70)	(0.69)	(0.71)	(0.70)	(0.70)
Knowledge about	-	-	-	-	-	-	0.45	0.74	0.50	0.72
Genome-edited							(0.69)	(0.81)	(0.71)	(0.81)
Feel about use of	1.71	2.74	1.55	2.58	1.64	2.57	1.60	2.59	1.64	2.57
agricultural	(1.04)	(1.16)	(1.17)	(1.07)	(1.21)	(1.06)	(1.16)	(1.08)	(1.19)	(1.08)
biotechnology										
Consumer beliefs on food technology										
GM safe	3.13	3.68	2.71	3.80	2.70	3.86	2.85	3.74	2.79	3.79
	(1.27)	(1.21)	(1.36)	(1.01)	(1.34)	(0.97)	(1.37)	(1.06)	(1.35)	(1.03)
Genome-editing safe	-	-	-	-	-	-	2.79	3.90	2.77	3.93
							(1.33)	(0.93)	(1.31)	(0.91)
GM benefits	3.16	3.73	2.71	3.86	2.75	3.89	2.83	3.82	2.85	3.82
	(1.28)	(1.18)	(1.36)	(0.98)	(1.34)	(0.96)	(1.36)	(1.02)	(1.35)	(1.03)
Genome-editing	-	-	-	-	-	-	2.86	3.93	2.86	3.95
benefits							(1.36)	(0.93)	(1.34)	(0.93)
GM labelling	4.00	3.97	3.89	4.04	3.89	4.05	3.87	4.06	3.85	4.07
	(1.21)	(1.13)	(1.39)	(1.02)	(1.37)	(1.01)	(1.37)	(1.02)	(1.38)	(1.00)

Genome-editing	-	-	-	-	-	-	3.93	4.08	3.91	4.10
labelling							(1.35)	(1.00)	(1.34)	(1.00)
Consumer preference for developer of food technology										
University	3.02	3.55	2.63	3.66	2.61	3.72	2.69	3.66	2.63	3.71
	(1.32)	(1.23)	(1.44)	(1.04)	(1.42)	(1.00)	(1.41)	(1.07)	(1.39)	(1.04)
Domestic start-up	2.95	3.63	2.60	3.67	2.63	3.71	2.66	3.67	2.64	3.70
	(1.29)	(1.17)	(1.40)	(1.00)	(1.37)	(1.00)	(1.38)	(1.02)	(1.36)	(1.01)
Multinational firm	2.83	3.46	2.51	3.49	2.53	3.53	2.54	3.51	2.53	3.53
	(1.30)	(1.23)	(1.43)	(1.08)	(1.41)	(1.06)	(1.39)	(1.10)	(1.39)	(1.08)
Consumer segments										
Cluster 1	0.37	0.40	0.28	0.45	0.30	0.44	0.31	0.44	0.32	0.43
	(0.48)	(0.49)	(0.45)	(0.50)	(0.46)	(0.50)	(0.46)	(0.50)	(0.47)	(0.50)
Cluster 2	0.52	0.41	0.52	0.44	0.51	0.45	0.51	0.44	0.50	0.45
	(0.50)	(0.49)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
Cluster 3	0.11	0.18	0.20	0.11	0.19	0.11	0.18	0.12	0.17	0.12
	(0.31)	(0.39)	(0.40)	(0.31)	(0.39)	(0.32)	(0.38)	(0.32)	(0.38)	(0.33)
Demographic characteristics										
Sex	0.53	0.48	0.62	0.44	0.61	0.44	0.61	0.44	0.61	0.44
	(0.50)	(0.50)	(0.49)	(0.50)	(0.49)	(0.50)	(0.49)	(0.50)	(0.49)	(0.50)
Age	4.10	3.15	4.02	3.43	3.82	3.53	3.90	3.48	3.81	3.54
	(1.66)	(1.57)	(1.68)	(1.64)	(1.73)	(1.64)	(1.68)	(1.67)	(1.67)	(1.68)
Education	2.18	2.32	2.13	2.32	2.18	2.30	2.16	2.31	2.20	2.28
	(0.55)	(0.60)	(0.57)	(0.57)	(0.57)	(0.58)	(0.58)	(0.57)	(0.58)	(0.57)
Annual Income	2.55	3.03	2.78	2.78	2.80	2.76	2.74	2.80	2.74	2.80
	(1.37)	(1.48)	(1.44)	(1.44)	(1.45)	(1.44)	(1.43)	(1.45)	(1.44)	(1.44)

**** Figure in parentheses represents standard deviation*

Appendix 9. Results from multivariate probit model for soybean oil

Variables	**Consume GM**	**Willingness to consume GM Soybean oil**	**Willingness to consume Genome-edited Soybean oil**
	Coefficient (SE)	*Coefficient (SE)*	*Coefficient (SE)*
AFTNS	0.01 (0.00)	-0.01 (0.01)	-0.01** (0.01)
Corporate Scale	0.00 (0.00)	0.00 (0.01)	0.01 (0.01)
NEP Scale	-0.00 (0.01)	0.01 (0.01)	0.02*** (0.01)
Treatment 1		-0.04 (0.09)	0.06 (0.09)
Treatment 2		-0.24*** (0.09)	-0.08 (0.09)
Knowledge about GM foods	0.84*** (0.08)	0.12 (0.08)	0.04 (0.09)
Knowledge about Genome-edited foods			0.24*** (0.09)
Feel about use of agricultural biotech	0.44*** (0.05)	0.35*** (0.06)	0.29*** (0.06)
GM safe	0.02 (0.05)	0.18*** (0.05)	-0.17** (0.07)
Genome-editing safe			0.38*** (0.06)
GM benefits	0.07 (0.05)	0.32*** (0.05)	0.12** (0.06)
Genome-editing benefits			0.24*** (0.05)
GM labelling	-0.07** (0.03)	-0.02 (0.04)	-0.03 (0.05)
Genome-editing labelling			-0.00 (0.04)
University	-0.08 (0.05)	-0.01 (0.05)	0.03 (0.05)
Domestic start-up	0.14*** (0.05)	0.19*** (0.05)	0.12** (0.05)
Cluster 1	0.10 (0.12)	0.23 (0.13)	0.30** (0.13)
Cluster 3	0.02 (0.14)	-0.70*** (0.17)	-0.45*** (0.17)
Sex	-0.05 (0.07)	-0.32*** (0.08)	-0.28*** (0.08)
Age	-0.12*** (0.02)	-0.09*** (0.02)	-0.03 (0.03)
Education	0.06 (0.06)	0.28*** (0.07)	0.24*** (0.07)
Annual Income	0.05 (0.03)	-0.11*** (0.03)	-0.10*** (0.03)
Constant	-1.44***(0.49)	-2.34*** (0.56)	-3.52*** (0.56)
Rho 12	0.29*** (0.05)		
Rho 13	0.15***(0.05)		
Rho 23	0.80*** (0.02)		
Observations	1,573	1,573	1,573

Robust standard errors in parentheses. *** p<0.01, ** p<0.05

Appendix 10. Results from multivariate probit model for apple

Variables	**Consume GM**	**Willingness to consume GM Apple**	**Willingness to consume Genome-edited Apple**
	Coefficient (SE)	*Coefficient (SE)*	*Coefficient (SE)*
AFTNS	0.01 (0.00)	-0.02*** (0.01)	-0.01 (0.01)
Corporate Scale	0.00 (0.00)	-0.00 (0.01)	0.00 (0.01)
NEP Scale	-0.00 (0.01)	0.01 (0.01)	0.02*** (0.01)
Treatment 1		-0.06 (0.09)	-0.11 (0.09)
Treatment 2		-0.19** (0.09)	-0.14 (0.09)
Knowledge about GM foods	0.84*** (0.08)	0.07 (0.08)	0.12 (0.09)
Knowledge about Genome-edited foods			0.14 (0.09)
Feel about use of agricultural biotech	0.44*** (0.05)	0.28*** (0.06)	0.29*** (0.06)
GM safe	0.02 (0.05)	0.25*** (0.05)	-0.01 (0.06)
Genome-editing safe			0.37*** (0.05)
GM benefits	0.07 (0.05)	0.23*** (0.05)	-0.05 (0.05)
Genome-editing benefits			0.24*** (0.05)
GM labelling	-0.07** (0.03)	-0.04 (0.04)	-0.04 (0.04)
Genome-editing labelling			-0.00 (0.04)
University	-0.08 (0.05)	0.06 (0.05)	0.10** (0.05)
Domestic start-up	0.14*** (0.05)	0.19*** (0.05)	0.11** (0.05)
Cluster 1	0.10 (0.12)	-0.02 (0.13)	0.12 (0.13)
Cluster 3	0.03 (0.14)	-0.55*** (0.16)	-0.51*** (0.17)
Sex	-0.05 (0.07)	-0.22*** (0.08)	-0.26*** (0.08)
Age	-0.12*** (0.02)	-0.01 (0.02)	0.00 (0.02)
Education	0.06 (0.06)	0.16** (0.07)	0.12 (0.07)
Annual Income	0.05 (0.03)	-0.11*** (0.03)	-0.09*** (0.03)
Constant	-1.42*** (0.48)	-1.63*** (0.56)	-3.06*** (0.55)
Rho 12	0.22*** (0.05)		
Rho 13	0.10** (0.05)		
Rho 23	0.77*** (0.03)		
Observations	1,573	1,573	1,573

Robust standard errors in parentheses. *** p<0.01, ** p<0.05