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Genetically engineered crops: Consumers' acceptance and farmers' adoption

Katherine M. Lacy
Iowa State University

Genetically engineered crops: Consumers' acceptance and farmers' adoption

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Katherine M. Lacy

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Wallace E. Huffman, Co-Major Professor
Peter F. Orazem, Co-Major Professor
J. Gordon Arbuckle
Elizabeth Hoffman
David Keiser
John A. Miranowski

The student author, whose presentation of the scholarship herein was approved by the program of study committee, is solely responsible for the content of this dissertation. The Graduate College will ensure this dissertation is globally accessible and will not permit alterations after a degree is conferred.

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DEDICATION

To my family

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ABSTRACT

This dissertation consists of three essays broadly themed around understanding consumer acceptance and farmer's use of genetically engineered crops. Genetic engineering (GE) has developed crops that improve food safety, such as the Innate Potato which produces low levels of acrylamide, known to be cancer-causing in humans. GE has also contributed to improved food security through yield improving crops such as herbicide tolerant crops. The first two essays of this dissertation examine consumer acceptance of the GE Innate Potato and the third essay evaluates adoption of farming practices associated with consequences from the over adopting of herbicide tolerant crops.

The first two essays use data from lab auctions to examine how injected information affects consumer's willingness-to-pay (WTP) for GE and conventional potato products. Consumers receiving information containing positive statements about genetic engineering to improve food safety and information containing the risks of acrylamide consumption had significantly higher WTP for GE potato products. The WTP was highest when these two types of information were paired. However, the injected information did not significantly impact a consumer's WTP for conventional potato products, even after being informed of the cancer-causing potential of acrylamide.

In the first essay I also find order of information is important when receiving both positive and negative information about GE products. Consumers had a significantly higher WTP when positive information follows negative information but not if the order is reversed. On the other hand, if neutral information precedes negative information consumers have a significantly higher WTP but not vice versa.

The third essay seeks to identify attributes of farmers that affect adoption of resistance management practices (RMPs) for coping with herbicide resistance in GE crop varieties. I find age, gender, and education significantly affect a farmer's use of certain RMP groups. Younger farmers are more likely to use cultural intensive, mechanical intensive, and labor intensive RMPs. Male farmers and farmers with more years of formal education are more likely to use chemical and cultural RMPs. I also test for complementarity of RMP bundles and find farmers are more likely to use all RMPs simultaneously than individually.

CHAPTER 1. INTRODUCTION

Over the past 70 years, U.S agricultural output has more than doubled due to increases in the genetic potential of crops through plant breeding and developing new inputs and management strategies to protect yield potential. Pathogens, including insects, weeds, and fungi exist in the environment and their presence is a threat to high crop yields. Historically, farmers have used hand-weeding and mechanical weed controls, but commercial herbicides were developed starting in the 1950s. Commercial insecticides were developed later. Pesticide use in the U.S. increased more than tenfold between 1948 and 1980. This increase was mainly due to higher crop yields (larger revenue), and reduced input costs (less labor, fuel, and machinery used) for pest control. Specifically, herbicide adoption for major crops allowed farmers to switch from cultivation or other weed control methods to rely solely on herbicides (Fernandez-Cornejo et al., 2014). However, pesticides pose a potential risk to human health from direct exposure to farm workers, from consumer exposure to pesticide residue, and from the environmental damage caused by pesticide infiltration of ground and surface water. In 1996, genetically engineered herbicide tolerant crops became commercially available to farmers, and this introduced a new method of weed control.

A string of scientific, technical, and legal advances was needed before herbicide tolerant (and insect resistant) crops became available to farmers. In 1953, James Watson and Francis Crick first correctly formulated the structure of the DNA molecule as a double helix and shortly thereafter showed how it replicated. In 1973, Stanley Cohen and Herbert Boyer discovered recombinant DNA, a method by which genetic material could be cut into small piece and inserted into another species. The insertion in other species was possible because the DNA from all organisms share the same chemical structure. In 1980, Stanford University applied for a patent on the Cohen and Boyer gene splicing techniques, and the patent permitted licensing of the key tool used in future genetic engineering, i.e., human introduction or changes in DNA, RNA, or proteins in an organism to express a new trait or change the expression of an existing trait. The final link in the change of necessary events was the US Patent Office decision in *ex parte* Hibberd (1985) that patent protection extends to plants, including hybrids and other plants. The use of biotech methods facilitated proof of novelty (Huffman 2011).

Genetically engineered (GE) crop traits can be classified into one of three generations, but I focus on the first two. First generation GE crops feature enhanced input traits, such as herbicide tolerant (HT) or insect resistant (IR) varieties. Some problems associated with this new GE technology were the rise of pesticide resistance with the intense use of these new biological controls. The second-generation features output-enhancing traits such as nutrient-enhancement and enhanced food safety as in the case of low-acrylamide forming crops. Lastly, the third-generation of GE crops include traits to allow the production of plant-made pharmaceuticals and products beyond traditional foods.

In 1994 the USDA Animal and Plant Health Inspective Service (APHIS) approved the first second-generation GE crop, the FlavrSavr Tomato. This tomato was modified to delay premature fruit softening leading to a longer shelf life. However, since 1994 there have been very few second-generation GE crops developed and approved by USDA APHIS with the most recent being the Arctic Apple and Innate Potato. The Arctic Apple is engineered to keep from browning to reduce food waste due to superficial bruising and browning. The Innate Potato is engineered to be low-bruising and low-blackening (reduces food waste in processing) and reduced potential for forming high concentrations of a probable carcinogen, acrylamide.

The objective of this dissertation is (1) to examine how subject's information and information injected into lab experiments affect how well-informed consumers are about biotechnology and acrylamide exposure and how much they are willing-to-pay for new low acrylamide GE potato products, and (2) identify attributes of farmers and farms that affect adoption of resistance management practices (RMPs) for coping with herbicide resistance in GE crop varieties. U.S. consumer acceptance of genetically engineered products has not been widespread, which is manifested in preferences for mandatory labels. Key factors influencing consumers' attitudes of GE crops are the perception of risk and benefits and knowledge about the enhanced traits (Lucht, 2015).

Weeds (and insects) are living organisms that inherently want to survive and have the capacity to change biologically becoming resistant to new pest controls. The widely used HT Roundup Ready crops are modified such that crops will have limited damage from direct exposure to Roundup. Roundup, also known by its active ingredient, glyphosate, was released in 1974. It is a broad-spectrum herbicide reported to have very low toxicity to mammals, birds, and fish. However, when first released, glyphosate could only be used before crop seeding since it is a non-selective herbicide and will damage crops in addition to the targeted weeds. The introduction of Roundup Ready crops allows glyphosate to be used on crops pre- and post-emergence (before, during, and after crops are planted). As a result, glyphosate use has increased dramatically since 1996 while the use of all other herbicides declined (Livingston et al., 2015).

Glyphosate is becoming less effective at controlling weeds and The International Survey of Herbicide Resistant Weeds identified 17 glyphosate-resistant weed species currently infesting farms in the United States (Heap, 2018). Glyphosate-resistant weeds are not dying with glyphosate applications and are decreasing crop yields and increasing weed control costs. Farmers are having to find alternative methods of weed control to delay the onset and spread of resistant weeds (known as resistance management practices).

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CHAPTER 2. HOW INFORMED ARE CONSUMERS ABOUT NEW FOOD TECHNOLOGY? A ROLE FOR NEW INFORMATION

Introduction

Potatoes have remained a leading vegetable crop in the United States. In 2017, the U.S. produced 44 billion pounds of potatoes. Sixty-four percent of the production are for processed potatoes, corresponding to 82 pounds of processed potatoes per capita. However, the per capita availability of processed potatoes has been gradually declining since 1996 (Parr et al., 2018).

In 2002, acrylamide was discovered in potatoes when cooked at temperatures exceeding 250 degrees Fahrenheit (Tareke et al., 2002). This occurs when potatoes are fried, baked, or roasted to make processed potato products, such as French fries, potato chips, and hash browns. The International Agency for Research on Cancer (IARC) designates acrylamide as a "probable human carcinogen" (Lineback et al., 2012). Under California's proposition 65, major restaurant chains that serve fried potato products must post a warning that the products contain acrylamide, a chemical known to the state of California to cause cancer (OAG, 2008). Acrylamide is a by-product of the Maillard reaction, which also produces the dark-colored pigments or browning of French fries, potato chips, and hash browns. Acrylamide occurs naturally when asparagine (an amino acid) and reducing sugars are heated to high temperatures (250°F). Generally, the acrylamide content rises as the pigments become darker (Bethke and Bussan, 2013).

Due to the cancer risk of acrylamide, the U.S. potato industry has sought to decrease or even eliminate acrylamide from potato products sold in California (California Department of Justice, 2008). Conventional breeding of potatoes and alternative potato storage procedures have been unsuccessful in significantly reducing acrylamide formation during high-temperature cooking of potatoes, but methods using biotechnology have seen success. Scientists have used gene editing technology to create low-acrylamide potatoes. The new potatoes have significantly reduced acrylamide formation during processing and low-bruising, while in storage, and low-blackening properties, when a fresh potato is cut by a knife (Bethke and Bussan, 2013).

Since acrylamide is not well known among U.S. consumers and low-acrylamide potatoes are a new product, this study evaluates consumers' willingness-to-pay (WTP) for these biotech potatoes. Further, we examine the effects of injecting pre-packaged information into consumers' decision making reflected in their WTP for conventional and low-acrylamide biotech potatoes. We test how the information received affects consumers' self-reported knowledge on biotechnology and acrylamide.

To elicit a consumer's true willingness-to-pay for conventional potatoes and potatoes made using biotechnology, we used a random *n*-th price auction. This auction mechanism was first developed by Shogren and others in 2001. They argue the mechanism induces sincere bidding by subjects especially by off-margin bidders. Here, off-margin bidders value the product much lower than the market-clearing price. In other price auctions, such as a second-price auction, these off-margin bidders do not bid their true value because they do not see a chance of winning the auction. However, with the *n*-th price auction, each participant has a positive probability of submitting the winning bid, which in turn elicits their true WTP for the product (Shogren et al, 2001).

Rousu and others (2007) developed a method for valuing information within the *n*-th price auction framework. Two *n*-th price auctions are completed. First subjects bid on the product before receiving any information. After the first auction, they are given third-party information followed by a second auction. The pre- and post-information bids are differenced to determine the value of information provided to the subjects.

In their application, Rousu and others (2007) evaluated the effect of pro-biotech and anti-biotech information on consumers' WTP for vegetable oil, tortilla chips, and potatoes, which might be genetically modified (made using biotechnology). The authors found that subjects receiving anti-biotech information had a higher WTP for conventional products compared to genetically modified products. Similarly, Huffman et al. (2007) show that subject-reported prior beliefs about genetic modification and new information affect bidding behavior for genetically modified products.

Using a similar methodology, Depositario and others (2009) found consumers have the highest WTP for genetically modified rice when they were provided positive GM information, followed by no information, negative GM information, or both positive and negative GM information. However, the difference between the effects of positive information and no information is very small. When testing the effect of receiving both positive and negative information, Depositario et al. (2009) did not consider an ordering effect. In an application to evaluate the demand for fish, Marette et al. (2008) found the order in which subjects receive information significantly affects their preferences. More participants switched to the healthier fish if they received information containing the benefits of the healthier fish followed by information containing the risks of the other option.

Using segments of the data for this study, McFadden and Huffman (2017a) found subjects exposed to negative information on technology significantly reduced WTP for potato products. Conversely, Lacy and Huffman (2016) find subjects exposed to positive information about the technology and risks associated with exposure to acrylamide, increases consumers' WTP for biotech potatoes. Additionally, information on the risks associated with acrylamide and information on the benefits of reducing acrylamide exposure increase consumers' WTP for biotech potatoes (McFadden & Huffman, 2017a; McFadden & Huffman, 2017b).

In this paper, we analyze the effect of varying information and order of information on consumer's willingness-to-pay for conventional and biotech potato products. This study shows new information significantly affects a consumer's WTP for biotech potato products and the impact depends on the order of information received. The probability of a consumer WTP more for biotech potatoes after receiving information is greatest when consumers receive both informative/neutral information on acrylamide and positive information on genetic engineering jointly. But the effect on WTP of these two statements separately paired with negative information varies and is dependent on information order.
Additionally, we evaluate how information affects self-reported knowledge of biotechnology and acrylamide. Individual differences affect a subject's perceived knowledge gain about biotechnology, but the information the consumer receives has no significant effect on biotechnology knowledge. On the other hand, receiving any of the information statement combinations included in this study leaves consumers significantly more informed about acrylamide.

Experimental Design

The experiments were conducted in three locations, each with their own recruiting agency. The Survey and Behavioral Research Services (SBRS) at Iowa State University developed the recruitment protocol. Target subjects were 18 to 65 years of age, could follow directions, write in English, and were willing to come to a common location at a specified time. Potential participants were told that an Iowa State University project was recruiting subjects to participate in sessions on how households select food and household products. Further, the sessions were described as a food preference experiment designed like an auction that would take 75 minutes for which participants would receive $65.

Recruitment for Des Moines, Iowa was conducted by SBRS who used a set of randomly selected landline telephone numbers. The recruitment for Los Angeles, California and Boston, Massachusetts was conducted in a different manner than Des Moines. For both locations we collaborated with market research companies. Focus and Testing, located in Los Angeles, has a subject pool of 100,000 adults. The company randomly selected participants from their pool to participate in our sessions. Similarly, Answer Quest, located in Boston, randomly selected participants from their list of 60,000 potential subjects. The subject pools for both locations are comprised of individuals who have previously participated in a market research projects with the company, but not experimental auctions.

At each location, the lab was laid out classroom-style with a display table in the front of the room. The products were placed on the table before subjects were admitted to the lab and covered with plastic totes until the subjects were placing bids on those specific products. Experimental potato products were packaged in transparent plastic bags with plainly designed food labels. This was to ensure no trademark, brand, or other information was on the bags that could further influence bid prices.

Subjects could choose among four starting times at each location with two concurrent sessions taking place at each time. Upon arrival at the lab site and completing a consent form, subjects were alternately assigned to rooms A and B. Each session was conducted by a session monitor (who remained the same for each location) and one assistant and consisted of the same ten steps (see Figure 2.1). The first three experiments (9:00AM, 11:30AM, and

1:30AM) had three different potato products - a 5 lb. bag of fresh whole potatoes, 12 oz. bag of classic cut potato chips, and 2 lb. bag of frozen French fries. The subjects participating in these experiments received a scientific perspective, industry perspective, environmental perspective, or a combination of two perspectives. While the day's fourth experiment (3:30PM) consisted of a 5lb. bag of fresh whole potatoes and 12 oz. bag of fresh cut diced potatoes labeled as fresh cut potato dices. The subjects in the last experimental sessions received a company perspective, environmental perspective, or both perspectives.

In Step 1, the subjects were greeted by a receptionist and asked to read and sign an informed consent form. Once the form was completed, the subjects were assigned an ID number, handed a packet of project materials, and told to enter the lab and take a seat.[1] While waiting for the experiment to start, subjects were asked to complete a pre-auction questionnaire that collected socio-economic information and information about use of food labels while shopping for food products. In addition, subjects were asked to state their knowledge about biotech foods, non-biotech foods, and acrylamide before the experiments.[2] This covers the type of pre-auction information collected. To relieve subjects' concerns about a credit constraint in the experiment, each subject was, at this point, paid $65 for participating in the experiments and asked to sign a receipt. The auction was not expected to exhaust the $65 so there is no expectation that the budget constraint would bind at $65.

In Step 2 subjects were informed that they would be participating in an auction, and there would be two practice rounds of bidding to learn the auction mechanism. Subjects

[1] Individuals who arrived together, e.g., a husband and wife, or mother and daughter, etc., were assigned to different sessions.

[2] By asking about knowledge in more than one area, we believe that any one of these questions is unlikely to bias our experimental results. Also, those subjects that indicate that biotechnology and GMOs are different are anticipated to be more informed about this area of science than others.

were told it was always in their best interest to bid their true preferences. Subjects were asked to direct all questions to the monitor and to refrain from communicating with other subjects.

Next, the session monitor read through an explanation of the random *n-th* price auction and addressed any questions raised by the subjects. The auction was explained in 5 easy steps: 1) subjects would be asked to come to the front of the room, single file, and examine product(s) on a display table, 2) subjects were to return to their seat and write down, on a bid sheet attached in their packet, the bid for the product(s), 3) bid sheets were collected by the session monitor and assistant, bid prices were ranked from highest to lowest for each product, and the binding round (when more than one round of bidding occurs) randomly selected, 4) the random price would be randomly selected, and 5) the monitor will notify winners for each product using ID numbers. The session monitors informed subjects it was in their best interest to bid how much they truly valued each product.

In Step 3, to get the subjects familiar with the auction mechanism, they were trained to bid on a single product, a generic ceramic coffee mug. Subjects were asked to come to the front of the room, one-by-one, to view the product and then return to their seats.[3] They were told to fill out a bid sheet attached to their packet, detach it and place it face down on the table in front of them. The monitor and assistant collected the bid sheets and recorded the bids and ID number for each bidder in an excel spreadsheet. Bids were ranked sequentially from highest to lowest. The rank of the winning bid was determined by randomly drawing a number from a uniform distribution over 2 to k, where k is the number of subjects in a session. The random number, n, determined the rank of the random price. For example, if

[3] We used non-food items in our practice rounds so as to reduce impacts on later bids on experimental products (Nunes and Boatwright 2004).

$k = 16$ and the random *n* is 4, the 3 subjects that bid strictly higher than the random price were the winners, and they paid the random price (4th highest price). These ranked bids with ID numbers and random *n-th* price were displayed on a screen in front of the room.

In Step 4, subjects were asked to complete a short, four question quiz on the auction format, and the session monitor reviewed the answers and addressed questions. After questions from this round were resolved, the monitor moved on to Step 5, the second practice round, to familiarize the subjects with bidding on three (or two) products at a time. The products were: a notepad, binder, and package of pens for the first three experimental times at each location and a notepad and package of pens for the last experiment time.

In Step 6, subjects placed bids on real experimental products: two rounds of bidding on a 5 lb. bag of Russet Potatoes, 12 oz. bag of classic cut potato chips, and 2 lb. bag of frozen French fries for the first three experiment times and a 5 lb. bag of Russet Potatoes and 12 oz. bag of fresh cut potato dices for the last sessions. To ease budget constraint issues, subjects were told that winners of these auctions would purchase at most one unit of each of the commodities. In round 1, the products carried either a conventional or biotech food label (see Figure 2.2).[4] The order in which subjects saw either conventional or biotech products was randomized to minimize order effects in bidding. Subjects were asked to come to the front of the room, view the products, return to their seats, and place their bids on bid sheets. Once completed, the bid sheets were collected by the monitor and assistant. In round 2, the participants were asked to bid on the same type of products as round 1 but this time the products were conventional if they were biotech in round one and vice versa.

[4] A private food company supplied the project with experimental products for the lab displaces that were authentic and matched the contents stated on the food labels.

In Step 7, subjects were asked to read the information statement(s) included in their packet. Copies of the information packets are presented in Figures 2.3 – 2.6. Subjects were given about 10 minutes to read the information. Each subject was randomly assigned to an information treatment group, which determined the particular information statement they received. The information treatments for the first three experimental starting times consisted of three different perspectives: an (positive) industry perspective on low acrylamide potatoes using biotechnology, a (informative) scientific perspective on acrylamide exposure, and an (negative) environmental group perspective on biotechnology. Subjects received one of these information statements or a combination of two with order randomized, resulting in 9 information treatment groups. While the information treatments for the last experiment sessions consisted of two different perspectives: a (positive) company perspective on using biotechnology to reduce bruising of potatoes in storage and processing and acrylamide levels in processed potato products and a (negative) environmental group perspective on biotechnology[5]. An additional two information-treatment groups were provided both information statements (company perspective followed by environmental perspective or environmental perspective followed by company perspective).[6]

After Step 7, the subjects moved on to Step 8 where they placed rounds 3 and 4 bids on experimental products. As with Step 6, the only difference between rounds 3 and 4 was whether the subjects were randomly placed in a group that saw food labels showing conventional products or biotechnology products first or second.

[5] This environmental perspective is the same for all time sessions.
[6] Some environmental groups, e.g., Greenpeace and Friends-of-the-Earth, have a strong negative perspective on GMOs and biotechnology in general, while others have a more moderated view (Greenpeace 2014; Friends-of-the-Earth 2014).

After all bids from Step 8 were collected by the monitor and assistant, subjects moved on to Step 9 where they were asked to complete a short post-auction questionnaire. There were questions about household consumption patterns for potatoes and potato products, about how well the subject understood the information treatment that they received and read and re-examined how well the subject was informed about biotechnology and acrylamide after participating in the auction and reading the information treatment included in their packet. While the participants were completing the questionnaire, the monitor and assistant were inputting the bids for experimental products into a computer spreadsheet.

In Step 10, subjects were informed that the biotechnology products were not currently available in grocery stores and that winners would receive conventional potato products obtained from a local grocery store. The monitor then randomly chose the binding round from the two rounds of bidding on the conventional products, displayed the ranked bids for this round for both products, and then chose the random price or random *n*.[7] Winners were then identified by ID number. Monitors and assistants then collected packets from the subjects in the session, the winners were escorted to the stock room to purchase the products, and the subjects who did not win were told that they were dismissed and free to leave.

Data

Table 2.1 presents the summary statistics for socioeconomic characteristics, location, and information statements and Table 2.2 displays mean bid differences by information. Of the 403 participants, 139 are from Los Angeles, 128 are from Boston, and 136 are from Des Moines. The average age of the participants is 43 years old with 14.4 years of education, equivalent to a two-year degree. Thirty-eight percent are male, which is similar to the

[7] For winners of fresh-cut potato dices, they received a 12 oz package of a close substitute, Simply Potatoes™, a product available in the dairy case of major grocery stores and super markets.

composition of grocery store shoppers, and the average household income is $75,177.06. When reporting their knowledge about biotechnology and acrylamide, 41% were at least somewhat informed about biotechnology while only 10% were at least somewhat informed about acrylamide. Additionally, 88% of the participants reported reading food labels when they purchase a new product for the first time, and 45% view GM and biotechnology as different.

Of the 403 participants, 235 received just one information statement and 168 received two information statements. On average, participants bid less post-information relative to pre-information as can be seen with the mean bid differences greater than zero, in Table 2.2, for all potato products. However, mean bid differences vary by information statements received.

Regression Model

First, we consider a model of willingness-to-pay for the g^{th} commodity, v^{th} variety, by the i^{th} subject receiving the j^{th} information treatment, W_{ij}^{gv}. The commodities are a 5 lb. bag of fresh whole potatoes, 12 oz. bag of classic cut potato chips, 2 lb. bag of frozen French fries, and 12 oz. bag of fresh cut potato dices. For all goods, the varieties are conventional and biotechnology products. For fresh cut potato dices, the varieties are slightly different; they are conventional (with sodium bisulfite) and low acrylamide and sulfite free (achieved using potatoes grown with seed improved by biotechnology).[8] Each subject bids on a set of products before receiving a packaged information treatment, and then again after the injection of the informative treatment: (1) industry perspective, (2) scientific perspective, and (3) an environmental group perspective on biotechnology (anti-biotech), or (4) a

[8] Sodium bisulfite is a preservative used in conventional dices to limit discoloration (turning black) of the product when exposed to the air.

combination of two of the information statements. Additionally, there was a set of participants that received (5) an environmental group perspective, (6) a (positive biotech) company perspective on using biotechnology to lower bruising and acrylamide potential, or (7) a combination of the two.

We write WTP for the g^{th} commodity, v^{th} variety for the i^{th} subject receiving the *j*-type of information as:

$$W_{ij}^{gv} = X_i\beta_j^{gv} + \tau_i^{gv}I_{ij} + \varepsilon_{ij}^{gv} \quad (2.1)$$

where X_i is a set of dummy variables to account for pre-experimental knowledge, I_{ij} is an indicator for information treatment, and ε_{ij}^{gv} represents other individually small effects on W_{ij}^{gv} and it has a zero mean. The baseline model is achieved when the i^{th} individual engages in the first round of bidding (before information treatment) is:

$$W_{i0}^{gv} = X_i\beta_0^{gv} + \varepsilon_{i0}^{gv} \quad (2.2)$$

In our experiments, each of the *i* subjects bids first on commodity *g* of variety *v* before information treatment and then a second time after receiving an information treatment. Following earlier studies, e.g., Hoffman et al. (1992) and Rousu et al. (2007), we convert the WTP model into one of WTP differences—WTP before information minus WTP after information treatment:

$$W_{i0}^{gv} - W_{i1}^{gv} = X_i\left(\beta_0^{gv} - \beta_1^{gv}\right) - \tau_i^{gv}I_{i1} + \varepsilon_{i0}^{gv} - \varepsilon_{i1}^{gv} \quad (2.3)$$

$$W_{i0}^{gv} - W_{i1}^{gv} = X_i\beta^{gv} - \tau_i^{gv}I_{i1} + \varepsilon_i^{gv} \quad (2.4)$$

where $\beta^{gv} = \left(\beta_0^{gv} - \beta_1^{gv}\right)$ and $\varepsilon_i^{gv} = \left(\varepsilon_{i0}^{gv} - \varepsilon_{i1}^{gv}\right)$ and the last disturbance terms has a zero mean. Further,

$$W_{i0}^{gv} - W_{i1}^{gv} = Y_i\alpha^{gv} + \varepsilon_i^{gv} \tag{2.5}$$

where Y_i includes X_i and I_{i1} and α^{gv} includes β^{gv} and τ_i^{gv}. The advantages to this specification include that the new dependent variable in equation (2.5) can be positive, zero, or negative, and hence, the disturbance of the random disturbance term ε_i^{gv} is more likely to be normally distributed than for ε_{ij}^{gv}. Taking differences also removes any common individual fixed or random effects, including individual idiosyncrasies, which would otherwise be a possible source of biases in the estimated coefficients of the WTP equation (Greene 2003).

We are interested in determining if the information statements increase or decrease the probability of paying more for biotech potato products and conventional potato products. Therefore, the probability that equation (2.3) is less than zero must be estimated. Specifically,

$$\begin{aligned} Prob\left(W_{i0}^{gv} - W_{i1}^{gv} < 0\right) &= Prob\left(X_i\left(\beta_0^{gv} - \beta_1^{gv}\right) - \tau_1^{gv} I_{i1} + \varepsilon_{i0}^{gv} - \varepsilon_{i1}^{gv} < 0\right) \\ &= Prob\left(\varepsilon_{i0}^{gv} - \varepsilon_{i1}^{gv} < Y_i\alpha^{gv}\right) \\ &= Prob\left(\varepsilon_i^{gv} < Y_i\alpha^{gv}\right) \\ &= F(Y_i\alpha^{gv}) \end{aligned} \tag{2.6}$$

where $\varepsilon_i^{gv} = \varepsilon_{i0}^{gv} - \varepsilon_{i1}^{gv}$ and $F(\cdot)$ is a cumulative distribution function evaluated at $Y_i\alpha^{gv}$. Therefore, we can estimate equation (2.6) using a probit model.

Results

Results from fitting equation (2.6) for biotech and conventional potatoes are reported in Table 2.3. We find the information statements had very little effect on changing a consumer's WTP for conventional potatoes but did have significant effects on the WTP for biotech potatoes.

Subjects who reported believing, pre-experiment, that biotechnology and genetically modified products were different had a significantly higher WTP post-information treatment for conventional potatoes. This effect was negative but insignificant for biotech potatoes. On the other hand, subjects who reported being informed about biotechnology before the experiment had a significantly higher WTP post-information treatment for biotech potatoes. But this effect was positive and insignificant for conventional potatoes.

Compared to receiving the environmental perspective, subjects who received the industry perspective, scientific perspective, or company perspective had a higher WTP post-information for biotech potatoes. Further, the results show the order subjects receive information, when presented with more than one perspective, was significant. A subject who received both industry and scientific perspectives had a significantly higher WTP post-information relative to pre-information for biotech potatoes regardless of information order. Additionally, pairing industry and scientific perspectives results in a greater probability of a higher WTP post-information compared to receiving these statements individually. The positive biotech information and informative acrylamide information complement each other and strengthen the effect on WTP for biotech potatoes. However, for conventional potatoes, subjects who read the industry perspective first had a significantly lower WTP post-information while subjects who read the industry perspective after the scientific perspective had a higher WTP post-information, but this effect was insignificant.

When bidding on biotech potatoes, if the subject received the environmental perspective before the industry perspective he/she had a significantly higher WTP post-information. But receiving the information in the opposite order did not have a significant effect on WTP. Similarly, reading the scientific perspective first followed by the environmental perspective resulted in a significantly higher WTP for biotech potatoes post-information but the opposite information order did not significantly affect WTP. On average, the positive biotech information outweighed negative biotech information if it followed the negative information instead of preceding it. But, informative (neutral) information outweighed negative biotech information only if it preceded the negative information.

For potato chips, French fries, and potato dices we found the information statements had no significant impact on the willingness to pay for the conventional products. Compared to the environmental perspective, a subject who received the industry or scientific perspective had a significantly higher WTP for biotech French fries and biotech potato chips. Also, compared to the environmental perspective, subjects had a significant higher WTP for biotech potato dices after receiving the company perspective. Regardless of order, when a subject read both the industry and scientific perspective their WTP was significant higher post-information for both biotech French fries and potato chips. This further supports the complementarity of positive biotech information and informative acrylamide information. However, pairing negative biotech information with either positive biotech information or informative acrylamide information does not affect WTP for biotech processed potato products.

Next, we examine how a subject's self-reported pre-experiment knowledge of biotechnology and acrylamide is affected by the information statements received. As can be seen in Tables 2.7 and 2.8, the information statements did not have a significant impact on self-reported knowledge of biotechnology but had significant impacts on self-reported knowledge of acrylamide. Since subjects entered the experiment with little to no knowledge of acrylamide, it is not surprising that information distributed in the experiment significantly increased their perceived knowledge.

Conversely, our demographic variables significantly affected a subject's self-reported post-experiment knowledge of biotechnology. When a male reported being uniformed, pre-experiment, he was significantly less likely to report being informed about biotechnology after the auction. Younger subjects and those with more years of education were less likely to report being more informed about biotechnology after the experiment if they previously reported being uninformed. Also, younger subjects and those who report reading food labels were significantly less likely to report becoming more informed about biotechnology after the experiment. Higher income subjects were significantly more likely to report being informed about biotechnology after the experiment when previously reported being uninformed. After excluding the demographic variables from our regression, we find little changes in the effect of the information statements.

We find all information statement combinations significantly increased a subject's self-reported knowledge of acrylamide. When a subject reported, pre-experiment, being uninformed about acrylamide, he/she was significantly more likely to report being informed about acrylamide after the experiment. Additionally, subjects were significantly more likely to report being more informed about acrylamide after the experiment with all information statement combinations. However, LA subjects were significantly less likely to be affected by acrylamide information provided during the experiment compared to Des Moines subjects.

Conclusion

This paper has shown new information affects consumer's willingness to pay for new biotech potatoes and self-reported knowledge of acrylamide. However, consumer's WTP for conventional potato products remain unaffected. Consumers are willing to pay more for products potentially viewed as safer or reduced cancer risk, but not willing to pay less for products which could potentially contain a cancer-causing agent. Many subjects entered our experiment with very little knowledge about this cancer-causing agent, acrylamide, but reported being more informed about acrylamide after reading injected information.

Additionally, we show order of information is important when consumers receive both positive and negative information. If positive information follows negative information consumers' WTP is significantly higher for biotech potatoes after receiving the information, but their WTP is not significantly different if positive information precedes negative information. If informative/neutral information precedes negative information, consumers have a significantly higher WTP post-information, which is not significantly different if the order is reversed. On the other hand, if consumers receive both positive and informative information the WTP for biotech potatoes is significantly higher post-information regardless of the order. And the effect is greater with both information statements compared to receiving the information separately.

To increase demand for low-acrylamide potato products, retailers should provide consumers with information on the benefits of genetic engineering to reduce acrylamide and potential cancer-causing attributes of acrylamide. From our results, providing this information will increase the demand for biotech potatoes while not affecting the demand for conventional potatoes. The information will also increase awareness of the potential dangers of acrylamide consumption, which is relatively unknown by the public.

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Figures and Tables

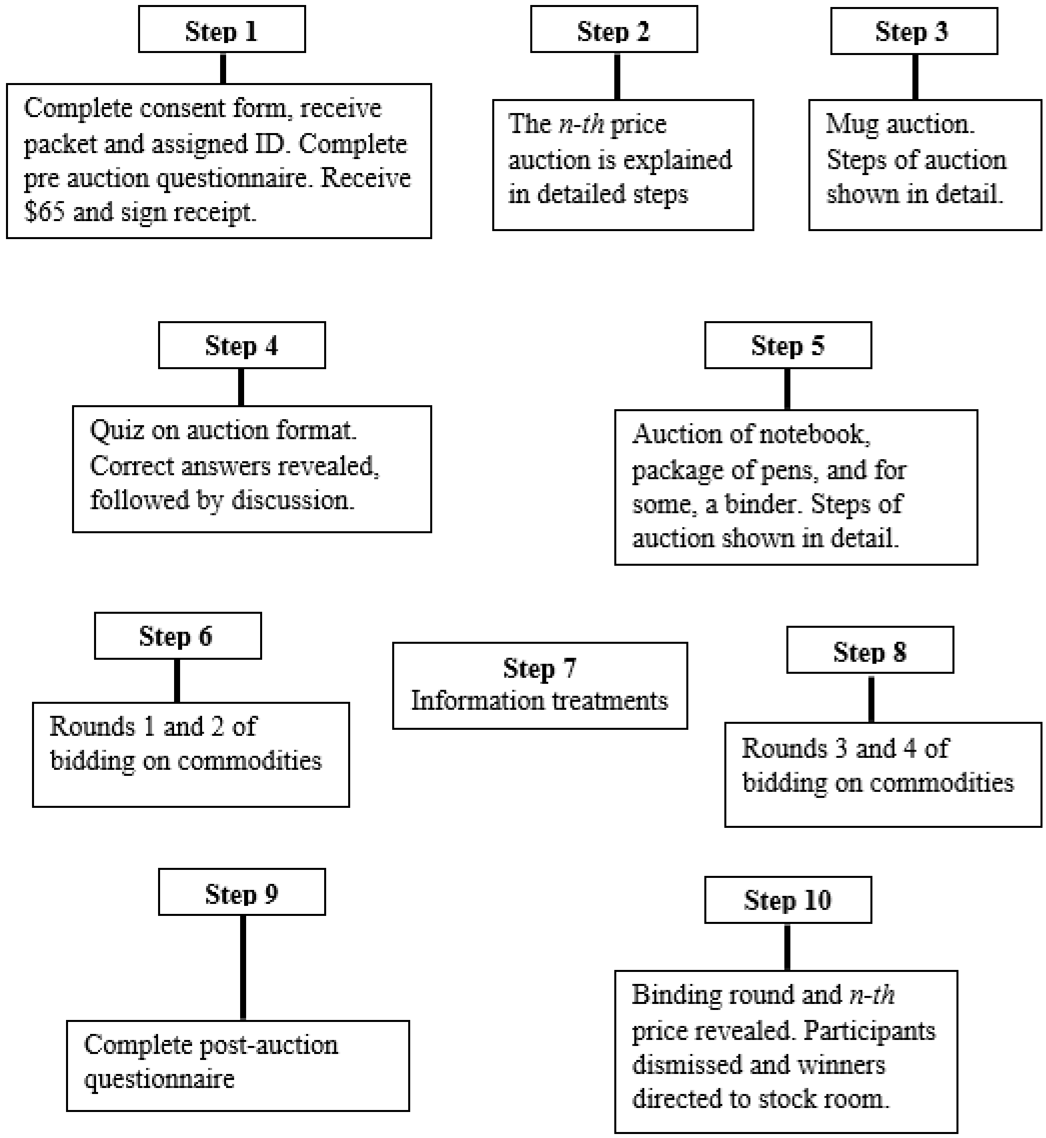

Figure 2.1 Steps in the Experiment

Conventional Product Labels	**Biotechnology Product Labels**
Fresh Russet Potatoes Net wt: 5 lbs.	Fresh, Low Acrylamide Russet Potatoes Net wt: 5 lbs. Product Made Using Biotechnology
Frozen, Crinkle Cut French Fries Net wt: 2 lbs.	Frozen, Low Acrylamide, Crinkle Cut French Fries Net wt: 2 lbs. Product Made Using Biotechnology
Potato Chips Net wt: 12 oz.	Low Acrylamide Potato Chips Net wt: 12 oz. Product Made Using Biotechnology
Fresh-Cut Potato Dices with Sodium Bisulfite Net wt: 12 oz.	Fresh-Cut Potato Dices, Low Acrylamide, Low Bruise Net wt: 12 oz. Potatoes Grown with Seed Improved by Biotechnology

Figure 2.2 Auction Labels

Table 2.1 Sample Summary Statistics

Variables	**Mean**	**Standard Deviation**
Demographics		
Income ($)	75,177.06	46,396.33
Male	0.382	0.487
Age	42.93	13.82
Education (years)	14.39	2.13
Reads Food Labels (=1)	0.881	0.324
GM and Biotech different (=1)	0.447	0.498
Informed about biotechnology before exp.	0.409	0.492
Informed about acrylamide before exp.	0.099	0.299
Location		
Los Angeles	0.345	0.476
Boston	0.318	0.466
Information Statements		
Scientific Perspective	0.136	0.344
Industry Perspective	0.139	0.346
Company Perspective	0.089	0.286
Industry followed by Scientific Perspective	0.067	0.250
Scientific followed by Industry Perspective	0.060	0.237
Scientific followed by Environmental Perspective	0.052	0.222
Environmental followed by Scientific Perspective	0.047	0.212
Industry followed by Environmental Perspective	0.055	0.227
Environmental followed by Industry Perspective	0.057	0.232
Company followed by Environmental Perspective	0.040	0.196
Environmental followed by Company Perspective	0.040	0.196

Table 2.2 Mean Bid Differences

Bid differences, WTP pre - WTP post information	**N**	**Mean**	**Std Dev**
All Bidders			
Conventional potatoes	403	0.060	1.246
Biotech potatoes	403	0.177	1.543
Conventional French fries	301	0.160	1.164
Biotech French fries	301	0.197	1.369
Conventional potato chips	301	0.087	1.011
Biotech potato chips	301	0.072	1.189
Conventional potato dices	102	0.046	1.157
Biotech potato dices	102	0.356	1.048
Bidders receiving environmental-only perspective			
Conventional potatoes	88	0.108	1.710
Biotech potatoes	88	1.155	1.952
Conventional French fries	54	0.261	1.692
Biotech French fries	54	1.040	1.847
Conventional potato chips	54	0.171	1.277
Biotech potato chips	54	0.777	1.465
Conventional potato dices	34	0.218	1.227
Biotech potato dices	34	0.731	1.095
Bidders receiving industry-only perspective			
Conventional potatoes	56	0.253	0.688
Biotech potatoes	56	-0.007	1.231
Conventional French fries	56	0.201	0.650
Biotech French fries	56	0.192	1.238
Conventional potato chips	56	0.065	0.657
Biotech potato chips	56	0.062	0.939
Bidders receiving science-only perspective			
Conventional potatoes	55	0.278	1.160
Biotech potatoes	55	-0.546	1.335
Conventional French fries	55	0.260	0.966
Biotech French fries	55	-0.301	1.227
Conventional potato chips	55	0.261	0.870
Biotech potato chips	55	-0.359	1.271
Bidders receiving company-only perspective			
Conventional potatoes	36	-0.092	0.687
Biotech potatoes	36	-0.193	1.274
Conventional potato dices	36	-0.034	1.068
Biotech potato dices	36	-0.039	0.834
Bidders receiving industry followed by science perspective			
Conventional potatoes	27	0.337	0.616
Biotech potatoes	27	-0.290	0.739
Conventional French fries	27	0.263	0.644
Biotech French fries	27	-0.254	0.813
Conventional potato chips	27	0.160	0.572
Biotech potato chips	27	-0.432	0.842

Table 2.2 (continued)			
Bid differences, WTP pre - WTP post information	**N**	**Mean**	**Std Dev**
Bidders receiving science followed by industry perspective			
Conventional potatoes	24	0.124	0.850
Biotech potatoes	24	-0.595	0.756
Conventional French fries	24	0.167	0.975
Biotech French fries	24	-0.509	0.882
Conventional potato chips	24	0.258	0.780
Biotech potato chips	24	-0.506	0.829
Bidders receiving industry followed by environmental perspective			
Conventional potatoes	22	-0.117	0.944
Biotech potatoes	22	0.567	0.768
Conventional French fries	22	0.157	0.714
Biotech French fries	22	0.457	1.103
Conventional potato chips	22	0.038	0.495
Biotech potato chips	22	0.245	0.443
Bidders receiving environmental followed by industry perspective			
Conventional potatoes	23	-0.650	2.127
Biotech potatoes	23	-0.004	1.231
Conventional French fries	23	-0.233	1.896
Biotech French fries	23	0.401	1.219
Conventional potato chips	23	-0.440	1.927
Biotech potato chips	23	0.180	1.094
Bidders receiving science followed by environmental perspective			
Conventional potatoes	21	-0.226	1.210
Biotech potatoes	21	0.191	1.098
Conventional French fries	21	-0.190	1.179
Biotech French fries	21	0.252	0.766
Conventional potato chips	21	-0.211	0.995
Biotech potato chips	21	0.380	0.701
Bidders receiving environmental followed by science perspective			
Conventional potatoes	19	-0.289	1.411
Biotech potatoes	19	0.184	2.386
Conventional French fries	19	0.177	1.132
Biotech French fries	19	0.186	1.467
Conventional potato chips	19	0.121	0.924
Biotech potato chips	19	0.123	1.575
Bidders receiving company followed by environmental perspective			
Conventional potatoes	16	-0.022	0.855
Biotech potatoes	16	-0.262	0.774
Conventional potato dices	16	-0.294	0.825
Biotech potato dices	16	0.079	0.737

Table 2.2 (continued)

Bid differences, WTP pre - WTP post information	**N**	**Mean**	**Std Dev**
Bidders receiving environmental followed by company perspective			
Conventional potatoes	16	0.294	0.737
Biotech potatoes	16	0.842	1.339
Conventional potato dices	16	0.204	1.456
Biotech potato dices	16	0.721	1.295

Table 2.3 Probit results: Probability of WTP more for biotech (and conventional) potatoes after information

	Biotech	Conventional
Biotech and GM are different	-0.0463 (-0.017)	-0.3198* (-0.114)
Informed about biotechnology before information	0.4030** (0.150)	0.1508 (0.053)
Informed about acrylamide before information	-0.1247 (-0.450)	-0.0662 (-0.024)
Industry Perspective	1.0988** (0.417)	-0.3622 (-0.135)
Science Perspective	1.3500** (0.499)	-0.5395* (-0.204)
Industry followed by Science Perspective	1.4007** (0.507)	-1.0669** (-0.406)
Science followed by industry perspective	1.4923** (0.530)	0.3309 (0.108)
Industry followed by Environmental Perspective	-0.6076 (-0.192)	-0.2415 (-0.090)
Environmental followed by Industry perspective	0.8703* (0.337)	0.1781 (0.061)
Science followed by environmental perspective	0.7262* (0.283)	-0.1934 (-0.071)
Environmental followed by Science perspective	0.3262 (0.126)	0.0003 (0.0001)
Company Perspective	1.1778** (0.443)	0.1414 (0.049)
Company followed by environmental perspective	0.7472 (0.291)	-0.1352 (-0.049)
Environmental followed by company perspective	0.3784 (0.146)	0.0886 (0.031)
330 Session	0.1161 (0.043)	-0.0453 (-0.016)
Boston	0.2577 (0.096)	-0.1886 (-0.068)
LA	0.4223* (0.158)	-0.0775 (-0.028)
Monitor	0.1526 (0.056)	-0.1884 (-0.067)
_cons	-1.6033**	0.9410**
N	403	403
R^2	0.158	0.065

* significant at the 5% level, ** significant at the 1% level
Marginal effects in parentheses

Table 2.4 Probit results: Probability of WTP more for biotech (and conventional) French fries after information

	Biotech	Conventional
Biotech and GM are different	0.1208 (0.043)	-0.2021 (-0.078)
Informed about biotechnology before information	0.0002 (0.0001)	-0.1431 (-0.055)
Informed about acrylamide before information	-0.0623 (-0.022)	0.4424 (0.159)
Industry Perspective	0.6961* (0.262)	-0.2378 (-0.093)
Science Perspective	0.9935** (0.375)	-0.3892 (-0.153)
Industry followed by Science Perspective	1.1408** (0.431)	-0.4793 (-0.189)
Science followed by industry perspective	1.3766** (0.507)	-0.2706 (-0.106)
Industry followed by Environmental Perspective	-0.0445 (-0.016)	-0.4303 (-0.170)
Environmental followed by Industry perspective	0.0476 (0.017)	-0.1909 (-0.075)
Science followed by environmental perspective	0.5002 (0.190)	-0.0409 (-0.016)
Environmental followed by Science perspective	0.2298 (0.085)	-0.1458 (-0.057)
Boston	0.3553 (0.129)	-0.1674 (-0.065)
LA	0.3402 (0.123)	-0.0860 (-0.033)
Monitor	0.2095 (0.074)	-0.2100 (-0.081)
Constant	-1.4498**	0.7938**
N	301	301
R^2	0.110	0.027

* significant at the 5% level, ** significant at the 1% level
Marginal effects in parentheses

Table 2.5 Probit results: Probability of WTP more for biotech (and conventional) potato chips after information

	Biotech	Conventional
Biotech and GM are different	0.0296 (0.011)	-0.3697* (-0.142)
Informed about biotechnology before information	0.1485 (0.053)	0.0227 (0.009)
Informed about acrylamide before information	0.1750 (0.064)	0.1359 (0.051)
Industry Perspective	0.6716* (0.255)	-0.1930 (-0.075)
Science Perspective	0.9943** (0.377)	-0.4266 (-0.167)
Industry followed by Science Perspective	1.313** (0.488)	-0.6080* (-0.239)
Science followed by industry perspective	1.2699** (0.474)	-0.2710 (-0.106)
Industry followed by Environmental Perspective	-0.0488 (-0.017)	-0.3281 (-0.129)
Environmental followed by Industry perspective	0.0942 (0.034)	-0.1753 (-0.068)
Science followed by environmental perspective	0.3153 (0.119)	0.1573 (0.059)
Environmental followed by Science perspective	0.5627 (0.216)	-0.1422 (-0.055)
Boston	0.1891 (0.069)	0.1100 (0.042)
LA	0.2725 (0.099)	0.0603 (0.023)
Monitor	0.1437 (0.051)	-0.1286 (-0.049)
Constant	-1.3798**	0.6514**
N	301	301
R^2	0.108	0.031

* significant at the 5% level, ** significant at the 1% level
Marginal effects in parentheses

Table 2.6 Probit results: Probability of WTP more for biotech (and conventional) potato dices after information

	Biotech	Conventional
Biotech and GM are different	-0.5127 (-0.153)	0.3209 (0.104)
Informed about biotechnology before information	0.3954 (0.125)	0.2452 (0.079)
Informed about acrylamide before information	-0.0173 (-0.005)	-0.8989 (-0.339)
Company Perspective	1.1420** (0.377)	0.5023 (0.157)
Company followed by environmental perspective	0.6764 (0.236)	0.6600 (0.183)
Environmental followed by company perspective	-0.0231 (-0.007)	0.0617 (0.020)
Boston	-0.5389 (-0.153)	-0.8636* (-0.303)
LA	0.5276 (0.171)	-0.8525* (-0.297)
Monitor	-0.3147 (-0.097)	0.1159 (0.038)
Constant	-1.0046*	0.6457
N	102	102
R^2	0.199	0.122

* significant at the 5% level, ** significant at the 1% level
Marginal effect in parentheses

Table 2.7 Changes in self-reported knowledge of biotechnology

	Informed about biotech after info when previously uninformed		More informed about biotech after information	
Income	0.000003* (0.0000)	--	0.000002 (0.000)	--
Male	-0.2917* (0.1358)	--	-0.2921* (0.1374)	--
Age	-0.0151** (0.0049)	--	-0.0199* (0.0051)*	--
Years of Education	-0.0957** (0.0334)	--	-0.0570 (0.3368)	--
Reads food labels	-0.3405 (0.2063)	--	-0.4337* (0.2208)	--
Biotech and GM are different	-0.2038 (0.1327)	--	-0.0454 (0.1358)	--
Industry Perspective	-0.1456 (0.2224)	-0.1802 (0.2152)	-0.1018 (0.2232)	-0.1413 (0.2154)
Science Perspective	-0.1750 (0.2249)	-0.1171 (0.2162)	-0.1746 (0.2267)	-0.1184 (0.2171)
Industry followed by Science Perspective	0.1410 (0.2976)	0.1395 (0.2763)	0.1400* (0.3001)	0.1979 (0.2834)
Science followed by industry perspective	0.1871 (0.3032)	0.1141 (0.2898)	0.4245 (0.3149)	0.3260 (03027.)
Industry followed by Environmental Perspective	0.3949 (0.3141)	0.3632 (0.3057)	0.9176 (0.3701)	0.8752* (0.3606)
Environmental followed by Industry perspective	0.1742 (0.3038)	0.1734 (0.2942)	0.1136 (0.3132)	0.1669 (0.3001)
Science followed by environmental perspective	-0.1423 (0.3139)	-0.1910 (0.3073)	0.0924 (0.3193)	0.0710 (0.3106)
Environmental followed by Science perspective	0.0261 (0.3296)	-0.0554 (0.3181)	0.0760 (0.3319)	-0.0236 (0.3208)
Company Perspective	0.0364 (0.2536)	-0.0002 (0.2489)	0.0909 (0.2564)	0.0521 (0.2519)
Company followed by environmental perspective	0.3756 (0.3550)	0.3086 (0.3442)	0.1180 (0.3569)	0.0791 (0.3448)
Environmental followed by company perspective	0.1873 (0.3587)	0.1518 (0.3432)	0.0965 (0.3680)	0.0851 (0.3479)
Boston	-0.1573 (0.1706)	-0.0942 (0.1554)	-0.1190 (0.1751)	-0.0310 (0.1591)
LA	-0.1329 (0.1603)	-0.2210 (0.1524)	-0.1227 (0.1637)	-0.1794 (0.1550)
Constant	2.3381** (0.5485)	0.1053 (0.1600)	2.3146 (0.5530)	0.3019* (0.1625)
R^2	0.070	0.014	0.080	0.023

* significant at the 5% level, ** significant at the 1% level

Table 2.8 Changes in self-reported knowledge of acrylamide

	Informed about acrylamide after info when previously uninformed		More informed about acrylamide after info	
Income	0.000001 (0.0000)	--	0.000002 (0.0000)	--
Male	0.0737 (0.1521)	--	0.1525 (0.1856)	--
Age	0.0024 (0.0056)	--	-0.0078 (0.0068)	--
Years of Education	-0.0205 (0.0380)	--	-0.0228 (0.0469)	--
Reads food labels	0.0856 (0.2280)	--	0.1411 (0.2674)	--
Biotech and GM are different	0.0927 (0.1495)	--	-0.0676 (0.1781)	--
Industry Perspective	1.1419** (0.2396)	1.1619** (0.2368)	0.9979** (0.2976)	0.9697** (0.2899)
Science Perspective	1.2281** (0.2469)	1.2717** (0.2437)	0.7707** (0.2802)	0.8323** (0.2756)
Industry followed by Science Perspective	1.7718** (0.3986)	1.7372** (0.3829)	1.2294* (0.4904)	1.2827** (0.4701)
Science followed by industry perspective	1.4628** (0.3624)	1.4817** (0.3597)	0.9375* (0.4056)	0.8919* (0.3945)
Industry followed by Environmental Perspective	1.0916** (0.3398)	1.0930** (0.3328)	0.8262* (0.4139)	0.8674* (0.4069)
Environmental followed by Industry perspective	1.1283** (0.3303)	1.1128** (0.3269)	0.8820* (0.4061)	0.8772* (0.3994)
Science followed by environmental perspective	1.1408** (0.3497)	1.1780** (0.3474)	1.1820* (0.4975)	1.1580* (0.4886)
Environmental followed by Science perspective	0.9161** (0.3478)	0.9586** (0.3429)	0.8328 (0.4300)	0.7817* (0.4179)
Company Perspective	1.3867** (0.3055)	1.4237** (0.3023)	1.0680** (0.3761)	1.1136** (0.3743)
Company followed by environmental perspective	1.2072** (0.3927)	1.1680** (0.3872)	1.0861* (0.5239)	1.0102* (0.5071)
Environmental followed by company perspective	1.4131** (0.4326)	1.4453** (0.4274)	--	--
Boston	-0.1285 (0.1983)	-0.0924 (0.1863)	-0.1769 (0.2392)	-0.0842 (0.2219)
LA	-0.4712* (0.1825)	-0.4296* (0.1755)	-0.2923 (0.2202)	-0.2497 (0.2108)
Constant	-0.1540 (0.5974)	-0.1139 (0.1704)	1.0326 (0.7293)	0.6174** (0.1889)
R^2	0.164	0.159	0.119	0.108

* significant at the 5% level, ** significant at the 1% level

Please take a few minutes to read the following.

An environmental group perspective on biotechnology

General Statement:

- Biotech plant breeding takes genes from one organism and places them into another. This process manipulates genes and alters genetic makeup and properties. The cutting of genetic material from one organism and inserting it into another is quite imprecise and can cause mutations. There has been inadequate testing of these products.
- Biotech methods frequently use antibiotic-resistant gene segments in soil bacteria or viruses and transfer them into plants. This process is risky, leading to unanticipated outcomes.
- Biotech plants are regulated by the federal government, but federal regulation relies heavily on data collected from field trials and other testing by the biotech industry.
- Biotech seeds were first marketed to U.S. farmers in the mid-1990s, and rapid farmer adoption occurred in field crops (corn, soybean, cotton and canola). Later developments have been in papaya and vegetables (sugar beet, squash and potato).
- In the United States, the sales of biotech foods have grown very rapidly. This growth is driven by self-interested producers and marketers seeking to maximize crop yields and minimize production costs.

Nutrition and Health:

- Of the laboratory plants that are successfully modified to express the “right” traits, genetic engineers select among those that look strong, healthy, and capable of further breeding. There is poor screening to eliminate varieties that produce harmful substances or low nutrient quality.
- New allergens are likely to be introduced into the food supply.
- Early research reported some health problems in laboratory animals consuming first-generation insect-resistant potatoes.
- Several scientific studies show that laboratory animals that have been fed biotech food developed one or more toxic effects on vital and/or reproductive organ functioning, relative to a control group.
- A recent Canadian study found a common protein from insect-resistant corn in the bloodstream of pregnant women and their fetuses. Another recent study found that high concentrations of this protein resulted in severe damage to human embryonic kidney cells.
- The nutritional content of biotech foods, relative to conventional foods, is variable.

Environmental Impacts and Food Security:

- Private companies are not capable of screening new biotech materials for every possible pathogen or environmental stress. Unnoticed and unsafe mutations could strike after the occurrence of extreme stress, such as plant disease outbreaks, droughts, floods, and heat waves.
- New biotech crops may cross-pollinate with other plants and are likely to cause super weeds.
- Some herbicides used on biotech crops diffuse into the air and leach into streams and waterways in some areas. These herbicides are toxic to amphibians (e.g., frogs, salamanders) and earthworms, which impacts bird populations.
- Biotech crops are doing little to help international food security or relieve hunger in poor countries. The major biotech crops, corn and soybeans, are mainly used for animal feed, biofuels, and processed human food in developed countries.

Figure 2.3 Information Statement - Environmental Perspective

Please take a few minutes to read the following

An industry perspective on low acrylamide potatoes using biotechnology

General Statement:

- In 2002, acrylamide was discovered in foods containing certain natural sugars when cooked at high temperatures (above roughly 250° F), such as French fries, hash browns and potato chips. They are also formed in the baking of bread (crust) and cookies and roasting of coffee beans.
- Acrylamide, a chemical compound, is formed in foods from naturally occurring sugars and asparagine (a building block of a protein). It is a toxin and possible carcinogen in humans.
- Conventional plant breeding efforts have resulted in only small reductions of acrylamide in processed potato products.
- In contrast, biotech methods have significantly reduced the acrylamide level in processed potato products, thereby improving food safety.
- Biotech plant breeding methods take genes from one organism and transfer them to another. In new biotech potatoes, all genes come from wild and domesticated potato varieties. Hence, this biotech method has much in common with conventional plant breeding.

Nutrition and Health:

- Long-term, low-level intake of acrylamide by lab animals has been shown to create serious health problems. One study found that consuming conventional potato chips regularly for a month caused some health changes in humans.
- Under Proposition 65, California requires certain restaurants, including Applebee's, Chili's, McDonalds, Burger King, Wendy's and KFC to post a warning stating that "cooked potatoes that have been browned, such as French fries, hash browns and baked potatoes, contain acrylamide, a chemical known to the State of California to cause cancer."
- A major biotech accomplishment has been the development of new potato varieties that have approximately a 70% reduction in acrylamide levels in processed potato products relative to conventional.
- Biotech methods were also used to develop golden rice, which enhanced vitamin A content. Other opportunities exist for enhancing consumer attributes, such as antioxidants and vitamins in food.
- All Food and Drug Administration (FDA)-approved biotech-foods have been assessed to be substantially equivalent in nutrient content to conventional foods. As such, labeling in the U.S. is voluntary.
- Biotech foods, relative to conventional foods, have similar low allergy potential.

Environmental Impacts and Food Security:

- Acrylamide is used in industrial processes to make paper, dyes, and plastics, but food and cigarette smoke are the two main sources of human exposure to acrylamide.
- Commercial potatoes are grown from pieces of whole potato and not seed. In addition, many commercial potatoes are either sterile or not sexually compatible with wild potatoes. Hence, there is very low risk of biotech potatoes crossing with other potato varieties or other plants.
- There are no adverse impacts on the environment of the new biotech potatoes.
- In general, biotech crops have reduced the use of toxic insecticides and increased the use of other environmentally friendly farming practices.
- Food security can be greatly improved with continued advancement and adoption of genetically modified crops.
- Approval is being sought for biotech potato exports to Canada, Mexico, South Korea and Japan.

Figure 2.4 Information Statement - Industry Perspective

Please take a few minutes to read the following

A scientific perspective on acrylamide exposure

General Statement:

- In 2002, acrylamide was discovered in foods containing certain natural sugars when cooked at high temperatures (above roughly 250° F), such as French fries, hash browns and potato chips. Acrylamide is also formed in the baking of bread (crust) and cookies and roasting of coffee beans.
- Acrylamide, a chemical compound, is formed in these foods from naturally occurring sugars and asparagine (a building block of a protein).
- Compared to other foods in the American diet, French fries and potato chips are a major source of acrylamide.
- The amount of acrylamide increases with longer frying or baking times and higher cooking temperatures. However, boiling, steaming, and microwaving potatoes produces negligible acrylamide.
- Under Proposition 65, California requires certain restaurants, including Applebee's, Chili's, McDonald's, Burger King, Wendy's and KFC, to post a warning stating that "cooked potatoes that have been browned, such as French fries, hash browns and baked potatoes, contain acrylamide, a chemical known to the State of California to cause cancer."
- However, the FDA has not advised people to stop eating these potato products.

Nutrition and Health:

- The International Agency for Research on Cancer (IARC) designates acrylamide as a "probable human carcinogen," and the US National Toxicology Program classifies acrylamide as "reasonably anticipated" to be capable of causing cancer in humans.
- The first health studies of acrylamide occurred in the 1960s and explored health hazards with on-the-job contact. Chronic exposure produces toxicity that weakens muscles and reflexes and leads to sensory loss.
- Evidence from studies in the 1970s and 1980s advanced the linkages between cancer and acrylamide.
- In a recent study, lab animals that consumed low doses of acrylamide placed in drinking water over a long period of time (roughly equal to annual acrylamide consumption of an adult) experienced gene damage.
- Another study found that humans who consumed conventional potato chips daily for four weeks had higher incidence of early development of cardio-vascular diseases.
- Additional studies suggest linkages between high acrylamide diets and development of breast cancer. High levels of acrylamide consumption by pregnant women have been associated with increased frequency of low birth weight babies.

Environmental Impacts and Food Security:

- Acrylamide is used in industrial processes to make paper, dyes, and plastics, but food and cigarette smoke are the two main sources of human exposure to acrylamide.
- If the occupational and health risks associated with acrylamide were to be substantially reduced or eliminated, food security would improve, especially in the United States and some other developed countries where a majority of the population regularly consumes foods that contain acrylamide.

Figure 2.5 Information Statement - Scientific Perspective

Please take a few minutes to read the following.

A company perspective on low bruising and low acrylamide potential using biotechnology

General Statement:

- Potatoes have well-known vulnerability to bruising during harvest and while in storage. In addition, a fresh potato turns brown upon cutting when exposed to the air. Recently, it has been discovered that frying or broiling potatoes at high temperatures forms acrylamide.
- This tendency for bruising causes a large amount of potato wastage and costs potato growers and processors millions of dollars annually. Sodium bisulfite is sometimes used to preserve freshness.
- In 2002, acrylamide, a chemical compound, was discovered in foods containing certain natural sugars when cooked at high temperatures (above roughly 250° F), such as French fries, hash browns and potato chips. They are also formed in the baking of bread (crust) and cookies and roasting of coffee beans.
- Acrylamide is formed from naturally occurring sugars and asparagine (a building block of a protein) in food. It is a toxin and possible carcinogen in humans.
- The Simplot Company has developed improved versions of three popular potato varieties that have significantly reduced bruising and acrylamide forming potential than conventional potato varieties. These new potato varieties are slower to oxidize after peeling or cutting. Hence, these new potato varieties provide major advantages to potato producers, processors and consumers.
- The new varieties were made possible using Innate™ technology, which is a new biotech process for moving genes swiftly and precisely from wild and domesticated potatoes into popular varieties.

Nutrition and Health:

- Food and cigarette smoke are the two main sources of human exposure to acrylamide. In the American diet, processed potato products (potato chips and cooked French fries) are the leading source of acrylamide. Long-term, low-level intake of acrylamide by lab animals has been shown to create serious health problems. One study found that consuming conventional potato chips regularly for a month caused some health changes in humans.
- Under Proposition 65, California requires certain restaurants, including Applebee's, Chili's, McDonald's, Burger King, Wendy's, and KFC, to post a warning stating that "cooked potatoes that have been browned, such as French fries, hash browns and baked potatoes, contain acrylamide, a chemical known to the State of California to cause cancer."
- Simplot's latest Innate™ potato varieties reduce acrylamide formation by approximately 90% in processed potato products cooked at high temperatures. This reduction places them below the minimum amounts of California's Proposition 65, and removes acrylamide level health concerns.
- Biotech methods were also used to develop golden rice, which enhanced vitamin A content. Other opportunities exist for enhancing consumer attributes such as antioxidants and vitamins in food.
- Biotech foods, relative to conventional foods, have similar low allergy potential.

Environmental Impacts and Food Security:

- Innate™ biotech modifies a plant's genes without incorporating foreign genes or antibiotic resistance. There are no adverse impacts on the environment or new food allergens.
- Commercial potatoes are grown from pieces of whole potato and not seed. Many commercial potatoes are either sterile or not sexually compatible with wild potatoes so there is very low risk of the Innate™ potato varieties crossing with other potato varieties or other plants.
- Innate™ potatoes have undergone extensive field testing and consumer taste testing by Simplot, and have been thoroughly evaluated by the USDA and FDA.
- Approval is being sought for Innate™ potato exports to Canada, Mexico, South Korea and Japan.

Figure 2.6 Information Statement - Company Perspective

CHAPTER 3. CONSUMER DEMAND FOR POTATO PRODUCTS AND WILLINGNESS-TO-PAY FOR LOW-ACRYLAMIDE, SULFITE-FREE, FRESH POTATO DICES: EVIDENCE FROM LAB AUCTIONS[9]

Katherine Lacy and Wallace E. Huffman[10]

Introduction

Potatoes remain a key vegetable in the American diet, being consumed as boiled, steamed, baked and fried whole potatoes, hash browns, French fries and potato chips. White potatoes are used largely for these purposes. Per capita use of white potatoes in 2013 is approximately the same as in 1980, about 115 lbs. per year, but the share going to processed foods increased from 53% to 69%. Since some of the potato is lost in processing waste, per capita consumption of white potatoes has actually declined over this period (NRC 2015). Richards et al. (1997) summarize factors affecting the aggregate demand for potatoes, but very limited up-to-date research exists on factors that affect individual household demand for fresh or processed potatoes in the United States.

In 2002, acrylamide was first identified in starchy foods cooked at high temperatures (Tareke 2002). This included high temperature cooking of traditional white potatoes, as in frying, baking or roasting to make fries, hash browns and chips, acrylamide is formed.[11] Acrylamide is a naturally occurring chemical when asparagine, an amino acid, and reducing sugars (fructose and glucose) are heated to above 250°F, such as in frying, baking and roasting. Once formed, acrylamide is a stable compound. The Maillard reaction, which

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[9] This chapter is reproduced from the published paper, Lacy, K. & Huffman, W. E. (2016). Consumer demand for potato products and willingness-to-pay for low-acrylamide, sulfite-free fresh potatoes and dices: evidence from lab auctions. *Journal of Agricultural and Resource Economics*, *41*(1), 116-137.

[10] Graduate student and Charles F. Curtiss Distinguished Professor in Agriculture and Life Sciences, respectively. Department of Economics, Iowa State University.

[11] Acrylamide does not exist in fresh potatoes or in boiled or steamed potatoes.

produces acrylamide, also produces the dark-colored pigments or browning of French fries, chips and hash browns (Bethke and Bussan 2013). In general, the acrylamide content rises with the darkening of the pigment. In addition, retail fresh cut white potatoes are treated with sodium bisulfite to retard bruising and blackening when exposed to the air (oxygen). Both acrylamide and sulfites raise food safety concerns. Based largely on animal studies, acrylamide is a neuro-toxin and potential carcinogen in humans. Moreover, as a result of a broad 2005 lawsuit brought by the State of California under Proposition 65 against the U.S. potato industry, many California restaurants are required to post signs that potato products that have browned in the cooking process contain acrylamide, a cancer-causing agent (California Office of Environmental Health Hazard Assessment). In addition, the U.S. potato industry has a mandate to largely eliminate acrylamide from potato products sold in California (California Department of Justice 2008), and it is working to lower acrylamide formation in processed potato products. Sodium bisulfite is a controversial preservative because some people are allergic to sulfides (Rangan 2010).

Biotech methods have been used to eliminate these two health risks in white potatoes.[12] Changes in potato growing and storage practices and conventional breeding of potatoes have been unsuccessful in bringing significant reductions in acrylamide content in high-temperature cooked potato products or darkening of fresh-cut potatoes. However, scientists have been successful in using genetic engineering of potatoes to significantly reduce acrylamide formation in potato products (Bethke and Bussan 2013). But the new low-acrylamide potatoes also have the advantage of low bruising and blackening of fresh-cut potatoes, and potato waste associated with processed potato products. Hence, no sodium

[12] In two decades of human consumption of GM foods, no food safety problems have arisen.

bisulfate is needed to reduce bruising and blackening in the new biotech fresh-cut potatoes. Hence, the new biotech potatoes reduce two types of food safety concerns—a major accomplishment.

In earlier lab auctions of genetically modified (GM) foods potentially carrying traits for herbicide tolerance and/or insect resistance, Huffman et al. (2003) and Rousu et al. (2007) found significant labeling and information treatment effects on willingness-to-pay (WTP) for GM foods. Huffman et al. (2003) found that most participants consistently bid less for products carrying GM food labels compared to products with conventional labels. However, the authors did not test for information treatment effects. In a later study, Rousu et al. (2007) examined both the effects of food labels and pre-packaged information on WTP differences—WTP for the conventional type minus WTP for the GM type. They found positive effects of pro-biotech information and negative effects of anti-biotech information on WTP differences. Colson et al. (2011) found that subjects were willing to pay more for fresh vegetables enhanced with antioxidants and vitamin C (consumer-oriented traits) using biotech methods.

The objective of this study is to assess consumer demand for traditional whole fresh white potatoes and processed potato products and WTP for new experimental fresh whole potatoes and potato dices that have low-acrylamide-forming and browning/bruising potential due to biotech advances. In addition, we examine the effects of food labeling and pre-packaged information on WTP for new potato products. To do this, we design an experimental lab auction and recruit a sample of 102 adult consumers (subjects) from three different regions of the U.S. to come to a central location in their area, a lab, to provide us with socio-economic information about themselves and their households and participate in our experimental auctions. Each of the subjects, 18-65 years of age, were paid 65 dollars for participating in the experiment.

Our empirical results show that the demand for traditional fresh potatoes and processed potato products is not responsive to subject's household income. However, households with more adults are more likely to consume fresh potatoes and French fries but not chips. This result may be driven by falling per capita household income as the number of adults per household increases. There is no significant effect of a subject's education on potato demand—fresh or processed. Subject's age has a significant quadratic effect on the demand for chips and fries but not for fresh potatoes. Surprising is that other things being equal, Boston and Los Angeles households are more likely to consume processed potato products (chips and fries) regularly than are Des Moines area households.

Our empirical results show that WTP differences for new experimental biotech fresh Russet potatoes and dices are also not significantly affected by household income. Compared to women, male subjects are willing to pay less for biotech potato products after receiving an industry perspective on using biotechnology to reduce acrylamide and sulfide exposure relative to WTP pre-information. Other socio-demographic factors do not matter for explaining these WTP differences. However, subjects who are informed about biotech foods pre-experiment are willing to pay more for the new experimental potato products than others. Also, subjects that receive the company perspective on using biotechnology to create low-acrylamide, sulfite-free fresh potatoes and fresh dices are willing to pay significantly more than those that receive the environmental group perspective. Hence, subjects are willing to pay for improved food safety achieved using biotechnology to improve the consumer attributes of fresh potatoes, a long-term traditional vegetable consumed in large quantities in the United States and on fresh potato dices, a totally new test food product.

Description of the Experiments

Experiments were planned for and conducted in the Boston, MA; Des Moines, IA; and Los Angeles, CA areas on a Saturday in April or May 2014. Survey and Behavioral Research Services (SBRS), Iowa State University, developed the protocol for recruiting subjects for this project. The target subjects were 18-65 years of age.[13] Potential participants were told that an Iowa State University project was recruiting subjects to participate in sessions on how households select food and household products. In particular, they were told that the sessions involved a food preference experiment set up like an auction, the sessions would take about 75 minutes of their time, and they would be paid $65 for participating in the project. Also, they needed to be able to follow instructions and write in English and be willing to come to a common location in their area for a 3:30PM session. Willing subjects were told that they would receive follow up confirmation of time and place.[14]

At each location, the lab was laid out in classroom style with a display table in the front of the room. Practice-round and experimental products were placed on the table before subjects were admitted to the lab. Experimental potato products were placed in clear plastic bags with experimental food labels. To avoid distractions to the subjects, no trademark, brand

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[13] When subjects are younger than 18 years of age or older than 65 years of age, the IRB requires that special procedures be followed to meet their special needs.

[14] To recruit subjects in the Boston area, we worked through Answer Quest, and in the Los Angeles area, we worked through Focus & Testing. Answer Quest and Focus & Testing are food marketing and testing companies that have accumulated databases of more than 50,000 individuals and 120,000 individuals, respectively, who had participated in earlier marketing research projects and agreed to be contacted for future projects. Individuals from these databases were called by employees of Answer Quest or Focus & Testing and read the common protocol for recruitment and follow up.

or other information was on the bags. Experimental products were covered by blue bins placed on the table in the front of the lab.

At each starting time, two concurrent sessions took place, and subjects were alternately assigned to each of them; Session A or Session B. Each session was conducted by a session monitor (remained the same for every location) and one assistant. The sessions consisted of the same exact 10 steps, which can be seen in Figure 3.1. In Step 1, the subjects were greeted by a receptionist and asked to read and sign an informed consent form. Once the form was completed, the subjects were assigned an ID number, handed a packet of project materials, and told to enter the lab and take a seat.[15] While waiting for the experiment to start, subjects were asked to complete a pre-auction questionnaire that collected socio-economic information and information about use of food labels while shopping for food products. In addition, subjects were asked to rate their knowledge about biotech foods, non-biotech foods, and acrylamide before the experiments.[16] This covers the type of pre-auction information collected. To relieve subjects' concerns about a credit constraint in the experiment, each subject was, at this point, paid $65 for participating in the experiments and asked to sign a receipt.

In Step 2 subjects were informed that they would be participating in an auction, and that there would be two practice rounds of bidding to learn the auction mechanism. Subjects were told that it was always in their best interest to bid their true preferences. Subjects were

[15] Individuals who arrived together, e.g., a husband and wife, or mother and daughter, etc., were assigned to different sessions.
[16] By asking about knowledge in more than one area, we believe that any one of these questions is unlikely to bias our experimental results. Also, those subjects that indicate that biotechnology and GMOs are different are anticipated to be more informed about this area of science than others.

asked to direct all questions to the monitor and to refrain from communicating with other subjects.

Next, the session monitor read through an explanation of the random n-th price auction and addressed any questions raised by the subjects. The auction was explained in 5 easy steps: 1) subjects would be asked to come to the front of the room and examine product(s) on a display table, 2) subjects were to return to their seat and write down, on a bid sheet attached in their packet, the bid for the product(s), 3) bid sheets were to be collected by the session monitor and assistant, the binding round (when more than one round of bidding occurs) would be randomly selected, bid prices would then be ranked from highest to lowest for each product, and, 4) the random *n* to determine the winners was then selected, and 5) the monitor will notify winners for each product using ID numbers. The session monitors informed subjects that it was in their best interest to bid how much they truly valued each product.

In Step 3, bidding on a single product, a generic ceramic coffee mug, was conducted to get the subjects familiar with the auction mechanism. Subjects were asked to come up to the front of the room, one-by-one, to view the product and then return to their seats.[17] They were told to fill out a bid sheet attached to their packet, detach it and place it face down on the table in front of them. The monitor and assistant collected the bid sheets and recorded the bids and ID number for each bidder in an excel spreadsheet. The bids were then ranked from highest to lowest. The rank of the winning bid was determined by randomly drawing a number from a uniform distribution over 2 to *k*, where *k* is the number of subjects in a session. The random number, *n*, determined the rank of the random price. For example, if

[17] We used non-food items in our practice rounds so as to reduce impacts on later bids on experimental products (Nunes and Boatwright 2004).

$k = 16$ and the random n is 4, the 3 subjects that bid strictly higher than the random price were the winners, and they paid the random price (4^{th} highest price). These ranked bids with ID numbers and random n-th price were displaced on a screen in front of the room.

In Step 4, subjects were asked to complete a short, four question quiz on the auction format, and the session monitor reviewed the answers and addressed questions. After questions from this round were resolved, the monitor moved on to Step 5, the second practice round, which was to get them familiar with bidding on two products at a time. The products were: a notepad and package of pens.

In Step 6, subjects placed bids on real experimental products: two rounds of bidding on a 5-pound bag of traditional and biotech Russet Potatoes and 12 ounces of fresh cut potato dices. To ease budget constraint issues, subjects were told that winners of these auctions would purchase at most one unit of each of the commodities (a 5lb bag of potatoes, a 12 oz. bag of dices). In round 1, the products carried either a conventional or biotech food label (see Figure 3.2).[18] The order in which subjects saw either conventional or biotech products was randomized to minimize order effects in bidding. Subjects were asked to come to the front of the room, view the products, return to their seats, and place their bids on bid sheets. Once completed, the bid sheets were collected by the monitor and assistant. In round 2, the participants were asked to bid on the same type of products as round 1 but this time the products were conventional if they were biotech in round one and vice versa.

In Step 7, subjects were asked to read the information statement(s) included in their packet. They were given about 10 minutes to do this. Each subject was randomly assigned to an information treatment group, which determined the information statements they received.

[18] A private food company supplied the project with experimental products for the lab displaces that were authentic and matched the contents stated on the food labels.

The information treatments consisted of two different perspectives: a (positive) company perspective on using biotechnology to reduce bruising of potatoes in storage and processing and acrylamide levels in processed potato products and a (negative) environmental group perspective on biotechnology. A third information-treatment group was provided both perspectives.[19] See Figure 3.3. After Step 7, the subjects moved on to Step 8 where they placed rounds 3 and 4 bids on experimental products. As with Step 6, the only difference between rounds 3 and 4 was whether the subjects saw food labels showing conventional products or biotechnology products first (which was randomized).

After all bids from Step 8 were collected by the monitor and assistant, subjects moved on to Step 9 where they were asked to complete a short post-auction questionnaire. There were questions about household consumption patterns for potatoes and potato products, how well the subject understood the information treatment that they received and read, and how well the subject was informed about biotechnology and acrylamide after participating in the auction and reading the information treatment included in their packet. While the participants were completing the questionnaire, the monitor and assistant were inputting the bids for experimental products into a computer spreadsheet.

In Step 10, subjects were informed that the biotechnology products were not currently available in grocery stores and that winners would receive conventional potato products obtained from a local grocery store. The monitor then randomly chose the binding round from the two rounds of bidding on the conventional products, displayed the ranked bids for this round for both products, and then chose the random price or random *n*.[20] Winners were

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[19] Some environmental groups, e.g., Greenpeace and Friends-of-the-Earth, have a strong negative perspective on GMOs and biotechnology in general, while others have a more moderated view (Greenpeace 2014; Friends-of-the-Earth 2014).

[20] For winners of fresh-cut potato dices, they received a 12 oz package of a close substitute, Simply Potatoes™,

then identified. Monitors and assistants then collected packets from the subjects in the session, the winners were escorted to the stock room to purchase the products, and the subjects who did not win were told that they were dismissed and free to leave.

Description of the Sample and Summary Results

Table 3.1 presents the summary statistics for socio-economic attributes of the 102 subjects and potato consumption frequency for subjects' households. Some highlights for these statistics follow. The average age of subjects was 43 years, and 39% of the subjects were male.[21] The mean education of subjects was 14 years, which is equivalent to a 2-year college degree. Eighty-seven percent of the subjects were white and 50% were married.[22] The average number of adults in the subject's household was 2.2, of children less than 8 years was 0.20 and children 8 years or older was 0.56. Thirteen percent of subjects reported being a blue-collar worker, and mean household income of subjects was $72,300.[23] Also, 93% reported that they exercise weekly, only 9% reported that they smoked cigarettes, and 79% of subjects indicated that they were in good to excellent health. Thirty-five percent of subjects indicated that someone in their household was on a diet.

Regarding potato consumption, 93% of the subjects reported that their household consumed potatoes weekly; 82% reported consuming potato chips regularly and 60% reported consuming French fries regularly. Given that we did not screen subjects for household potato product consumption, this high frequency of potato consumption in the

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a product available in the dairy case of major grocery stores and super markets.

[21] Approximately 60% of grocery store shoppers are women.

[22] The large share of subjects who are white, even for the Boston and Los Angeles areas, can be explained by the fact that recruiters of subjects screened for ability to communicate in English.

[23] A blue-collar worker was defined as anyone with an occupation of "building and grounds cleaning and maintenance," "construction/installation/repair," "farming/fishing/forestry," "production/manufacturing," or "transportation."

sample is good news for those worrying about the ability to generalize our results—at least to the population of people who can communicate in English.

In the pre-auction questionnaire, 6% of the subjects reported that they were informed about acrylamide and 38% reported that they were informed about biotechnology. In the experiments, 35% of subjects received the company perspective, 33% received the environmental perspective and 31% received both perspectives.

Table 3.2 provides summary statistics of the subjects' bids by product and information treatment. In bidding rounds 1 and 2 (which are before packaged information treatment were injected into the experiment), the average bid for conventional potatoes (5 lb. bag) was $2.71 and the average bid for biotechnology potatoes (5 lb. bag) was $2.87. Hence, the average bid was 16 cents per bag higher for biotechnology than conventional potatoes, pre-information treatment. After each subject read his or her information treatment, the average bid for conventional potatoes was $2.69 per bag, and the average bid for biotechnology potatoes was $2.50 per bag. Hence, the average subject's bid for a bag of conventional potatoes was 2 cents lower after she received an information treatment than before, and for biotech potatoes the average bid was 37 cents per bag lower after receiving the information treatment than before. These results imply that the negative information treatments had stronger effects on bidding behavior than positive information. In addition, the average bid for a bag of conventional potatoes was 19 cents higher than for the biotechnology potato after subjects received an information treatment.

The conventional fresh potato dices were treated with a chemical called sodium bisulfide to prevent them from turning an unattractive brown color, and "sodium bisulfide" content was clearly presented on the label (see Figure 3.2). Before information treatment, the average subject's bid for conventional potato dices (12 oz. bag) was \$1.82 and the average bid for a bag of biotechnology potato dices treated with sulfites (12 oz. bag) was \$2.13. Hence, the average subject's bid for a bag of biotechnology dices (no sodium bisulfide treatment) was 31 cents higher than for conventional dices, pre-information treatment. After information treatment, the average subject's bid for a bag of conventional potato dices was \$1.77, and the average bid for a bag of biotechnology potato dices was \$1.78. Hence, the average subject's bid for conventional potato dices was 5 cents per bag lower after the information treatment than before, and the average bid for biotechnology dices was 35 cents per bag lower. The average bid for conventional potato dices was 1 cent per bag less than for a bag of biotechnology potato dices after the information treatment.[24]

Regression Models

First, a model of a household's decision to consume potato products is presented, and it is followed by a model of a household's willingness-to-pay for low acrylamide potato products. We specify a reference (no potato product consumed) household random indirect utility function

$$U_{i0} = X_{i0}\beta_0 + \mu_{i0} \tag{3.1}$$

U_{i0} is the utility of the *i*-th household when it does not consume a potato product, X_{i0} includes household income and prices of products purchased for consumption and socio-economic variables that affect preferences. The far-right term μ_{io} represents other individually small effects on U_{i0}, and it has a zero mean, and β_0 is a set of unknown coefficients.

[24] We had very few zero bids and no cases where a subject bid zero on both products—whole potatoes and dices, GM or conventional.

In contrast, the household's random indirect utility when its members choose to consume at least one unit of a potato product is

$$U_{i1} = X_{i1}\beta_1 + \mu_{i1} \qquad (3.2)$$

U_{i1} is the utility of a household, given a decision to consume a potato product, X_{i1} includes household income and prices of potato products and other good purchased for consumption and socio-economic attributes that affect tastes, and μ_{i1} represents other individually small effects on U_{i1}, and it has a zero mean. The coefficient vector β_1 is a set of unknown coefficients.

A household consumes one unit of a potato product when its indirect utility is larger for consuming than not consuming them. We define D_i = 1 if $U_{i0} \prec U_{i1}$, and it equals 0 otherwise. Hence, the probability that $D_i = 1$ can be represented as follows:

$$\begin{aligned} P_r(D_i = 1) &= P_r(X_{i0}\beta_0 + \mu_{i0} < X_{i1}\beta_1 + \mu_{i1}) \qquad (3.3) \\ &= P_r(\mu_{i0} - \mu_{i1} < X_{i1}\beta_1 - X_{i0}\beta_0) \\ &= P_r(\mu_i < X_i\beta) \\ &= F(X_i\beta) \end{aligned}$$

where F (•) is a distribution function evaluated at $X_i\beta$. Equation (3.3) provides the conceptual framework for a model explaining the probability that a subject's household consumes a potato product over some time interval, say a week—one indication of the demand for a potato product. Equation (3.3) is fitted using the probit estimation routine, and then we calculate the marginal effect for each regressor.

In addition to household income, socio-economic variables included in X are number of adults, children under age 8 and children 8 years of age and older in the subject's household; whether anyone in the subject's household is on a diet; and gender, age, education, marital status, and racial-ethnic background of subject. In addition, *X* includes dummy variables for whether the subject reads food labels on new purchases, exercises weekly, is in good health, and smokes cigarettes. We expect those subjects that have more education and read food labels when making new purchases will in general be more health conscious and be less likely to consume processed potatoes and potato products. We don't directly have price data that the subject's household faces for potato products, but we expect prices of potatoes, chips and fries to differ between (be higher in) rural than urban areas and in Boston and Los Angeles areas than in the Des Moines area. Hence, *X* also includes dummy variables for a subject's rural-urban residence and location in the Boston area (vs Des Moines) and in the Los Angeles area (vs Des Moines).

Next, consider a model of willingness-to-pay for the *g*-th commodity, *v*-th variety, by the *i*-th subject receiving the *j*-th information treatment, W_{ij}^{gv}. The commodities are a 5 lb. bag of fresh whole potatoes and 12 oz. bag of fresh cut potato dices. For fresh potatoes, the varieties (*v*) are conventional and low acrylamide achieved using "Potatoes grown with seed improved by biotechnology", and for fresh cut potato dices the varieties are conventional (with sodium bisulfite) and low acrylamide and sulfite free (achieved using potatoes grown with seed improved by biotechnology).[25] Each subject bids on a set of products before receiving a packaged information treatment, and then again after the injection of the informative treatment: (1) an environmental group perspective on biotechnology (anti-

[25] Sodium bisulfite is a preservative used in conventional dices to limit discoloration of the product when exposed to the air.

biotech), (2) a (positive biotech) company perspective on using biotechnology to lower bruising and acrylamide potential, or (3) both perspectives.

We write WTP for the *g*-th commodity, *v*-th variety for the *i*-th subject receiving the *j*-type of information as:

$$W_{ij}^{gv} = X_i\beta_j^{gv} + \tau_1^{gv} I_{ij} + \varepsilon_{ij}^{gv} \tag{3.4}$$

where X_i is a set of socio-economic attributes of the subject and his or her household, I_{ij} is 1 for information treatment of "a company perspective on low bruising and low acrylamide potential using biotechnology" (treatment 2) and 0 for receiving "an environmental group perspective on biotechnology" (treatment 1) or both perspectives (treatment 3). The last term of equation (3.4), ε_{ij}^{gv}, represents other individually small effects on W_{ij}^{gv} and has a zero mean. The baseline model is achieved when the *i*-th individual engages in the first round of bidding (before information treatment):

$$W_{i0}^{gv} = X_i\beta_0^{gv} + \varepsilon_{i0}^{gv} \tag{3.5}$$

In our experiments, each of the *i* subjects bid first on commodity *g* of variety *v* before information treatment and then a second time after receiving an information treatment. Following earlier studies, e.g., Hoffman et al. (1992) and Rousu et al. (2007), we convert the WTP model into one of WTP differences—WTP before relative to WTP after information treatment:

$$W_{i0}^{gv} - W_{i1}^{gv} = X_i(\beta_0^{gv} - \beta_1^{gv}) + \tau_1^{gv} I_{i1} + \varepsilon_{i0}^{gv} - \varepsilon_{i1}^{gv} = X_i\beta^{gv} + \tau_1^{gv} I_{i1} + \varepsilon_i^{gv} \tag{3.6}$$

where β^{gv} = $(\beta_0^{gv} - \beta_1^{gv})$ and ε_i^{gv} = $(\varepsilon_{i0}^{gv} - \varepsilon_{i1}^{gv})$ and the last disturbance terms has a zero mean. The advantages to this specification include that the new dependent variable in equation (3.6) can be positive, zero, or negative, and hence, the disturbance of the random disturbance term

ε_i^{gv} is more likely to be normally distributed than for ε_{ij}^{gv}. Taking differences also removes any common individual fixed or random effects, including individual idiosyncrasies, which would otherwise be a possible source of biases in the estimated coefficients of the WTP equation (Greene 2003).

Socio-economic variables that are included in X_i are a subject's household income; number of children less than age 8 in subject's household; gender, age and years of schooling completed of subject; whether subject indicated that they were informed about acrylamide and biotechnology in the pre-auction survey, reads food labels when purchasing new food items, or viewed biotech and GMO foods as different, indicates that their household regularly consumes potatoes, and dummy variable for city location of subject (Des Moines, Boston or Los Angeles area). Subjects in households with children under 8 years of age may be more concerned about the food safety dimension of the food that they purchase in grocery stores, especially foods containing sulfites, than others. Because there is no scientific evidence of biotech foods being unsafe for human consumption, it is uncertain what effect food carrying the words "Made using potatoes growth with seed improved by biotechnology" in the label will have. Although the perspective presented by Greenpeace and Friends of the Earth are quite negative about GMOs, Colson et al (2011) show that in experimental lab auctions of GM products with enhanced antioxidants and vitamin C consumers are willing to pay more for the GM products achieved using genes from within the species (intragenic). Women are more intensely involved in food shopping than men, and this difference in experience could affect the size of WTP differences, but we do not know in what direction. A subject's age is included to control for life-stage effects and to permit differences in WTP to occur by age. Individuals with more education are better able to read and digest consumer and food safety information (Schultz 1975; Huffman 1974), and hence may show larger responsiveness to information treatments injected into the food experiments. The effect of a subject being informed about biotechnology could have a positive or negative effect on how they bid, but Rousu et al. (2007) found that those who were informed bid more for GM products. Those that read food labels may be more conscious shoppers, but uncertain as to how this attribute will affect bidding behavior. Households that regularly consume potatoes may behave differently in bidding on potato products than other households because they have more information about their tastes.

The locations of our food experiments are more than 1,300 miles apart and are in vastly different parts of the country where the daily attention to food production differs considerably. Iowa and California are large producers of food and agricultural products while farmers in Massachusetts are engaged in small-scale farming, including agro-tourism. Massachusetts is heavily urbanized and far from centers of U.S. large-scale food production. Hence, we expect Boston subjects to be most strongly anti-biotech. In addition, three New England States have voted recently to require some type of mandatory labeling of GM foods. All state level votes in other regions of the US have failed (Huffman and McCluskey 2014).

Regression results for probability of consumer potatoes, chips and fries

The results from fitting the empirical probit model explaining the probability of a subject's household consuming traditional potatoes and processed potato products weekly are reported in Table 3.4. A general model for equation (3.3) with 15 regressors, including city fixed effects and intercept term, is first fitted. Then, variables having coefficients with unusually small z-values, implying that they are not significantly different from zero at even the 10% level, are deleted, except for a few core variables—household income, number of adults in household, and city dummies, and the model is re-fitted. The expectation is that the size of the estimated coefficients that have large z-values at the first stage will be relatively unaffected when insignificant regressors are excluded, but that their z-values may increase in size due to less near-multicollinearity among the remaining set of regressors.[26]

Fresh Potatoes

In regression (1) of Table 3.4, there are 15 included regressors, largely socio-economic variables, and in regression (2) five of the insignificant regressors are excluded.[27] The probit results and marginal effects are in Table 3.4. In regression (2), a $1,000 per year increase in household annual income reduces the probability of a subject's household consuming fresh potatoes slightly but not significantly. Adding one adult to a subject's household or a subject being married increases the probability of a subject's household consuming potatoes by 3.0 and 5.2 percentage points, respectively. Male subjects are 4.3 percentage points less likely to be in a household that consumes potatoes than female subjects. The marginal effects of a subject's age on the probability of the household consuming potatoes increases from age 18 to 40, and then the probability of the household consuming potatoes decreases for subjects older than 40 and continues to decrease as age increases. However, this age effect is statistically weak. If the subject reported someone in the household was on a diet, then the probability of consuming potatoes decreases by 2.8 percentage points. Because most diets suggest reducing carbohydrate intensive and high starch foods, this result is not surprising. The probability is slightly higher for Boston and Los Angeles area household to consume potatoes than for Des Moines area household.

[26] Although we might test for information order effects, we do not expect them to be significant. In a related study with a larger sample size there was not order effects (McFadden and Huffman 2015).
[27] The excluded regressors are whether a child of or over the age of 8 lives in the household, subject's gender, subject is white, exercises weekly, and in good health.

Potato Chips

Regression (3) starts with the same 15 included regressors as for potatoes; largely socio-economic variables, and in regression (4) six of the insignificant regressors are excluded.[28] In regression (4), the most significant factor affecting the probability of a subject's household consuming chips is his or her age.[29] The marginal effect of a subject's age on the probability of his or her household consuming chips increases from 18 to 43 years, and for subjects older than 43 years, his or her aging reduces the probability of the household consuming chips. Female subjects are 9.2 percentage point more likely to have a household that consume potato chips than male subjects and adding an additional adult to a subject's household increases the probability of the household consuming potato chips by 5.3 percentage points. If the subject reported he or she exercised regularly then the probability of his or her household consuming chips is 17.7 percentage points more likely to consume chips than the household where the subject reported not exercising regularly. Boston and Los Angeles households are 24.4 and 17.0 percentage points more likely to consume chips than Des Moines area households.

French Fries

Regression (5) starts with the same set of 15 included regressors as for potatoes; largely socio-economic variables, and in regression (6) six of the insignificant regressors are excluded.[30] In the latter regression, an additional $1,000 in a subject's household income

[28] These regressors are whether a child of or over the age of 8 lives in the household, anyone in household is on a diet, subject's education, subject is married, white, and is in good health.
[29] Additional household income has no economic effect on the probability of a subject's household consuming chips.
[30] These regressors are whether a child of or over the age of 8 lives in the household, anyone in household is on a diet, subject's education, subject is married, white, and is in good health.

reduces slightly the probability of his or her household consuming fries (but effects are not statistically significant). An additional adult in the subject's household increases the probability of the household consuming fries by 14 percentage points. The probability of a household consuming fries increases as the subject's age increases from 18 years of age to 46 years of age and then declines as subject's age increases further. When the subject is a woman the probability that the household consumes fries is 14 percentage points more likely than if the subject is a man. Also, if the subject reported exercising regularly then the household was 33 percentage points less likely to consume fries than when the subject reported not exercising regularly. Boston and Los Angeles area households are 34.3 and 29.6 percentage points more likely to consume fries that Des Moines area households.

Across the three potato products, major differences exist in how the regressors affect the probability of a household consuming fresh potatoes vs processed potato products (chips and fries). A subject's marital status and whether someone in the household is on a diet are important variables for explaining fresh potato consumption but not chip or fry consumption. Since people who consider themselves on a diet are usually more conscious about the foods they eat as well as the food everyone else in the household eats, it is surprising that "diet" is not an important explanatory variable for chips and fries. In contrast, a subject reporting exercising regularly is quite important for explaining consumption of chips and fries but not fresh potatoes. A subject's household income has no significant effect on the probability of his or her household consuming potato products. In addition, our empirical model of the probability of a subject's household consuming potato products has the highest explanatory power for fresh potatoes, pseudo $R^2 = 0.285$, but is significantly lower for processed potatoes—fries and chips, pseudo R^2 of 0.195 and 0.169, respectively.

Regression analysis of WTP differences

Results from fitting equation (6) for the two commodities (a 5 lbs. bag of fresh potatoes and a 12 oz. bag of fresh potato dices) are reported. For a given commodity, within-subject WTP differences are expressed both within-variety and across-variety.

Fresh Potatoes

In regressions (1) and (2) in table 5, the variety of fresh potatoes is "biotech," i.e., the food label on the front of the package displayed the phrase "Potatoes Grown With Seed Improved By Biotechnology." Subjects bid twice on the biotech potatoes; first without information and then a second time after receiving an information treatment. The dependent variable is a subject's WTP for biotech potatoes before information less WTP for biotech potatoes after receiving an information treatment. Hence, the estimated coefficients on regressors reflect how a variable impacts the way treatment information changes WTP behavior of subjects.[31] In our regressions, the dummy variable for a household being located in the Des Moines area is excluded and its effect is part of the intercept term.[32]

In regression (1) of Table 3.5, there are 15 included regressors, largely socio-economic variables, information treatment effects and city dummy variables, and in regression (2), five of the insignificant regressors are excluded.[33] For regression (2), an increase of $1,000 in a

[31] One information treatment must be assigned to the intercept term to provide identification of the effects of the other treatment effects relative to the excluded one. Hence, in our results the intercept term absorbs the negative effect of the "environmental group perspective." This arrangement provides results that are the easiest for the reader to interpret.

[32] There was no significant order effect, i.e., whether a subject first bid on biotech or conventional products.

[33] The excluded regressors are the number of children less than 8 years of age in the subject's household; subject's age and education; whether the subject is informed about acrylamide; and an indicator for a subject's household consuming potatoes weekly. The null hypothesis that these 5 coefficients on the excluded variables are jointly zero yields a sample value of the F statistic of 0.001, but the tabled critical value of the F with 5 and 86 degrees of freedom at the 5% significance level is 2.33. Hence, we cannot reject the null hypothesis at the 5% significance level.

subject's household income reduces subject's WTP for a 5 lb. bag of biotech potatoes post-information treatment relative to their pre-information treatment by 0.00006, which is very small. Male subjects have a $0.62 per bag lower WTP for biotech potatoes post-information treatment relative to pre-information treatment; or women have larger WTP post-information. If a subject reported being informed about biotechnology pre-experiment, he or she had a $0.74 per bag higher WTP for biotech potatoes post-information treatment than pre-information treatment. If a subject indicated in the pre-auction survey that he or she reads food labels when buying new foods for the first time or views biotech and GM foods as being different, his or her WTP for a bag of biotech potatoes post-information treatment is $0.75 lower than for the pre-information treatment WTP. However, if the subject receives the "company perspective" information treatment, his or her WTP for a bag of biotech potatoes is $1.43 higher post-information treatment than pre-information treatment. Hence, the "company perspective" is influential in modifying subject's WTP for improved food safety using biotechnology. If a subject received the third information treatment (the company perspective and the environmental group perspective), his or her WTP for a bag of biotech potatoes was $0.85 higher post-information treatment than pre-information treatment. Hence, the positive "company perspective" continues to weigh heavily on WTP differences relative to the negative environmental group perspective. Subjects from the Los Angeles area are willing to pay $0.65 more per bag of biotech potatoes post-information than pre-information treatment relative to Des Moines area subjects. There was no difference in WTP for a bag of biotech potatoes post- vs pre-information treatment for Boston area subjects than Iowa subjects. Hence, Los Angeles subjects were most favorably impacted by the company information treatment.

Regressions (3) and (4) of Table 3.5 present a different perspective on WTP for biotech potatoes. It is a comparison of WTP for a 5 lb. bag of biotech potatoes post-information treatment with WTP for a 5 lb. bag of conventional potatoes pre-information treatment—a type of comparison that a consumer might face in a marketing campaign for new biotech potatoes appearing in grocery stores and super markets. Hence, both the variety type and information treatments are different in this comparison, and it is similar to the framing of WTP differences in the econometric analysis presented by Rousu et al. (2007). Regression (3) contains the same set of regressors as regression (1). The regressors that are much less significant in regression (3) than (1) are a subject's household income, whether a subject reads food labels and whether a subject resides in the Los Angeles area. In regression (4) six regressors having small z-values are excluded.[34] For the remaining estimated coefficients, it is surprising that all of them are 30-50% smaller than for regression (2), except for the coefficient of the Boston area dummy variable, which is not significantly different from zero in both regressions.

Fresh Potato Dices

In regressions (1) and (2) in Table 3.6, the variety of fresh potato dices is "biotech," i.e., the food label on the front of the package displayed the phrase "Potatoes Grown With Seed Improved By Biotechnology." Subjects bid twice on the biotech dices; first before receiving the information treatment and then a second time after receiving an information

[34] The excluded regressors are the number of children less than 8 years of age in the subject's household; subject's age and education; whether subject was informed about acrylamide; whether subject reads food labels on new goods; and an indicator for a subject's household consuming fresh potatoes weekly. The null hypothesis that the estimated coefficients on these 6 regressors are jointly equal to zero yields a sample value of the F statistic of 0.34, but the tabled critical value of the F with 6 and 87 degrees of freedom at the 5% significance level is 2.20. Hence, we cannot reject the null hypothesis of no joint effects at the 5% significance level.

treatment. The dependent variable is a subject's WTP for a 12 oz bag of biotech dices before information less WTP for biotech dices after receiving an information treatment.

In regression (1), there are 15 included regressors, largely socio-economic variables, information treatment effects and city dummy variables, and in regression (2), eight of the insignificant regressors are excluded.[35] In regression (2), if the subject indicated that he or she reads food labels then his or her WTP post-information treatment declines by $0.43 per bag relative to the pre-information treatment WTP. Similarly, if the subject considers biotech and GM foods as being different, a subtle dimension, then his or her WTP is $0.44 less per bag post information than pre-information treatment. If the subject received the "company perspective" information treatments, his or her WTP for a bag of dices increases by $0.88 relative to his or her WTP pre-information treatment. Like previously stated, this is not surprising since the "company perspective" provides positive information about biotechnology and biotech foods. If the subject receives the "company perspective" and "environmental group perspective" in the information treatment, his or her WTP for a bag of dices increases by $0.38 relative to his or her WTP pre-information treatment. This is a decline of $0.50 per bag compared to just the "company perspective", and shows that the "environmental group perspective," where packaged with the "company perspective" only slightly reduces the positive effect of the "company perspective" only treatment on WTP for

[35] The excluded regressors are a subject's household income; the number of children less than 8 years of age in subject's household; subject's gender, age, and education; whether subject was informed about acrylamide; whether subject was informed about biotechnology; and an indicator for a subject's household consuming potatoes weekly. The null hypothesis that the coefficients of these 8 coefficients variables are jointly zero yields a sample value of the F statistic of 0.43, but the tabled critical value of the F with 8 and 87 degrees of freedom at the 5% significance level is 2.05. Hence, we cannot reject the null hypothesis of no joint effects at the 5% significance level.

biotech dices. Hence, the environmental group perspective does little to moderate the effects of the company perspective.

Regressions (3) and (4) in table 6 present a different perspective on WTP for fresh cut potato dices. The dependent variable in these regressions is a subject's WTP for fresh-cut potato dices made from "Potatoes Grown with Seed Improved by Biotechnology" post-information treatment relative to his or her WTP for a 12 oz bag of fresh cut potato dices made using "sodium bisulfite" (a preservative to reduce discoloration). Hence, the "variety" of the commodity (dices) and available information are different in computing the WTP differences—fresh biotech dices without sulfites vs non-biotech dices with sodium bisulfite added. Regression (3) contains the same 15 regressors as for regression (1). A regressor that is more significant in (3) than (1) is the effect of a subject indicating in the pre-auction survey that he or she reads food labels when buying a food item for the first time. A regressor that is less significant in (3) than (1) is the effect of a subject reporting in the pre-auction survey that biotech and GM foods are different. In regression (4), when a subject reports in the pre-auction survey that he or she is informed about biotechnology, his or her WTP for a bag of dices is $0.29 higher post-information treatment relative to pre-information treatment. When a subject indicates that he or she reads food labels, his or her WTP for a bag of biotech dices declines by $0.41 post-information treatment relative to a bag of dices containing sodium bisulfite per-information treatment. If a subject receives the "company perspective," he or she is willing to pay $0.82 more for a bag of biotech dices post-information treatment than for a bag of dices containing sodium bisulfite pre-information treatment. If a subject receives the "company perspective" and "environmental group perspective" information treatment, their WTP is $0.61 higher for a bag of biotech dices post-information than for a bag of sodium bisulfide dices pre-information treatment. Hence, the WTP difference per bag is only reduced by $0.20 when the "environmental group perspective" is added to the "company perspective." This is similar to the findings for fresh potatoes. Although subjects from the Boston area tend to pay less and for Los Angeles area to pay more for a bag of biotech dices relative to Des Moines residents, these city effects are not significantly different from zero at the 5 percent level.

The information treatment effects on WTP differences for fresh potatoes and dices are consistent with the information treatment effects obtained by Rousu et al. (2007) and Colson et al. (2011) for biotech foods. The explanatory power of the empirical models of WTP differences is largest for the comparisons of within-variety differences; R^2 being 0.312 for biotech potatoes and 0.256 for biotech dices. We lose about 0.10 from the R^2 in the comparisons of WTP for biotech product post-information treatment relative to conventional product pre-information. This suggests that there is additional unexplained noise in the cross-variety comparisons that does not exist in the within-variety comparisons.

Conclusion

This study provides new empirical evidence on household demand for traditional fresh potato and processed potato products and consumers' willingness to pay for a new variety of fresh biotech potato and a new potato product—fresh potato dices; products with low-acrylamide, and fresh dices that are also sulfite-free. The probability of a subject's household consuming traditional fresh potatoes, chips and fries is not significantly related to their household income. Hence, the results suggest that the demand for potatoes in the U.S. will not change much as real household incomes rise over time. However, aging of the adult population is expected to decrease the probability of households consuming chips but not potatoes or fries. The probability of a household consuming potato products is unaffected by a subject's education. It is perhaps surprising that households in the Boston and Los Angeles areas were significantly more likely to consume processed potato products than households in the Des Moines area.

We find empirical evidence that some participants are willing to pay for food safety—fresh Russet potatoes having low potential to produce acrylamide and white potato dices that also are sulfite free—all achieved using biotechnology, but not transgenic GMOs. However, WTP is conditioned by the information injected into the experimental auction. Retailers could segment their consumers into those that are receptive to GMOs and distribute information to them that is packaged to show the benefits of low-acrylamide potato products. In this way, they can increase the demand for these products. Retailers can retain consumers who have non-GMO preferences by carrying both GMO and non-GMO varieties of potato products. In the long run, biotech potato products that have improved food safety are expected to achieve higher rates of consumer acceptance in the U.S. than those with earlier traits for herbicide tolerance and/or insect resistance.

Limitations to our study include small sample size and under representation of rural subjects and households. However, none of our preliminary results showed that subjects from rural households responded differently from subjects in urban households.

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Figures and Tables

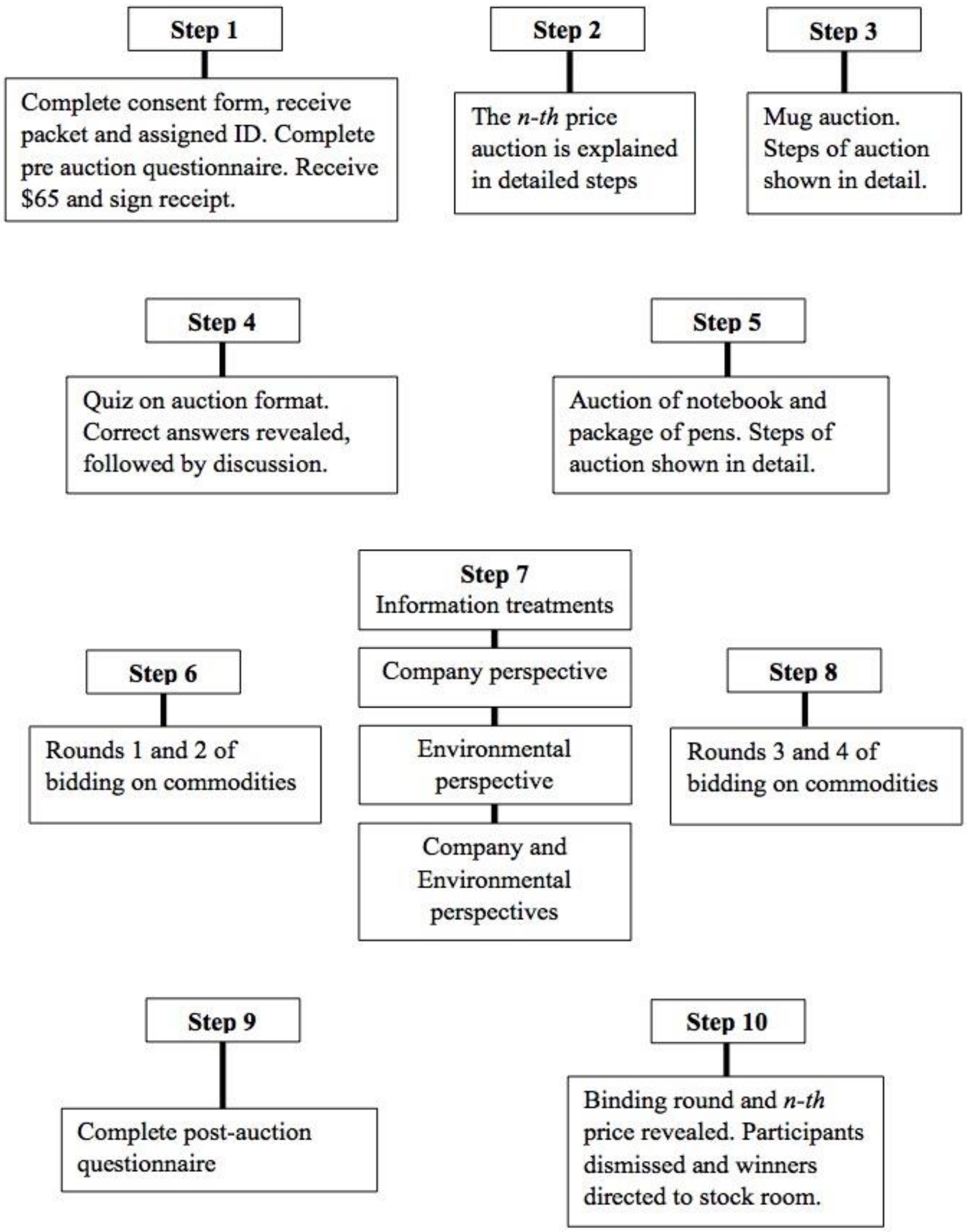

Figure 3.1 Steps in the Experiments

Conventional Product Labels

Fresh Russet Potatoes **Net wt: 5 lbs.**	**Fresh-Cut Potato Dices with Sodium Bisulfite** **Net wt: 12 oz.**

Biotechnology Product Labels

Fresh Russet Potatoes **Net wt: 5 lbs.**	**Fresh-Cut Potato Dices, Low Acrylamide, Low Bruise** **Net wt: 12 oz.**
Potatoes Grown with Seed Improved by Biotechnology	**Potatoes Grown with Seed Improved by Biotechnology**

Figure 3.2 Product Labels

A company perspective on low bruising and low acrylamide potential using biotechnology

General Statement:

- Potatoes have well-known vulnerability to bruising during harvest and while in storage. In addition, a fresh potato turns brown upon cutting when exposed to the air. Recently, it has been discovered that frying or broiling potatoes at high temperatures forms acrylamide.
- This tendency for bruising causes a large amount of potato wastage and costs potato growers and processors millions of dollars annually. Sodium bisulfite is sometimes used to preserve freshness.
- In 2002, acrylamide, a chemical compound, was discovered in foods containing certain natural sugars when cooked at high temperatures (above roughly 250° F), such as French fries, hash browns and potato chips. They are also formed in the baking of bread (crust) and cookies and roasting of coffee beans.
- Acrylamide is formed from naturally occurring sugars and asparagine (a building block of a protein) in food. It is a toxin and possible carcinogen in humans.
- The Simplot Company has developed improved versions of three popular potato varieties that have significantly reduced bruising and acrylamide forming potential than conventional potato varieties. These new potato varieties are slower to oxidize after peeling or cutting. Hence, these new potato varieties provide major advantages to potato producers, processors and consumers.
- The new varieties were made possible using Innate™ technology, which is a new biotech process for moving genes swiftly and precisely from wild and domesticated potatoes into popular varieties.

Nutrition and Health:

- Food and cigarette smoke are the two main sources of human exposure to acrylamide. In the American diet, processed potato products (potato chips and cooked French fries) are the leading source of acrylamide. Long-term, low-level intake of acrylamide by lab animals has been shown to create serious health problems. One study found that consuming conventional potato chips regularly for a month caused some health changes in humans.
- Under Proposition 65, California requires certain restaurants, including Applebee's, Chili's, McDonald's, Burger King, Wendy's, and KFC, to post a warning stating that "cooked potatoes that have been browned, such as French fries, hash browns and baked potatoes, contain acrylamide, a chemical known to the State of California to cause cancer."
- Simplot's latest Innate™ potato varieties reduce acrylamide formation by approximately 90% in processed potato products cooked at high temperatures. This reduction places them below the minimum amounts of California's Proposition 65, and removes acrylamide level health concerns.
- Biotech methods were also used to develop golden rice, which enhanced vitamin A content. Other opportunities exist for enhancing consumer attributes such as antioxidants and vitamins in food.
- Biotech foods, relative to conventional foods, have similar low allergy potential.

Environmental Impacts and Food Security:

- Innate™ biotech modifies a plant's genes without incorporating foreign genes or antibiotic resistance. There are no adverse impacts on the environment or new food allergens.
- Commercial potatoes are grown from pieces of whole potato and not seed. Many commercial potatoes are either sterile or not sexually compatible with wild potatoes so there is very low risk of the Innate™ potato varieties crossing with other potato varieties or other plants.
- Innate™ potatoes have undergone extensive field testing and consumer taste testing by Simplot, and have been thoroughly evaluated by the USDA and FDA.
- Approval is being sought for Innate™ potato exports to Canada, Mexico, South Korea and Japan.

Figure 3.3 Company Perspective

An environmental group perspective on biotechnology

General Statement:

- Biotech plant breeding takes genes from one organism and places them into another. This process manipulates genes and alters genetic makeup and properties. The cutting of genetic material from one organism and inserting it into another is quite imprecise and can cause mutations. There has been inadequate testing of these products.
- Biotech methods frequently use antibiotic-resistant gene segments in soil bacteria or viruses and transfer them into plants. This process is risky, leading to unanticipated outcomes.
- Biotech plants are regulated by the federal government, but federal regulation relies heavily on data collected from field trials and other testing by the biotech industry.
- Biotech seeds were first marketed to U.S. farmers in the mid-1990s, and rapid farmer adoption occurred in field crops (corn, soybean, cotton and canola). Later developments have been in papaya and vegetables (sugar beet, squash and potato).
- In the United States, the sales of biotech foods have grown very rapidly. This growth is driven by self-interested producers and marketers seeking to maximize crop yields and minimize production costs.

Nutrition and Health:

- Of the laboratory plants that are successfully modified to express the "right" traits, genetic engineers select among those that look strong, healthy, and capable of further breeding. There is poor screening to eliminate varieties that produce harmful substances or low nutrient quality.
- New allergens are likely to be introduced into the food supply.
- Early research reported some health problems in laboratory animals consuming first-generation insect-resistant potatoes.
- Several scientific studies show that laboratory animals that have been fed biotech food developed one or more toxic effects on vital and/or reproductive organ functioning, relative to a control group.
- A recent Canadian study found a common protein from insect-resistant corn in the bloodstream of pregnant women and their fetuses. Another recent study found that high concentrations of this protein resulted in severe damage to human embryonic kidney cells.
- The nutritional content of biotech foods, relative to conventional foods, is variable.

Environmental Impacts and Food Security:

- Private companies are not capable of screening new biotech materials for every possible pathogen or environmental stress. Unnoticed and unsafe mutations could strike after the occurrence of extreme stress, such as plant disease outbreaks, droughts, floods, and heat waves.
- New biotech crops may cross-pollinate with other plants and are likely to cause super weeds.
- Some herbicides used on biotech crops diffuse into the air and leach into streams and waterways in some areas. These herbicides are toxic to amphibians (e.g., frogs, salamanders) and earthworms, which impacts bird populations.
- Biotech crops are doing little to help international food security or relieve hunger in poor countries. The major biotech crops, corn and soybeans, are mainly used for animal feed, biofuels, and processed human food in developed countries.

Figure 3.4 Environmental Perspective

Table 3.1 Sample Summary Statistics

Variables	Mean	Standard Deviation
Potato Consumption Weekly (=1)	0.931	0.254
Potato Chip Consumption Weekly (=1)	0.824	0.383
French Fry Consumption Weekly (=1)	0.598	0.493
Household Income ($1,000)	72.30	47.04
Number of Adults	2.19	1.07
Number of Children < 8yrs	0.196	0.508
Number of Children ≥ 8yrs	0.559	0.874
Rural (=1)	0.059	0.237
Anyone on Diet (=1)	0.353	0.480
Gender (1=Male)	0.392	0.491
Age	43.32	13.13
Education (yrs.)	14.38	2.00
Married (=1)	0.510	0.502
White (=1)	0.873	0.335
Reads Food Label (=1)[a/]	0.882	0.324
Exercises Weekly (=1)	0.931	0.254
Good Health (=1)[b/]	0.794	0.406
Smokes Cigarettes (=1)	0.088	0.285
Blue Collar Occupation (=1)[c/]	0.128	0.335
Boston (=1)	0.314	0.466
Los Angeles (=1)	0.333	0.474

[a/] A 1 if responded “Some of the time,” “Often,” or “Always” reads food labels when buying a food product for the first time and 0 otherwise.
[b/] A 1 if respondent is in good or excellent physical health and 0 otherwise.
[c/] A 1 if respondent is in an occupation of “building and grounds cleaning and maintenance,” “construction/installation/repair,” “farming/fishing/forestry,” “production /manufacturing,” or “transportation” and 0 otherwise.

Table 3.2 Bid (WTP) Summary Statistics for Participants

Commodity	N	Mean Bid	Standard Deviation	Minimum	Maximum
A. All Bids: Pre-Information					
Conventional Potatoes	102	2.71	1.43	0.01	6.75
Conventional Potato Dices	102	1.82	1.26	0	6
Biotech Potatoes	102	2.87	1.52	0	6.95
Biotech Potato Dices	102	2.13	1.34	0	5.95
B. All Bids: Post Information					
Conventional Potatoes	102	2.69	1.45	0.01	6
Conventional Potato Dices	102	1.77	1.36	0	6.99
Biotech Potatoes	102	2.50	1.84	0	7.95
Biotech Potato Dices	102	1.78	1.31	0	6
A1. Bids Pre-Information: Before B1					
Conventional Potatoes	36	2.84	1.53	0.25	6.75
Conventional Potato Dices	36	1.94	1.12	0.1	4.89
Biotech Potatoes	36	2.92	1.60	0	6
Biotech Potato Dices	36	2.17	1.12	0	4.5
B1. Bids Post-Information: Company Perspective Only					
Conventional Potatoes	36	2.93	1.57	0.3	5.99
Conventional Potato Dices	36	1.98	1.14	0.1	5
Biotech Potatoes	36	3.11	1.77	0.01	7
Biotech Potato Dices	36	2.21	1.25	0.01	6
A2. Bids Pre-Information: Before B2					
Conventional Potatoes	34	2.75	1.29	0.89	6
Conventional Potato Dices	34	1.99	1.43	0.25	6
Biotech Potatoes	34	2.95	1.40	0.99	6
Biotech Potato Dices	34	2.19	1.42	0.49	5.95
B2. Bids Post-Information: Environmental Perspective Only					
Conventional Potatoes	34	2.73	1.29	0.75	6
Conventional Potato Dices	34	1.77	1.39	0	5.65
Biotech Potatoes	34	1.89	1.77	0	7
Biotech Potato Dices	34	1.46	1.29	0	5
A3. Binds Pre-Information: Before B3					
Conventional Potatoes	34	2.51	1.49	0.01	5.99
Conventional Potato Dices	34	1.51	1.19	0	4.25
Biotech Potatoes	34	2.74	1.59	0.01	6.95
Biotech Potato Dices	34	2.03	1.49	0	4.99
B3. Bids Post-Information: Company and Environmental Perspectives					
Conventional Potatoes	34	2.37	1.46	0.01	5.99
Conventional Potato Dices	34	1.56	1.54	0	6.99
Biotech Potatoes	34	2.45	1.82	0	7.95
Biotech Potato Dices	34	1.63	1.31	0	4.65

Table 3.3 WTP Differences and Other Summary Statistics

Variables	Mean	Standard Deviation
WTP for improved biotechnology potatoes after information treatment less WTP for improved biotechnology potatoes before information treatment ($)	-0.38	$1.49
WTP for improved biotechnology potatoes after information treatment less WTP for conventional potatoes before information treatment ($)	-0.21	1.40
WTP for improved biotechnology dices after information treatment less WTP for improved biotechnology dices before information treatment ($)	-0.36	1.05
WTP for improved biotechnology dices after information treatment less WTP for conventional dices with sodium bisulfide before information treatment ($)	-0.05	0.98
Pre-auction, subject informed about: acrylamide	0.059	0.236
biotechnology	0.382	0.488
Subject received information treatment:		
Environmental group perspective	0.333	0.474
Company perspective	0.353	0.480
Company & environmental group perspectives	0.314	0.466

Table 3.4 Probit: Probability of Household Consuming Commodities Weekly[a/]

	Potatoes		Potato Chips		French Fries	
Regressors	(1)	(2)	(3)	(4)	(5)	(6)
Household income ($1,000)	-0.00002	-0.00001	-0.00000	-0.00000	-0.00000	-0.00000
	(1.59)	(1.68)	(0.03)	(1.07)	(0.95)	(1.35)
	[-0.0000]	[-0.0000]	[0.0000]	[-0.000]	[-0.000]	[-0.000]
Number of Adults	0.901	0.610	0.247	0.256	0.382	0.371
	(1.65)	(1.61)	(1.12)	(1.33)	(1.86)	(2.00)
	[0.017]	[0.030]	[0.047]	[0.053]	[0.144]	[0.140]
Number of Children ≥ 8yrs	0.618	–	-0.227	–	0.034	–
	(0.92)		(1.04)		(0.19)	
	[0.011]		[-0.043]		[0.013]	
Anyone on diet (=1)	-0.841	-0.474	-0.047	–	-0.235	–
	(1.13)	(0.94)	(0.12)		(0.73)	
	[-0.024]	[-0.028]	[-0.009]		[-0.090]	
Gender (1=male)	-0.690	-0.706	-0.463	-0.420	0.731	0.699
	(1.14)	(1.40)	(1.31)	(1.23)	(2.33)	(2.33)
	[-0.017]	[-0.043]	[-0.094]	[-0.092]	[0.264]	[0.253]
Age	0.333	0.209	0.426	0.332	0.134	0.148
	(1.32)	(1.29)	(3.06)	(3.09)	(1.27)	(1.65)
	[0.006]	[0.010]	[0.081]	[0.069]	[0.051]	[0.056]
Age^2	-0.004	-0.002	-0.005	-0.004	-0.002	-0.002
	(1.37)	(1.40)	(3.03)	(3.02)	(1.30)	(1.66)
	[-0.0001]	[-0.0001]	[-0.001]	[-0.001]	[-0.001]	[-0.001]
Education (yrs.)	-0.012	–	-0.146	–	0.003	–
	(0.07)		(1.38)		(0.03)	
	[-0.0002]		[-0.028]		[0.001]	
Married (=1)	1.030	0.928	-0.198	–	-0.124	–
	(1.34)	(1.40)	(0.49)		(0.34)	
	[0.024]	[0.052]	[-0.038]		[-0.047]	
White (=1)	0.755	–	-0.555	–	-0.067	–
	(0.76)		(0.84)		(0.14)	
	[0.029]		[-0.082]		[-0.025]	
Exercises Weekly (=1)	1.155	–	-0.829	0.668	-0.971	-1.102
	(1.12)		(1.57)	(1.38)	(1.81)	(2.15)
	[0.065]		[0.217]	[0.177]	[-0.301]	[-0.329]
Good Health (=1)	0.791	–	0.088	–	-0.389	–
	(0.88)		(0.17)		(0.95)	
	[0.028]		[0.017]		[-0.140]	
Boston (=1)	0.779	0.728	1.11	1.12	1.019	1.003
	(0.86)	(0.97)	(2.07)	(2.27)	(2.43)	(2.58)
	[0.011]	[0.029]	[0.169]	[0.186]	[0.345]	[0.340]
Los Angeles (=1)	0.751	0.701	0.756	0.830	1.047	1.020
	(0.97)	(1.03)	(1.75)	(2.04)	(2.60)	(2.77)
	[0.011]	[0.029]	[0.125]	[0.148]	[0.356]	[0.348]
Intercept	-7.587	-2.937	-6.583	-7.052	-2.525	-3.030
	(1.09)	(0.77)	(2.02)	(2.76)	(0.97)	(1.39)
Pseudo R^2	0.348	0.285	0.212	0.169	0.210	0.195

[a/]Absolute value of z-values in parentheses. t-values larger than 1.98 are significantly different from zero at the 5% level; larger than 1.65 are significant at 10% level. The marginal effects are in square brackets.

Table 3.5 Regression Analysis of WTP differences: WTP After Information Treatment Less WTP before Treatment - Fresh Potatoes, 5lbs (n=102)[a/]

	Biotech Potatoes		Biotech Potatoes vs. Conventional Potatoes	
Regressors	(1)	(2)	(3)	(4)
Household income ($1,000)	-0.00006	-0.00006	-0.00004	-0.00003
	(1.69)	(1.73)	(1.06)	(1.16)
Number of Children < 8yrs	-0.042	–	-0.164	–
	(0.15)		(0.58)	
Gender (1=male)	-0.636	-0.621	-0.486	-0.461
	(2.32)	(2.34)	(1.79)	(1.75)
Age	-0.002	–	0.003	–
	(0.22)		(0.32)	
Education (yrs.)	0.018	–	-0.002	–
	(0.23)		(0.02)	
Informed about acrylamide (=1)	-0.192	–	0.498	–
	(0.32)		(0.82)	
Informed about biotechnology (=1)	0.782	0.738	0.584	0.583
	(2.64)	(2.67)	(2.00)	(2.18)
Reads food label (=1)	-0.774	-0.748	-0.398	–
	(1.77)	(1.78)	(0.92)	
Biotech and GM foods are different	-0.727	-0.732	-0.536	-0.493
(=1)	(2.56)	(2.72)	(1.91)	(1.85)
Company perspective	1.424	1.423	1.249	1.200
	(4.34)	(4.51)	(3.84)	(3.86)
Company perspective ×	0.808	0.845	0.874	0.898
Environmental group perspective	(2.36)	(2.61)	(2.59)	(2.82)
Household consumes potatoes weekly	-0.358	–	-0.243	–
	(0.65)		(0.45)	
Boston (=1)	0.143	0.144	-0.99	-0.093
	(0.38)	(0.42)	(0.27)	(0.27)
Los Angeles (=1)	0.684	0.654	0.241	0.215
	(1.93)	(2.01)	(0.69)	(0.67)
Intercept	0.164	-0.090	0.058	-0.532
	(0.11)	(0.18)	(0.04)	(1.55)
R^2	0.318	0.312	0.241	0.223

[a/] Absolute value of t-values in parentheses. Coefficients with t-values larger than 1.98 are significantly different from zero at the 5% level; larger than 1.65 are significant at 10% level. Environmental group perspective on biotechnology is the excluded information treatment.

Table 3.6 Regression Analysis of Willingness-to-Pay Differences: WTP After information Treatment less WTP Before Treatment - Fresh Cut Potato Dices, 12oz (n=102)[a/]

	Low Acrylamide Biotech Dices		Low Acrylamide Biotech Dices vs. Dices w Sodium Bisulfite	
Regressors	(1)	(2)	(3)	(4)
Household income ($1,000)	-0.00001	–	-0.00001	–
	(0.56)		(0.53)	
Number of Children < 8yrs	0.116	–	-0.112	–
	(0.56)		(0.55)	
Gender (1=male)	-0.074	–	-0.017	–
	(0.37)		(0.09)	
Age	0.008	–	0.003	–
	(0.98)		(0.33)	
Education (yrs.)	0.018	–	0.023	–
	(0.32)		(0.42)	
Informed about acrylamide (=1)	-0.310	–	-0.017	–
	(0.70)		(0.04)	
Informed about biotechnology (=1)	0.261	–	0.279	0.291
	(1.23)		(1.32)	(1.51)
Reads food label (=1)	-0.550	-0.432	-0.400	-0.413
	(1.75)	(1.46)	(1.28)	(1.39)
Biotech and GM foods are different	-0.475	-0.441	-0.107	–
(=1)	(2.33)	(2.29)	(0.52)	
Company perspective	0.863	0.876	0.830	0.816
	(3.65)	(3.89)	(3.53)	(3.70)
Company perspective ×	0.341	0.376	0.613	0.614
Environmental group perspective	(1.38)	(1.61)	(2.51)	(2.70)
Household consumes potatoes weekly	-0.033	–	0.180	–
	(0.08)		(0.46)	
Boston (=1)	-0.428	-0.522	-0.233	-0.299
	(1.58)	(2.29)	(0.87)	(1.34)
Los Angeles (=1)	0.417	0.365	0.244	0.148
	(1.63)	(1.60)	(0.96)	(0.67)
Intercept	-0.614	-0.169	-0.729	-0.229
	(0.50)	(0.50)	(0.70)	(0.70)
R^2	0.287	0.256	0.199	0.187

[a/] Absolute value of t-values in parentheses. Coefficients with t-values larger than 1.98 are significantly different from zero at the 5% level; larger than 1.65 are significant at 10% level. Environmental group perspective on biotechnology is the excluded information treatment.

CHAPTER 4. THE SIMULTANEOUS ADOPTION OF RESISTANCE MANAGEMENT PRACTICES TO CONTROL WEEDS

Introduction

Over the past 70 years pesticides have contributed to substantial yield increases by controlling weeds, diseases, and insects that damage crops. Due to the ease of application, pesticides have substituted for labor, machinery, and fuel use in pest control. As a result, farmers saw an increase in net returns making pesticides more attractive. However, as weeds and other pests become resistant to pesticides, the chemicals become less effective causing farmers to use more and more chemicals to kill the pests.

Glyphosate, a broad-spectrum herbicide, was released for commercial use in 1974. Due to its very low toxicity to mammals, birds, and fish, glyphosate became an attractive herbicide to farmers. Additionally, it was believed that due to glyphosate's mode of action and the lack of metabolism in plants, plants could not become resistant to glyphosate (Shaner, 2000; Bonny, 2016). Until 1996, glyphosate was restricted to use prior to crop seeding for weed control (Duke and Powles, 2009) and was generally used along with other chemicals or other weed control mechanisms. Since glyphosate is a non-selective herbicide, it could control almost all weed species and was very effective as a pre-emergence herbicide. Due to these use limitations, during the first 26 years of availability there was little evolution of glyphosate resistance weeds (Duke and Powles, 2009). As can be seen in Figure 4.1 there were only 2 glyphosate resistant weed species in the US in 2000 (Heap, 2016).

In 1996, the first genetically modified soybean, corn and cotton plants became commercially available. These GM crops are herbicide tolerant (HT) and/or insect resistant (IR) crops. The herbicide tolerant crops are modified such that the crops will have limited damage from direct pesticide applications. The most common and popular HT trait is the glyphosate tolerant (GT) trait, which was released in 1996. The insect resistant crops are modified in a way that prevents insects from harming crops (Frisvold & Reeves, 2011). Specifically, IR, also known as Bt crops, contains a gene, Bacillus thuringiensis (Bt), which is a soil dwelling bacterium that produces a protein toxic to insects (Fernandez-Cornejo el al, 2014).

When GT crops were released, Monsanto recommended only using glyphosate when using GT crops. In soybeans specifically, Monsanto recommended that farmers use glyphosate as a pre-emergence herbicide and then follow up with one or two more glyphosate applications (Shaner, 2000). These beliefs and recommendations may have led to the rapid rise in glyphosate application rates in recent years and may have impacted the development of glyphosate resistance in weed species (Fernandez-Cornejo et al, 2014). As can be seen in Figure 4.1, the number of glyphosate resistant weed species in the US rapidly increased from 2003 until 2010 with 13 glyphosate resistant weed species. From 2010 until 2015, the growth rate of glyphosate resistant weed species slowed with the development of only 2 new resistant weed species. As of 2015 there are 15 glyphosate resistant weed species in the US (Heap, 2016).

As the weed resistance to herbicides grows, farmers must adopt different technologies to kill or prevent the weed growth on their farms. The objective of this study is to assess farmers' adoption of 4 weed resistance management practice (RMP) groups, using Iowa Farm and Rural Life Poll data. Additionally, we to evaluate the complementarity of RMP groups (e.g., which groups are more likely to be used together than not used together), which has not been done previously.

Previous Research

Following Griliches (1957) study on adoption rates of hybrid seed corn, a vast literature studying technology adoption in agriculture emerged. Research into the adoption of resistance management practices (RMPs) was sparser until recently, and a majority of the RMP adoption research was from a weed science approach. Two major branches for explaining adoption decisions can be found in the literature: the economics constraint and innovation-diffusion theories (Adesina & Zinnah, 1993). Economic constraint models assert that constraints such as, liquidity, land/farm size, and risk attitudes are the major determinants of observed technology adoption behavior (Dorfman, 1996; Havens and Flinn, 1976; Mauceri et al, 2004). While innovation-diffusion models, which began with the work of Ryan and Gross (1943) followed by Rogers (1962), assert that access to information about the new technology is the key factor to determining adoption (Adesina & Zinnah, 1993; Truong Thi, 2008; DeDecker et al, 2014; Borkhani et al, 2010).

Most like our study, Frisvold et al. (2009) examined the adoption of 10 different RMPs used to control weed resistance to herbicides. The authors found that farmers who used a greater number of RMPs often had more education but less farming experience (younger in age). They also expected higher yields relative to the county average. Frisvold and others also found that yield expectations and variability were significant predictors of adoption of individual RMPs. Out of the 10 RMPs analyzed cleaning equipment, using multiple herbicides with different modes of action, and supplemental tillage were the least used RMPs.

In a different approach from other weed RMP studies, which maximizes farmer's net present value, we assume farmer's make cost minimizing decisions and therefore maximize their utility of profit.

Conceptual Framework

Suppose that farms have access to $j = 1, 2, \dots, J$ technologies that aim to accomplish a similar function such as pest eradication, $T_1, T_2, \dots, T_J$. Technologies can be used independently or in combination with one another. The production function is given by $F(T_1, T_2, \dots, T_J, Z; \Omega)$ where Z is a composite input reflecting labor, capital, and other factors employed on the farm, and Ω reflects exogenous environmental and geoclimatic factors that raise or lower farm productivity. Each technology can be used at varying intensities subject to positive but diminishing marginal products so that $\frac{\partial F}{\partial T_j} > 0$ and $\frac{\partial^2 F}{\partial T_j^2} < 0$. Each farm *i* has a target output level $\bar{Q}_i$. Its objective is to minimize the cost of production

$$\min C_i = P_1 T_1 + P_2 T_2 + \cdots + P_J T_J + P_Z Z + \mu\left(\bar{Q}_i - F\left(T_1, T_2, \dots, T_J, Z_i, \Omega_i\right)\right) \quad (4.1)$$

The first-order conditions are

$$\frac{\partial C_i}{\partial T_1} = P_1 - \mu F_{T_1} \geq 0 \quad (4.2A)$$

$$\frac{\partial C_i}{\partial T_2} = P_2 - \mu F_{T_2} \geq 0 \quad (4.2B)$$

$$\vdots$$

$$\frac{\partial C_i}{\partial T_J} = P_J - \mu F_{T_J} \geq 0 \quad (4.2C)$$

$$\frac{\partial C_i}{\partial Z} = P_Z - \mu F_{T_i} \geq 0 \quad (4.2D)$$

$$\frac{\partial C_i}{\partial \mu} = \bar{Q}_i - F\left(T_1, T_2, \dots, T_J, Z_i, \Omega_i\right) = 0 \quad (4.2E)$$

If a technology is used, its intensity will be such that the marginal cost is lower than for other technologies for at least some range of use, meaning that

$$\frac{P_j}{F_{T_j}} \leq \frac{P_l}{F_{T_l}} \; \nabla l \neq j \tag{4.3}$$

With rising marginal cost of intensity of use, it is possible that a technology is adopted up to some level of intensity after which a second technology satisfies condition (4.3). This is illustrated in Figure 4.2. In this case, at *Q=0*, the first technology has the lowest marginal cost. As the application of the technology increases with output, the marginal cost is rising. Eventually, the marginal cost of an additional increase in intensity of use of the first technology rises above the marginal cost of using the second technology. Moreover, the slope of the marginal cost curve for the second technology will be less than that of the first due to the diminishing marginal productivity condition. As a result, there will be a range of output where the farmer is using both the first and second technology, but again, diminishing marginal productivity will eventually make a third technology economically viable. The implication is that large farms or farms with intense use of technologies will be more likely to use multiple technologies rather than a single one. Assuming equality conditions hold, the reduced-form equation for technology *j* will be

$$T_{ij} = f_i(P_1, P_2, \ldots, P_J, P_Z, \bar{Q}_i, \Omega_i) \tag{4.4}$$

In practice, the prices will be identical across farms and so their effect on technology choice will be captured as a common effect. Variation in technology choice will depend on the remaining factors, farm size and the exogenous environmental factors.

Data

In this study, we use data from the Iowa Farm and Rural Life Poll (IFRLP), developed and conducted by Iowa State University Extension Sociology, in partnership with the Iowa Department of Agricultural and Land Stewardship and Iowa Agricultural Statistics.

The IFRLP is an annual survey of approximately 2,000 Iowa farmers developed to learn how the ongoing changes in Iowa's agriculture and rural areas affect farmers and rural society.

The main source of data is from the 2013 IFRLP, which focused on soil health and compaction, climate change, rented land, weed and insect management, and farm and farmer characteristics. However, this survey was missing information on farmer education, which was included in the 2011 and 2015 polls. There were 726 farmers who responded to every question used from the 2013 survey and provided their highest earned degree in either 2011 or 2015. Therefore, the farmers included in our study had to respond to the survey multiple times.

In 2013, farmers were given a list of 11 methods for managing herbicide resistant weeds on their fields and asked to indicate whether he/she have used each of the methods. These eleven RMP methods were selected and recommended to be included in the survey by weed scientists at Iowa State University. The list of RMPs and rate of use by responding farmers can be found in Table 4.1. I use two different methods of grouping RMPs and report results for both methods. First, I principle component analysis (PCA) to group the RMPs into 4 technology groups. The technologies ended up in groups that could be defined based on how the technology enhanced the productivity of the factor inputs:

1. Chemical intensive technologies: Multiple herbicide application timings, multiple modes of herbicide action used each season, and multiple modes of action used in each herbicide application
2. Labor intensive technologies: Mechanical weed control (i.e., cultivation), hand-weeding, and inclusion of forage in the crop rotation, and cover crops
3. Capital intensive technologies: Tillage and higher planting rates.

4. Biological intensive technologies: Rotation of crops and use of crop cultivars that are resistant to herbicides other than glyphosate

Details on the PCA are presented in the Appendix. The rate of RMP group use and RMP bundles can be found in Table 4.2. The second RMP grouping method I developed by speaking with a weed specialist at Iowa State University, who recommended grouping the RMPs into three groups.[36] There are three technology groups based on a weed science classification of resistance management practices:

1. Cultural intensive: rotation of crops, inclusion of forage in the crop rotation, cover crops, and higher planting rates
2. Chemical intensive technologies: use of crop cultivars that are resistant to herbicides other than glyphosate, multiple herbicide application timings, multiple modes of herbicide action used each season, and multiple modes of action used in each herbicide application
3. Mechanical intensive technologies: tillage, mechanical weed control (i.e., cultivation), and hand-weeding.[37]

The rate of RMP group use and RMP bundles can be found in Table 4.3.

The sample means are reported in Table 4.4. The ages of our 726 respondents ranged from 32 to 93 years old with an average of 64 years of age. Ninety-seven percent are male with an average education of 14 years, which is equivalent to an associate's degree. Additionally, 76% of the farmers reported having a spouse in 2013 with an average of 59%

[36] I would like to thank Dr. Bob Hartzler for his expert advice on weed management.
[37] Hand-weeding is included in mechanical intensive RMPs since it is a mechanism which is physically disruptive of weeds similar to cultivation or tilling.

of household income coming from the farm operations. Farmers in our sample farm an average of 508 acres.

Methods

To analyze farmer's RMP adoption decisions we estimate the utility of profit maximization. The farmer's random utility function to adopt RMP_j $(j = 1, 2, \dots, J)$, is represented as

$$U_{ij} = \alpha_{Qj}\bar{Q}_i + \alpha_{\Omega j}\Omega_i' + \beta_j X_i' + \varepsilon_{ij}, \tag{4.5}$$

where U_{ij} is the utility of the *i*-th farmer who adopts RMP_j. The technology adoption decision is affected by farm size and environmental factors. We also include a vector X_i' of farm and farmer characteristics that affect preferences. The random error ε_{ij} would include unobservable factors known by the farmer that affect the utility of using technology *j*. The error terms are assumed to be jointly distributed multivariate normal random variables with zero conditional mean and variance normalized to one,

$$\varepsilon = \begin{bmatrix}\varepsilon_{i1} & \varepsilon_{i2} & \cdots & \varepsilon_{iJ}\end{bmatrix} \sim MVN(0, \Sigma) \tag{4.6}$$

where Σ is the covariance matrix,

$$\Sigma = \begin{bmatrix} 1 & \cdots & \rho_{1J} \\ \vdots & \ddots & \vdots \\ \rho_{1J} & \cdots & 1 \end{bmatrix}. \tag{4.7}$$

A farmer will adopt an RMP when the utility is larger for adopting that RMP compared to the utility from all other RMPs. Thus, we will denote $Y_{ij} = 1$ as the farmer's choice to adopt RMP_j, implying that $U_{ij} > U_{il}$ for all $j \neq l = 1, 2, \dots, J$. Let W_i represent all the factors included in (5) that influence farmer *i*'s decision regarding technology *j* with associated coefficients θ_j. Following Maddala (1983), the probability that $Y_{ij} = 1$ can be represented as,

$$Prob\left(Y_{ij} = 1 \middle| W_i'\theta_j, \Sigma\right) = Prob\left(U_{il} < U_{ij}, \forall\, j \neq l = 1, 2, \ldots J\right) \tag{4.8}$$

$$= Prob\left(\varepsilon_{il} - \varepsilon_{ij} < W_i'\theta_j - W_i'\theta_\iota, \forall\, j \neq l = 1, 2, \ldots J\right)$$

$$= Prob\left(\eta_{lj} < W_i'\left(\theta_j - \theta_l\right), \forall\, j \neq l = 1, 2, \ldots J\right)$$

$$= \Phi\left(W_i'\left(\theta_j - \theta_l\right), \Sigma\right)$$

where $n_{lj} = \varepsilon_{il} - \varepsilon_{ij}$ for all $j \neq l = 1, 2, \ldots, J$ and $\Phi(\cdot)$ is the multivariate normal distribution function.

$$\text{Prob}\left(Y_{ij} = 1 \middle| W_i'\theta_j, \Sigma\right) = \int_{-\infty}^{W_i'(\theta_j - \theta_1)} \cdots \int_{-\infty}^{W_i'(\theta_j - \theta_J)} f\left(\eta_{1j}, \ldots, \eta_{Jj}\right) d\eta_{1j}, \ldots d\eta_{Jj}. \tag{4.9}$$

where $f\left(\eta_{1j}, \eta_{2j}, \ldots, \eta_{Jj}\right)$ has a multivariate normal distribution.

The farmer characteristics include age, years of education, whether the farmer has a spouse, gender, total acres farmed, and percent of household income from the farm operation. Typically, younger farmers are less risk-averse and more likely to try new technologies (Adesina and Zinnah, 1993; Mauceri et al, 2005). However, older farmers are less subject to credit constraints. Further, Sharma and others (2011) find that younger farmers are more likely to adopt multiple pest management practices compared to older farmers. Overall, we would expect to see a negative correlation with age and more advanced technologies, such as labor-intensive technologies.

Farmers who have completed more years of formal education are more likely to understand information concerning new technologies and the benefits of early adoption (Mauceri et al, 2005; Fernandez-Cornejo & McBride, 2002). Fernandez-Cornejo and others (2001) found education as a significant factor in the adoption of technologies requiring greater managerial skills leading us to expect a positive effect of education on the adoption of RMPs that could require hiring labor such as with labor intensive technologies. Additionally, studies show higher education leads to the adoption of multiple agricultural technologies (Chaves & Riley, 2001; Lohr & Park, 2002).

Studies have found household size contributes to technology adoption. De Souza Filho and others (1999) found households with a larger number of family members to work on the farm were more likely to adopt sustainable agricultural technologies. However, Mauceri et al (2005) found larger households adopt less integrated pest management strategies. Due to these results, we have included whether the farmer has a spouse, who could potentially contribute to farm labor.

In addition to household size, farm size impacts a farmer's decision to adopt certain technologies. Most research has shown that adoption increases as farm size increases (Fernandez-Cornejo et al (2001); Fernandez-Cornejo & McBride (2002); Isgin et al (2008); Sharma et al (2009)). Adopting new technologies can cause high fixed costs, which is easier for larger farms to absorb than smaller farms. As previously stated in the conceptual framework and supported by previous research, we expect larger farms to adopt more RMPs. Including the percent of household income that is generated from the farm operation is a proxy for the farmer's opportunity cost. If a majority of the income comes from off-farm work, the farmer does not have much time to contribute to the farm operations and therefore may be less likely to adopt time-intensive RMPs. However, off farm income could relax a credit constraint.

Regression Results

PCA RMP groupings

The results from estimating the coefficients of the empirical model explaining a farmer's probability of adopting four different RMP groups, determined using PCA, are reported in Table 4.5. As a farmer's age increases, he/she is significantly less likely to use labor and capital intensive RMPs. Younger farmers could be more able-bodied making labor intensive (hand-weeding) RMPs a more reasonable option for them compared to older farmers. While, a farmer with more years of formal education is significantly more likely to use chemical intensive and biological intensive RMPs.

The presence of a spouse increases the likelihood a farmer will use chemical intensive RMPs but is not statistically significant for the use of other RMPs. Therefore, our results do not support the previous findings in literature that households with more family farm labor adopt more technologies. Additionally, if the farmer is male he is more likely to use chemical intensive and biological intensive RMPs than a female farmer.

An increase in acres farmed increases the probability the farmer is to use chemical intensive RMPs. However, as farms continue to increase in size, the marginal effect of size becomes negative, due to the negative coefficient on the quadratic farm size variable. Specifically, a farmer is more likely to use chemical intensive RMPs until he/she is farming 256 acres, after which he/she is significantly less likely to use chemical intensive RMPs. Acres farmed is an insignificant predictor of using biological intensive RMPs, but the quadratic term is negative and significant. Specifically, once a farmer is farming 181 acres, he/she is significantly less likely to use biological intensive RMPs. Additionally, as the percent of household income from the farm operation increases, the farmer is significantly more likely to use chemical intensive RMPs.

All of the correlation coefficients from the multivariate probit model are positive and significant but the correlation between chemical and labor-intensive technologies and labor and capital-intensive technologies are insignificant. Based on this model, individual RMP groups are more likely to be used together than not used together.

Weed Science RMP groupings

Table 4.7 contains the results from estimating the coefficients of the multivariate probit model, explaining a farmer's probability of adopting three different RMP groups, based on a weed scientists approach. These results are not much different from the results reported above from the first RMP grouping.

As a farmer's age increases, he/she is significantly less likely to use cultural or mechanical based RMPs. Similar to the results above, younger farmers may be more able-bodied making labor (and time) intensive RMPs a more reasonable option compared to older farmers. More years of formal education significantly increases the probability a farmer will use cultural or chemical based RMPs. The presence of a spouse significantly increases the probability that a farmer will use chemical intensive RMPs but does not significantly impact the probability of use of cultural or mechanical RMP groups. Additionally, if the farmer is a male, he is significantly more likely to use chemical intensive RMPs than a female farmer.

An increase in acres farmed significantly increases the probability a farmer will use chemical intensive RMPs until a farm operation reaches 272 acres, after which the probability of using chemical intensive RMPs significantly decrease. Also, as the percent of income from the farm operation increases, the farmer is significantly more likely to use chemical intensive RMPs.

Complementarity

In addition to evaluating farmers' adoption of RMPs, we test the complementarity of the numerous potential RMP bundles using an analysis developed by Yu, et. al (2012). This analysis allows us to test if RMP bundles are used more or less frequently in our sample than if these bundles were chosen at random (assumption of independence). First, under the assumption of independent RMPs, we construct the expected probability that a given bundle of RMPs will be chosen at random. Next, we compare the actual frequency farmers use a given bundle of RMPs to the predicted probability under the assumption of independence. If the bundle is selected significantly more frequent than under the hypothesis of independence, the RMPs within the bundle are mutually complementary. If the bundle is selected significantly less frequently than under the hypothesis of independence, the RMPs within the bundle can be viewed as substitutes (not used together frequently) (Yu, Hurley, Kliebenstein, & Orazem, 2012).

With J RMPs that can be used alone or in combination, there are 2^J potential bundles. Following Yu, et at. (2012), the probability $RMP_j, j = 1, 2, \ldots, J,$ is adopted is defined as $1 > p_j > 0$. Let Z_j, $(j = 1, 2, \ldots J)$ be equal to 1 if the j^{th} RMP is adopted and 0 otherwise, such that the set of RMP bundles is defined as $Y_r = \{Z_1, Z_2, \ldots, Z_j\}$, where $r = 1, 2, \ldots, 2^J$. The probability RMP bundle r is adopted is defined as $1 > q_r > 0$, such that $\sum_{r=1}^{2^J} q_r = 1$. Furthermore, let's define the set of RMPs used in RMP bundle Y_r as $\Omega_r^A = \{j \middle| j = 1, 2, \ldots, J \ and \ X_j = 1\}$ and the set of RMPs not used in the bundle is $\Omega_r^N = \{j | j = 1, 2, \ldots J \ and \ Z_j = 0\}$.

The expected probability that RMP bundle r is adopted is

$$q_r^0 = \prod_{j \in \Omega_r^A} p_j \prod_{l \in \Omega_r^N} (1 - p_l). \tag{4.10}$$

Using these estimated probabilities, we can assess whether technologies within bundle j are independent, mutual complements, or substitutes:

$$\begin{array}{lll} Independence & H_0: & q_r = q_r^0 \\ Complementarity & H_c: & q_r > q_r^0 \\ substitutatbility & H_s: & q_r < q_r^0 \end{array}$$

In order to test these hypotheses, we need estimates of the sampling distribution. Given a random sample of F farmers (our sample includes 726 farmers), denoted by $i = 1, 2, \dots F$, let $Z_j^i = 1$ if farmer i adopts RMP j and 0 otherwise. Similarly, let $Y_r^i = 1$, if farmer i adopts RMP bundle r and 0 otherwise.

Under the hypothesis of independence, the likelihood function for p_j is

$$L = \prod_{i=1}^{F} \prod_{j=1}^{J} p_j^{Z_j^i} (1 - p_j)^{1 - Z_j^i}, \tag{4.11}$$

resulting in a log-likelihood function of

$$\ln L = \sum_{j=1}^{J} \left[\left(\sum_{i=1}^{F} Z_j^i \right) ln(p_j) + \left(F - \sum_{i=1}^{F} Z_j^i \right) ln(1 - p_j) \right]. \tag{4.12}$$

Maximizing the log-likelihood function with respect to p_j, yields

$$\hat{p}_j = \frac{\sum_{i=1}^{F} Z_j^i}{F} \tag{4.13}$$

for $j = 1, 2, \dots J$. Next, the probability of adopting a given RMP j can be calculated by the frequency of its occurrence in the random sample under independence,

$$\hat{q}_r^0 = \prod_{j \in \Omega_r^A} \hat{p}_j \prod_{l \in \Omega_r^A} (1 - \hat{p}_l). \tag{4.14}$$

Using the sampling data to estimate the probability that RMP bundle r is adopted, the log-likelihood function is

$$\ln L = \sum_{r}^{2^J - 1} \ln(q_r) \sum_{i=1}^{F} Y_r^i + ln\left(1 - \sum_{r=1}^{2^J - 1} q_r \right) \sum_{i=1}^{F} Y_{2^J}^i . \tag{4.15}$$

Maximum likelihood estimation of the equation above yields the estimates

$$\hat{q}_r = \frac{\sum_{i=1}^{F} Y_r^i}{F} \tag{4.16}$$

for $r = 1, 2, \dots 2^J - 1$ and

$$\hat{q}_{2^J} = 1 - \sum_{r=1}^{2^J-1} \hat{q}_r. \tag{4.17}$$

To test the hypotheses listed above, sample variances are calculated using percentile bootstrapping. We draw 5,000 replacement samples from the data. For each of these samples $\hat{q}_r$ and $\hat{q}_r^0$ are calculated as well as the adoption rate differences $(\hat{q}_r - \hat{q}_r^0)$. The differences are ordered from smallest to largest and the 2.5th and 97.5th percentiles are located, which is the confidence interval at the 95% significance level. If zero lies within the confidence interval, the null hypothesis of independence cannot be rejected. If the lower bound of the confidence interval is positive, independence and substitutability can be rejected, but complementarity cannot be rejected. If the upper bound of the confidence interval is positive, independence and complementarity can be rejected, while substitutability cannot be rejected.

Complementarity Results

PCA RMP groupings

Our results show that the RMPs are mutual complements (bundle used more often than under independence) and are more likely to be complementary when no RMP is used or all four RMPs are used. This supports our hypothesis that farmers use an RMP until the marginal cost of increasing the intensity of the first RMP is greater than the marginal cost of introducing a second RMP. Farmers then add this second RMP into their resistant management plan. This continues until the farmer is using all the potential RMPs.

We also find chemical intensive and labor intensive RMPs are less likely to be used together than under independence. Similarly, using capital intensive and biological intensive RMPs jointly and using chemical intensive, labor intensive, and capital intensive RMPs jointly is less likely than under the assumption of independence. These results further support our insignificant correlation coefficients from the multivariate probit model.

Weed Science RMP groupings

Similar to the results above, all three RMPs are mutual complements. The use of all three RMP groups simultaneously occurs in our sample more often than would be expected under independence. Additionally, using two of the RMP groups together, without the third, occurs less often than under the assumption of independence. Farmers are no longer able to use just one or even two RMP groups and have resorted to using a combination of all three groups. As chemicals are becoming a less effective measure of pest control, farmers are adopting cultural and mechanical RMPs to control pests on their fields.

Conclusion

This study shows that age, education and gender significantly impact the probability a farmer will adopt certain RMP groups. Specifically, younger farmers are more likely to adopt labor, mechanical and capital intensive RMPs. While male farmers or farmers with more years of formal education are more likely to adopt chemical and cultural intensive RMPs. Additionally, the use of chemical intensive RMPs are positively and significantly correlated with the use of capital intensive and cultural intensive RMPs. The use of labor intensive and capital intensive RMPs are positively and significantly correlated with the use of biological intensive RMPs.

Further, the complementarity of RMP bundles is evaluated. With the four PCA based groupings of RMPs, there are 16 potential RMP bundles and with the three weed science based groupings of RMPs, there are 8 potential bundles. Farmers use all RMP groups, in both cases, simultaneously more often than is predicted under independence. Looking at the data further, 39% of the farmers in the sample use a combination of all four PCA RMP groups and 70% of the farmers use a combination of all three weed science based RMP groups.

This supports the hypothesis that due to rising marginal cost of pesticide use intensity, the RMP is adopted up to some level after which a second RMP is adopted. This continues until the farmer is using a combination of all RMP groups.

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Figures and Tables

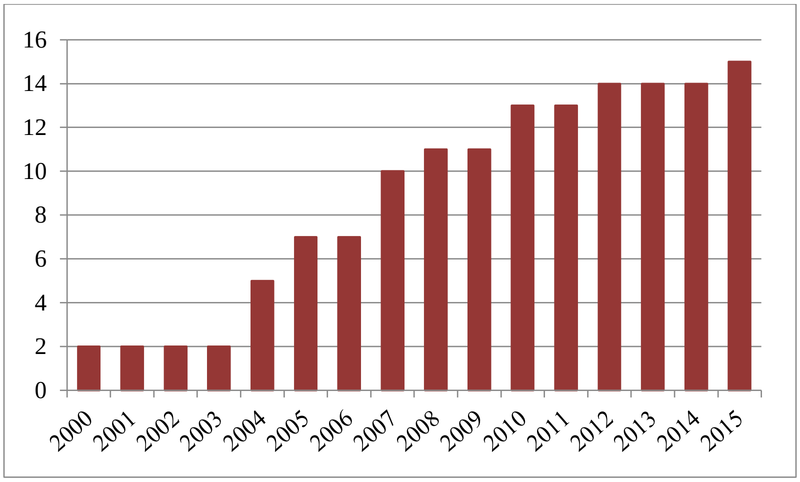

Figure 4.1 The Number of Glyphosate Resistant Weed Species in the US

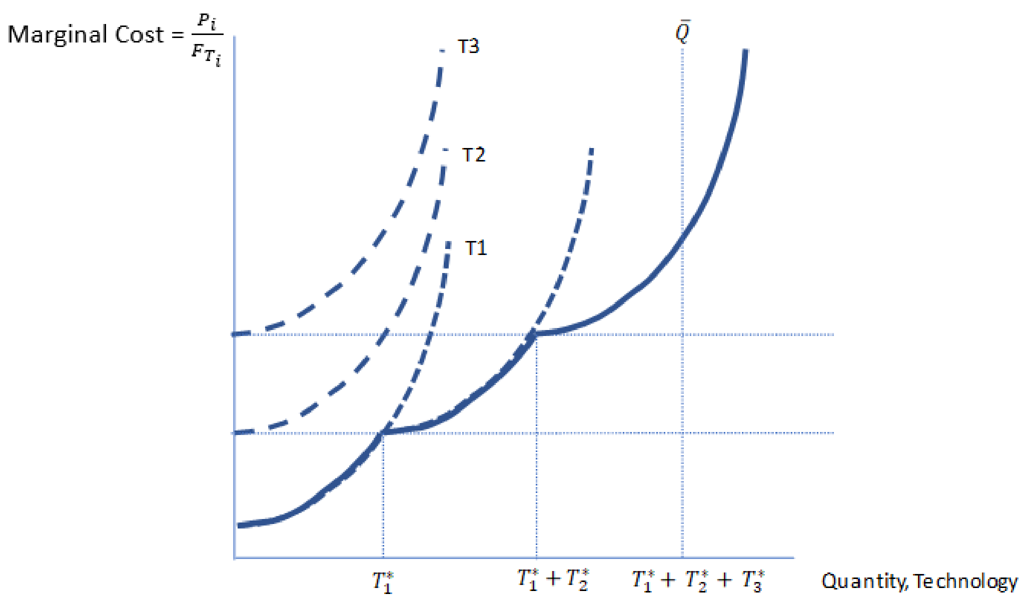

Figure 4.2 Illustration of Technology Choices as a Function of Desired Output

Table 4.1 Herbicide Resistance Management Practices	
RMP	**Percent of farmers that use the RMP**
Rotation of crops	92.70
Inclusion of forage in the crop rotation	23.42
Use of cover crops	15.70
Use of crop cultivars that are resistant to herbicides other than glyphosate	25.76
Multiple herbicide application timings	80.03
Multiple modes of herbicide action used each season	69.56
Multiple modes of herbicide action used in each herbicide application	57.16
Tillage	72.45
Mechanical weed control (cultivation)	23.83
Hand-weeding	28.93
Higher planting rates	47.66

Table 4.2 Resistance Management Practice Groupings using PCA	
RMP	**Percent of farmers that use the RMP bundles***
Chemical intensive only	0.69
Labor intensive (forage/cover crops/mechanical/hand-weed) only	0.28
Capital intensive (tillage/higher planting rates) only	0.28
Biological intensive (rotate crops/use cultivars) only	1.4
Chemical and labor intensive	0.14
Chemical and capital intensive	1.8
Chemical and biological intensive	6.1
Labor and capital intensive	0.55
Labor and biological intensive	1.4
Capital and biological intensive	2.3
Chemical, labor, and capital intensive	1.4
Chemical, labor, and biological intensive	6.9
Chemical, capital, and biological intensive	31.3
Labor, capital, and biological intensive	5.1
Chemical, labor, capital, and biological intensive (all four RMPs)	39.4
*There are 8 of 726 (or 1.1 percent) farmers who report not using any RMPs	

Table 4.3 Resistance Management Practice Groupings using Weed Science Approach	
RMP	**Pct. of farmers that use the RMP group***
Cultural intensive (rotation, forage, cover crops, and higher planting rates) only	2.3
Chemical intensive only	0.69
Mechanical intensive (tillage, cultivation, hand-weeding) only	0.28
Cultural and chemical intensive	16.7
Cultural and mechanical intensive	7.0
Chemical and mechanical intensive	2.1
Cultural, chemical, and mechanical intensive	69.8
*There are 8 of 726 (or 1.1 percent) farmers who report not using any RMPs	

Table 4.4 Sample Means	
Variables	**Mean**
Age	63.71
Years of education	14.12
Spouse (=1 if yes)	0.76
Male (=1 if yes)	0.97
Total acres farmed (hundreds)	0.5079
Percent of Income from Farm Operation	0.589

Table 4.5 Multivariate Probit: Probability of adopting RMP_j (PCA)				
Technology Type by Input Intensity				
	Chemical	Labor	Capital	Biological
Age	0.002 (0.006)	-0.019*** (0.005)	-0.021*** (0.006)	-0.011 (0.008)
Years of Education	0.046* (0.027)	0.019 (0.020)	-0.027 (0.023)	0.080** (0.033)
Spouse (=1 if yes)	0.335** (0.140)	0.132 (0.112)	0.169 (0.129)	-0.147 (0.184)
Male (=1 if yes)	0.860*** (0.295)	-0.027 (0.278)	0.275 (0.292)	0.585* (0.351)
Total Acres Farmed	0.893*** (0.258)	0.160 (0.172)	-0.215 (0.269)	0.428 (0.265)
Total Acres Farmed Squared	-0.163*** (0.052)	-0.020 (0.046)	0.092 (0.105)	-0.118** (0.052)
Percent of Income from Farm Operation	0.684*** (0.253)	-0.265 (0.199)	0.065 (0.236)	0.206 (0.305)
Constant	-1.317* (0.713)	1.085* (0.555)	2.309*** (0.642)	0.441 (0.868)
Correlation Coefficients				
Chemical	1			
Labor	0.040	1		
Capital	0.259***	0.061	1	
Biological	0.303***	0.171**	0.295***	1
* significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level				

Table 4.6 RMP Complementarity Test Results (PCA)	
Complement bundles	No RMP All 4 RMPs
Substitute bundles	Chemical & Labor Capital & Biological Chemical & Labor & Capital

Table 4.7 Multivariate Probit: Probability of Adopting RMP_j (Weed Sci.)

Technology Type by Input Intensity			
	Cultural	Chemical	Mechanical
Age	-0.018*	-0.002	-0.028***
	(0.009)	(0.006)	(0.006)
Years of Education	0.092**	0.059**	-0.021
	(0.040)	(0.028)	(0.022)
Spouse (=1 if yes)	0.112	0.340**	0.087
	(0.200)	(0.144)	(0.127)
Male (=1 if yes)	-0.008	0.822***	0.386
	(0.521)	(0.301)	(0.283)
Total Acres Farmed	0.061	0.937***	-0.055
	(0.339)	(0.270)	(0.260)
Total Acres Farmed Squared	-0.029	-0.172***	0.049
	(0.088)	(0.053)	(0.102)
Percent of Income from Farm Operation	0.589	0.540**	-0.197
	(0.360)	(0.260)	(0.229)
Constant	1.252	-1.085	2.625***
	(1.078)	(0.740)	(0.628)
Correlation Coefficients			
Cultural	1		
Chemical	0.205*	1	
Mechanical	0.250***	0.182**	1

* significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level

Table 4.8 RMP Complementarity Test Results (Weed Sci.)

Complement bundles	No RMP All 3 RMPs
Substitute bundles	Cultural & Chemical Cultural & Mechanical Chemical & Mechanical

Appendix. Principal Component Analysis

Principal component analysis (PCA) allows us the observe patterns of similarity of the resistance management practice variables. Based on the results from the PCA, we combine resistance management practices into groups. The eigenvalues from PCA and Scree plot are displayed in the tables and figure below.

According to Kaiser's rule (Kaiser, 1961), an eigenvalue greater than 1 indicates the principal components account for more variance than is accounted by one of original variables. Additionally, this is a good cut-off rule for determining the number of principal components to retain. Applying the rule to our results leads us to believe we have 4 RMP groupings. However, cutting off at 4 PCs only explains 54% of the variation in our data. Jolliffe (2002) argues, a sensible cut-off is a total variation of 70% to 90%. The author does go on to explain the range can be lower or higher depending on the details for the data set (Jolliffe, 2002).

The Scree plot, which is a plot of the eigenvalues ordered from largest to smallest, provides another useful mechanism to aid in our cut-off decision. The number of PCs to retain (k) is determined by examining the slope of the lines to the left of the selected PC and to the right. Ideally, the slope of the lines to the left of k are steep and to the right of k are not steep. Using our Scree plot, we decided the optimal number of RMP groupings is 4. The slope of the line to the left of 4 is relatively steep and the slope to the right of 4 starts to flatten out.

Therefore, based on the three rules mentioned about it was determined to use 4 RMP groupings. To determine which RMPs to group together, the eigenvectors associated with the first four components (Table A.2) and the most significantly correlated variables within a given component (Tables A.3 – A.7).

The first principal component is highly correlated with using multiple herbicide timings, multiple modes of herbicide action used each season, and multiple modes of action used in each herbicide application, which is our first RMP group (chemical intensive RMPs). From the correlations in the second principal component, our second RMP group consists of inclusion of forage in the crop rotation, cover crops, mechanical weed control, and hand-weeding (labor intensive RMPs). Likewise, our third RMP group is tillage and higher planting rates (capital intensive RMPs). Finally, our fourth RMP group is rotation of crops and use of crop cultivars that are resistant to herbicides other than glyphosate (biological intensive RMPs).

Table A9 Principal Component Analysis Results

	Eigenvalue	Variance Percent	Cumulative Variance Percent
Comp 1	2.0157	18.32	18.32
Comp 2	1.6731	15.21	33.53
Comp 3	1.2016	10.92	44.46
Comp 4	1.0707	9.73	54.19
Comp 5	0.9468	8.61	62.80
Comp 6	0.9254	8.41	71.21
Comp 7	0.8045	7.31	78.53
Comp 8	0.7103	6.46	84.98
Comp 9	0.6566	5.97	90.95
Comp 10	0.5873	5.34	96.29
Comp 11	0.4080	3.71	100

Table A10 Eigenvectors for the first four components of PCA

Variable	Comp1	Comp2	Comp3	Comp4
Rotate crops	0.1815	0.1308	**0.2302**	0.4103
Include forage in rotation	-0.0493	**0.5257**	0.3381	0.1235
Cover crops	-0.0327	**0.4637**	0.4514	-0.0765
Use of cultivars other than glyphosate resistant	0.1888	0.0716	**0.3112**	0.1114
Multiple herbicide applications	**0.4819**	-0.1668	0.0158	-0.0566
Multiple MOA used each season	**0.5775**	-0.14	0.0756	-0.1388
Multiple MOA used each application	**0.5016**	-0.0638	0.1964	-0.0486
Tillage	0.1643	0.284	-0.5001	**0.3062**
Mechanical weed control	0.1463	**0.468**	-0.3401	-0.2448
Hand weed	0.1946	**0.3596**	-0.2641	-0.4087
Higher planting rates	0.1559	0.0766	-0.2282	**0.6727**

Table A11 Correlation coefficients between variables and PC1

Variables	Correlation
Multiple MOA used each season	0.8199
Multiple MOA used each application	0.7121
Multiple herbicide applications	0.6842
Hand-weeding	0.2762
Use of cultivars other than glyphosate resistant	0.2680
Rotation of crops	0.2576
Tillage	0.2333
Higher planting rates	0.2214
Mechanical weed control	0.2078

Table A12 Correlation coefficients between variables and PC2	
Variables	**Correlation**
Inclusion of forage in rotation	0.6800
Mechanical weed control	0.6053
Cover crops	0.5998
Hand-weeding	0.4652
Tillage	0.3674
Rotation of crops	0.1692
Higher planting rates	0.0991
Use of cultivars other than glyphosate resistant	0.0926
Multiple MOA used each application	-0.0826
Multiple MOA used each season	-0.1811
Multiple herbicide applications	-0.2158

Table A13 Correlation coefficients between variables and PC3	
Variables	**Correlation**
Cover crops	0.4948
Inclusion of forage in rotation	0.3706
Use of cultivars other than glyphosate resistant	0.3411
Rotation of crops	0.2524
Multiple MOA used each application	0.2153
Multiple MOA used each season	0.0829
Higher planting rates	-0.2502
Hand-weeding	-0.2895
Mechanical weed control	-0.3728
Tillage	-0.5482

Table A14 Correlation coefficients between variables and PC4	
Variables	**Correlation**
Higher planting rates	0.6961
Rotation of crops	0.4246
Tillage	0.3169
Inclusion of forage in rotation	0.1278
Use of cultivars other than glyphosate resistant	0.1153
Cover crops	-0.0792
multiple MOA used each season	-0.1436
Mechanical weed control	-0.2533
Hand-weeding	-0.4230

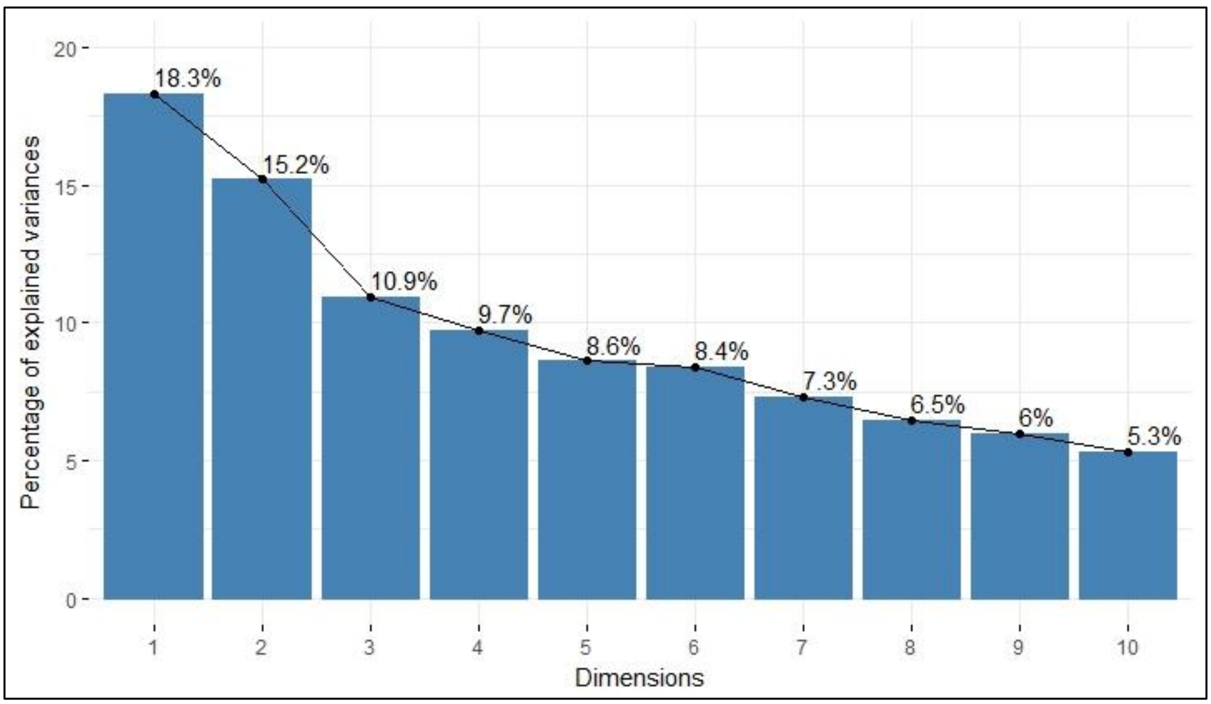

Figure A3 Scree Plot

CHAPTER 5. CONCLUSION

This dissertation explores two distinct but related areas: how injected information affects consumer's demand for genetically engineered food products, and how farm and farmer attributes affect adoption of resistance management practices to cope with herbicide resistance in genetically engineered crop varieties. Genetic engineering has produced crops that improve food safety and food security for our growing population. Innate Potatoes have been genetically engineered to produce low levels of acrylamide, which is a known cancer-causing agent in humans. Additionally, it has low browning and low bruising properties, which reduces food waste. Consumer acceptance of these second-generation genetically engineered potatoes can be very beneficial to society.

The first two essays support previous research that consumers are accepting of genetically engineered (GE) products if viewed as benefiting the public. When consumers received positive information about genetic engineering and information on the benefit of low-acrylamide products, consumers were willing to pay significantly more for GE products after reading this information. Further, consumers had the highest willingness-to-pay (WTP) for GE potato products when these two types of information were paired. The effect on WTP was not as strong when positive GE information and informative acrylamide information was separated. However, information did not significantly impact a consumer's WTP for conventional potato products, even after being informed of the cancer-causing potential of acrylamide. Therefore, we see consumers are willing to pay more for "safer" or less risky food products but not willing to pay less for these riskier, potentially cancer-causing, conventional products.

Genetic engineering has also produced herbicide tolerant (HT) crops, which allow herbicides to be used on crops with minimal crop damage. The most widespread HT crops are glyphosate tolerant. Glyphosate is a broad-spectrum and low toxicity herbicide. The introduction of glyphosate tolerant crops allowed farmers to use glyphosate in place of highly toxic alternative chemicals. However, this led to the overuse of glyphosate and rapid rise of weeds resistant to glyphosate. With glyphosate becoming ineffective on these resistant weed species, farmers must seek other resistance management practices (RMPs), or methods of weed control.

In the third essay, I find age, gender, and education significantly affect a farmer's use of certain RMP groups. Specifically, younger farmers are more likely to use cultural intensive and mechanical intensive RMPs, where mechanical also includes labor intensive (hand-weeding) practices. Farmers with more years of formal education and male farmers are more likely to use chemical and cultural RMPs. Additionally, using a test of complementarity among RMP bundles, we find all RMP groups are more likely to be used simultaneously than individually. Farmers first adopt the RMP with the lowest marginal cost and increase intensity of use until the marginal cost of increasing intensity of use is greater than the marginal cost of adopting another RMP. This continues until the farmer has adopted all potential RMP groups, which is evident in our results.

Widespread acceptance of genetically engineered crops can be valuable to society. GE food products offer increased food safety and security. Consumer acceptance of these food products is significantly impacted by the type of information they receive. But unexpected consequences from the GE crop adoption can occur, such as the rapid increase of weeds resistant to herbicides which complement the GE crops. These consequences have led to the adoption of costly alternative weed control practices. Additional insights into the diffusion of information on GE crops and potential unintended consequences of adoption will support the acceptance of our transforming agricultural practice.