Consumers' Willingness to Pay for New Genetically Modified Food Products: Evidence from Experimental Auctions of Intragenic and Transgenic Foods

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Abstract

Genetically modified (GM) foods were first marketed about a decade ago and have been surrounded by much controversy. Although the first GM traits were introduced into vegetables, GM grain and oilseed crops have been most successful because of their direct benefits to farmers. Recent advances in GM techniques enable new GM foods that contain enhanced consumer attributes. Private information from the biotech industry and from environmental groups paint extreme pictures of likely benefits, costs, and risks of new GM crops and foods. Given the complex nature of the GM food market, new experimental economic methods are used to assess consumers' willingness to pay for food products that might be made using new GM technologies. Participants in these auctions are randomly chosen adult consumers in major U.S. metropolitan areas; food labels are kept simple and focused on key attributes of experimental goods; and diverse private information from the agricultural biotech industry (e.g. Monsanto and Syngenta), environmental groups (e.g. Greenpeace and Friends of the Earth) and independent third-party information are used to construct information treatments. Food labels and information treatments are randomized; and auctions are best described as private value, sealed bid, random n-th price. The econometric model of participants' bid prices, or willingness to pay, for three products—potato, tomato and broccoli—is a Bayesian seemingly-unrelated regression Tobit model. For a given food label, we find significant information treatment effects, controlling for demographic attributes of participants, prior opinions about GM foods, and healthiness of lifestyle. Moreover, these effects are shown to differ across food labels and for commodities with and without enhanced consumer attributes. Information is shown to have significant value.

1 Introduction

Since the introduction and deregulation of the first commercially available genetically modified (GM) crops in the mid-90s, the Flavr-Savr tomato by Calgene and the Russet Burbank New Leaf Potato by Monsanto, GM field crops (e.g. soybeans, canola, corn, and cotton) have been major successes, surpassing the one-billionth acre milestone in 2005. The latter crops are largely used for livestock feed and fiber, but are also sometimes consumed by people. Yet, despite the rapid expansion and worldwide market penetration of bioengineered field crops, the adoption of GM crop varieties has been slowed (or largely stalled in some countries) due in part to the staunch opposition of environmental groups and some consumer groups due to economic, environmental, health, and religious concerns and general uncertain future outcomes[1]. This contentious debate over genetic modification encompasses a wide array of interested parties who have disseminated information into the public domain with positions on GM foods spanning the spectrum from "frankenfoods"

[1] For reviews see Herdt (2006) and van den Bergh and Holley (2002).

to "foods to feed the world" (e.g. Lewis 1992, Gates 2000). Given uncertainty and the presence of private information by interested parties, it is questionable whether consumers can make fully informed decisions regarding GM foods due to the incomplete and asymmetric characterization of publicly available information. However, in this conflicted information environment, independent third-party information may have value to both consumers and producers and serve as a moderating force (Rousu et al. 2007).

The early GM crops were all transgenic, i.e., genes from a *different* organism (typically soil bacteria) were transferred into commercial crop varieties to introduce a trait of interest (e.g. herbicide tolerance or insect resistance). Because of the continued opposition to transgenic GM crops and foods, a new line of biotech research has emerged to transfer genes a long distance quickly across the *same* species, i.e., intragenic GM technology. For example, a potato is very difficult to manipulate with conventional plant breeding methods, but biotech methods can be used to rapidly move genes from primate potato varieties to commercial varieties. Thereby genomic and metabolic pathway discoveries can be rapidly introduced into established commercial varieties to fast-track the breeding processes. Not only does this new GM technology not transfer foreign DNA, but it also does not use antibiotic markers to identify the location of inserted genes[2]. These are all proffered reasons for a low regulatory hurdle.

A second neoteric development tied to intragenic breakthroughs is a renewed interest by bioengineering companies in the development of GM food crops with "enhanced consumer traits" that are directly valuable to many consumers. With the exception of the short-lived marketing attempts of the "Flavr-Savr tomato" and a "high solids tomato" produced by Zeneca, all commercially successful GM crops in the US have possessed input traits (traits that reduce either the cost of production or the variance in the cost of production to farmers), and hence, have only benefited consumers to the extent that they have lowered food prices[3]. With new intragenic GM techniques it is feasible to dramatically enhance attributes such as antioxidant and vitamin content in horticulture crops, resulting in a direct positive value of genetic modification for consumers relative to conventionally bred crops.

The emergence of intragenic engineering methods raises several new questions as well as revealing gaps in previous research. While consumers' view of GM Free food products as being weakly superior to transgenic GM foods has been well documented, no research has addressed exactly what aspect of the production of GM food products results in this inferiority. Namely, is it the use of genetic techniques for producing a product that would otherwise not appear in nature, the utilization and presence of foreign genetic content, or a combination of both factors? The answer to this question rests squarely on whether consumers place a different value on intragenic food products when compared to otherwise equivalent transgenic food products.

[2] For a more technical overview of intragenic versus transgenic engineering see Rommens et al. (2004).

[3] This indirect value of genetic modification to consumers has been estimated to by quite sizable by Falck-Zepeda, Traxler, and Nelson (2000) and Moschini, Lapan, and Sobolevsky (2000)

Furthermore, while past attempts in marketing GM food products with enhanced consumer attributes have been wholly unsuccessful, do consumers respond favorably to genetic modification that yields more readily understandable and quantifiable consumer desired attributes such as improved nutrition? Finally, while there is voluminous information regarding the benefits and dangers of genetic modification, there is a relative void of information in the public domain, pro and con, regarding the differences between intragenics and transgenics. As the debate angles in this new direction, what is the impact of diverging views and information on consumer valuations and what is the value of this new information to consumers? This paper serves to address these questions utilizing data collected from a unique set of experimental auctions designed to elicit consumers' willingness to pay (WTP) for a variety of different food products of varying types of genetic modification.

Our experimental procedure is innovative in several regards. We incorporate and refine both standard experimental procedures (e.g., see Shogren et al. 1994 and Lusk et al. 2001) and the advances of Rousu et al. (2007). First, we use adult consumers from two distinct geographic regions that were drawn from a random phone book sample. This ensures our results are not artifacts of a single geographic region. Second, we chose not to endow participants with products and have them bid to upgrade to another product (e.g. see Alfnes and Rickertsen 2003). Recent research has shown that there is an "endowment effect" that distorts bids (see Corrigan and Rousu 2006). Third, we use the nth price auction mechanism (Shogren et al. 2001) which has been shown to be a demand revealing mechanism that better engages off-margin bidders (e.g. Fox, Hayes, and Shogren 2002). Fourth, we randomize all food labels to eliminate sequencing effects. Finally, in many previous experiments where information is disseminated to participants (e.g. Lusk et al. 2004 and Rousu et al. 2007), each "group" receives the same information treatment. In our experiment, we disseminate multiple information treatments within the same "group". This helps ensure that the treatment effect is not tainted by a "group effect". In addition to the experimental refinements, we develop an econometric model that, for analysis of experimental auction data, is uncommonly encompassing. We utilize Bayesian econometric techniques to simultaneously control for bid censoring, commodity specific effects, round effects, and cross-round bid correlations.

The paper is organized as follows. In the following section an overview of the conducted experimental auction is provided. Section 3 presents a summary of the collected data. Section 4 develops a Bayesian seemingly unrelated regression (SUR) Tobit model which is used to estimate the impact of information and other confounding factors on consumers' WTP for GM foods. Section 5 develops a methodology for valuing verifiable information which is estimated under a variety of scenarios. Finally, section 6 concludes the paper.

2 Experimental Auction Design

To elicit information regarding the willingness to pay of consumers for food products produced through varying types of genetic modification and the impact of controversial/verifiable information, a series of experimental auctions were conducted in the spring of 2007 following an experimental design with some similarities to Rousu et al. (2007). Experiments were conducted in two cities, Des Moines, Iowa and Harrisburg, Pennsylvania. Two geographically separated cities were chosen in order to control for potential dissimilarities between residents in different regions of the US. Individuals for the study were randomly solicited from the general public by the Iowa State University Center for Survey Statistics and Methods (CSSM) to ensure a representative sample of the population was obtained. Individuals were invited to participate in a university study, but were not told beforehand the nature of the project. A total of 190 individuals participated in the study and each was paid $45 at the beginning of the session as compensation. A total of fourteen sessions (eight in Des Moines and six in Harrisburg), each session lasting approximately 90 minutes[4], were conducted consisting of between nine and seventeen participants in each session. The steps of each session are as follows.

In step 1, after arrival, participants were randomly assigned to a session room (two separate sessions were conducted simultaneously) where they were provided their financial compensation and asked to complete a brief questionnaire.

In step 2, participants were informed that they would be participating in an auction in which some common food products would be sold. As well, they were informed that the type of auction that they would be participating in would likely be different from any auction experience they may have previously had. They were told that the auction would consist of four rounds, but only one round would be randomly selected to be binding (i.e. there would only be a single round in which participants would win the products and have to pay the clearing bid price). This was done to ensure that bids would not be affected by concerns of winning similar products in multiple rounds.

In step 3, participants were provided with instructions and examples about the auction method utilized in the study: the nth price auction (Shogren et al. 2001)[5]. Instead of using the more common Vickrey sealed bid second-price auction mechanism (Vickrey 1962) (e.g., see Fox, Hayes, and Shogren 2002), the nth price auction was selected for the study based upon evidence that it better engages off-margin bidders while still being a demand revealing mechanism[6].

[4] Many experimental studies are now being conducted in settings that are more familiar to consumers (e.g. see Lusk, Pruitt, and Norwood 2006 and Monchuck et al. 2007). We also considered the possibility of using an intercept sample in a grocery store in a "framed field experiment" (Harrison and List 2004), but the length of the experiment prohibited that option.

[5] In this type of auction, all individuals who bid higher than the randomly selected "nth price" win the auction and pay the nth price for the commodity.

[6] The Becker-Degroot-Marshak (1964) mechanism is also demand revealing, but the random nth-price auction has been shown

In step 4, participants engaged in two rounds of a practice auction in order to obtain experience with the nth price auction. Any final questions regarding the mechanism were answered.

In step 5, participants were randomly provided one of five information treatments. The information treatments included 1) *no information* – as a control group, 2) the *industry (pro-biotech) perspective* – a collection of mainly positive or optimistic statements and information on genetic modification provided by a group of leading biotechnology companies, 3) the *environmental (anti-biotech) perspective* – a collection of mainly negative statements and information on genetic modification from leading environmental groups, 4) *industry and environmental perspectives* – both information statements 2 and 3, and 4) *industry, environmental, and third-party (verifiable information) perspectives* – this treatment included statements 2 and 3 as well as an objective statement on genetic modification approved by a third-party group consisting of a variety of individuals knowledgeable about GM foods, including scientists, professionals, religious leaders, and academics, non of whom have financial stake in GM foods.[7] To ensure that the volume of information contained in these statements was not overwhelming for participants, each statement was limited to a single standard page size and clearly organized in a common fashion. For information treatments consisting of more than one perspective, the order in which the pro-biotech and anti-biotech perspectives were presented was randomized. The verifiable perspective was always presented last.

In steps 6-9, participants engaged in an auction consisting of four rounds. In each round participants were asked to place bids on three different products: broccoli, beefsteak tomatoes, and russet potatoes. These three products were selected in anticipation that consumers would potentially have heterogeneous tastes for different food products and production methods. In each round, the three food products were presented in packaging as one would find in a grocery store and affixed with a label indicating the type of product. In half of the sessions (3 sessions in Harrisburg and 4 sessions in Des Moines), the four labels used (one in each round) were: GM Free, Intragenic GM, Transgenic GM, and No Label[8]. For examples of these four labels see figure 1 in the Appendix. In the other half of the sessions (seven total), the first three rounds of the auction[9] had products with either GM, Intragenic GM, or Transgenic GM labels with an additional statement: "Enhanced levels of Antioxidants and Vitamin C". For examples of these three labels see figure 2 in the Appendix. All three products within a round had the same label and the order in which labels were presented was randomized across sessions. In each round, after the products for auction were revealed,

to be more accurate at revealing preferences in experiments, potentially due to the endogenous clearing price (e.g. see Lusk and Rousu 2007).

[7] Throughout this paper, the following terms will be used synonymously to refer to types of information: 1) industry, positive, and pro-biotech, 2) environmental, negative, and anti-biotech, and 3) verifiable and 3rd party.

[8] For each of the labels, the name of the product (e.g. Russet Potatoes) and the product weight is listed. The phrase "No Label" is used to describe a label that only contains the above information without any description of genetic modification that may or may not be present.

[9] The label in the fourth round of these sessions contained a different label not pertinent to this paper. This alternative label always appeared in the fourth round of the auction and does not affect bids in the earlier three rounds.

participants were permitted to inspect the products prior to writing their three bids which were collected before proceeding to the next round.

In step 10, after conclusion of the bidding rounds the binding round and the nth price were randomly selected. No information regarding bids was revealed prior to completion of the bidding rounds in order to ensure that no posted price bias would occur. Participants were informed of the winners of the auction and the clearing bid prices and asked to purchase their goods after completing a brief exit questionnaire.

3 Summary of Data

In this section basic summary statistics regarding the demographics of the auction participants and their willingness to pay for food products produced under varying bioengineering techniques are presented. Table 1 displays a summary of responses to a portion of the questionnaire provided to auction participants. Two interesting points to note are that a relatively small percentage of individuals consider themselves well or extremely well informed regarding genetic modification and that few individuals would characterize themselves as having a strong positive view towards GM. Yet, while the majority of individuals do not consider themselves well informed about GM, the majority of participants stated that they often or always read food labels.

In Tables 2 and 3, participants' bids from the experimental auctions are summarized. Table 2 contains the means and standard deviations of bids for products without enhanced consumer attributes broken down by information treatments. Table 3 presents similar results for products with enhanced consumer attributes. Comparing across labeling treatments, it can be seen that in general for all information treatments the preference relation $GM\ Free \succeq No\ Label \succeq Transgenic$ holds for products without enhanced attributes, but the relationship between No Label and Intragenic products is not consistent and varies across information treatments. For products with enhanced attributes, the preference relation $Intragenic \succeq Transgenic$ in general holds, but the relationship between GM and Intragenic fluctuates across information treatments. The absence of a consistent pattern in the relative willingness to pay between No Label and Intragenic products without enhanced attributes and GM and Intragenic products with enhanced attributes across the different information treatments is to be expected given the dichotomous views contained in the provided perspectives.

Table 1

Summary Statistics for Auction Participants (N=190)

Variable	Variable Definition	Mean	Stdev
Gender	1 if female	0.68	0.47
Age	Participant's age	44.33	15.80
Income	Household income (in 1000s)	51.09	35.23
Education	Years of schooling	14.47	2.26
Married	1 if married	0.53	0.50
Household	Number of people in household	2.74	1.41
Race	1 if participant is white	0.85	0.36
Informed	1 if well or extremely well informed about GM	0.11	0.31
Opinion	1 if opinion towards GM is support or strongly support	0.17	0.38
Read_Labels	1 if often or always read food labels	0.63	0.48
Envi_Mem	1 if member of environmental group	0.04	0.20
Farm	1 if previously/currently engaged in farming	0.22	0.43
Vegan	1 if vegan	0.02	0.14
Smoke	1 if smoke	0.23	0.42
Exercise	1 if exercise regularly	0.51	0.51
Health_Diet	Self assessed healthiness of diet (1-10 scale)	6.73	1.61
Health_Phys	Self assessed healthiness of physical health (1-10 scale)	7.16	1.69

Table 2

Mean Bid Prices for Food Products Without Enhanced Attributes by Information Treatment

Broccoli				Tomatoes				Potatoes			
No	GMF	Intra	Trans	No	GMF	Intra	Trans	No	GMF	Intra	Trans
All Treatments (N=92)											
1.28	1.46	1.42	1.20	1.38	1.52	1.36	1.18	2.16	2.34	2.16	2.00
(0.76)	(0.77)	(0.86)	(0.78)	(0.98)	(0.91)	(0.97)	(0.87)	(1.16)	(1.16)	(1.23)	(1.22)
No Information (N=17)											
1.38	1.69	1.54	1.37	1.39	1.47	1.35	1.25	1.99	2.36	2.03	2.07
(0.61)	(0.82)	(0.70)	(0.66)	(1.08)	(1.04)	(0.88)	(0.83)	(0.84)	(1.05)	(0.79)	(0.88)
Pro-biotech Information only (N=20)											
1.30	1.37	1.74	1.24	1.49	1.46	1.62	1.29	2.33	2.33	2.54	2.21
(0.90)	(0.71)	(0.83)	(0.83)	(1.16)	(0.88)	(1.01)	(1.06)	(1.22)	(1.15)	(0.99)	(1.23)
Anti-biotech Information only (N=17)											
1.21	1.60	1.07	1.14	1.24	1.67	0.95	0.98	2.19	2.71	1.84	1.81
(0.72)	(0.73)	(0.83)	(0.84)	(0.93)	(0.97)	(0.81)	(0.74)	(0.85)	(0.96)	(1.20)	(1.13)
Pro-biotech & Anti-biotech Information (N=21)											
1.45	1.58	1.56	1.22	1.48	1.73	1.60	1.25	2.34	2.43	2.45	2.18
(0.79)	(0.76)	(0.99)	(0.76)	(0.86)	(0.87)	(1.11)	(0.83)	(1.19)	(1.14)	(1.42)	(1.22)
Pro-biotech, Anti-biotech, and Verifiable Information (N=17)											
1.03	1.07	1.08	1.03	1.23	1.22	1.19	1.09	1.86	1.86	1.83	1.66
(0.73)	(0.76)	(0.78)	(0.84)	(0.93)	(0.82)	(0.87)	(0.88)	(1.56)	(1.42)	(1.51)	(1.59)

Note: Standard deviations in parenthesis. "No, "GMF", "Intra", "Trans" denote No Label, GM Free, Intragenic GM, and Transgenic GM respectively.

Table 3

Mean Bid Prices for Food Products With Enhanced Attributes by Information Treatment

Broccoli			Tomatoes			Potatoes		
GM	Intra	Trans	GM	Intra	Trans	GM	Intra	Trans
All Treatments (N=98)								
1.51	1.67	1.45	1.42	1.76	1.41	2.45	2.61	2.27
(1.01)	(1.14)	(1.01)	(0.86)	(1.26)	(0.97)	(1.76)	(1.84)	(1.96)
No Information (N=20)								
1.91	1.86	1.83	1.65	1.95	1.73	3.18	3.20	3.23
(1.54)	(1.16)	(1.28)	(1.23)	(1.34)	(1.32)	(3.06)	(2.73)	(3.40)
Pro-biotech Information only (N=18)								
1.63	2.52	1.79	1.81	2.64	1.90	2.73	3.49	2.65
(0.65)	(1.20)	(0.68)	(0.70)	(0.94)	(0.68)	(1.00)	(1.89)	(1.35)
Anti-biotech Information only (N=18)								
1.25	1.07	1.06	1.23	1.10	0.98	2.12	1.92	1.71
(0.82)	(0.89)	(0.89)	(0.69)	(0.66)	(0.63)	(1.46)	(1.34)	(1.37)
Pro-biotech & Anti-biotech Information (N=20)								
1.67	1.84	1.63	1.36	1.74	1.43	2.54	2.64	2.34
(0.87)	(1.15)	(1.04)	(0.67)	(1.32)	(1.04)	(1.14)	(1.45)	(1.24)
Pro-biotech, Anti-biotech, and Verifiable Information (N=22)								
1.10	1.16	0.97	1.11	1.44	1.05	1.74	1.90	1.48
(0.77)	(0.70)	(0.74)	(0.75)	(1.38)	(0.72)	(0.98)	(0.87)	(0.97)

Note: Standard deviations in parenthesis. "No, "GMF", "Intra", "Trans" denote No Label, GM Free,Intragenic GM, and Transgenic GM respectively.

Tables 4 and 5 present the difference in mean bids between different labels and the results of an unpaired equal variance t-test[10]. Table 4 contains a comparison of GM Free products with Intragenic and Transgenic products without consumer attributes.

Table 4

Difference in Mean Bid Prices for Products Without Enhanced Attributes: Test of Null Hypothesis of No Difference in Bid Prices between GM Free and GM Intragenic and Transgenic Labeled Products

	GM Free w/o versus Intragenic w/o			GM Free w/o versus Transgenic w/o		
Information Treatment	Broccoli	Tomatoes	Potatoes	Broccoli	Tomatoes	Potatoes
ALL	$0.05	$0.15	$0.18	$0.26**	$0.34**	$0.34**
No info	$0.15	$0.12	$0.33	$0.32	$0.22	$0.29
Pro	$-0.36	$-0.16	$-0.21	$0.13	$0.17	$0.13
Anti	$0.53**	$0.72**	$0.87**	$0.46**	$0.69**	$0.90**
Pro & Anti	$0.01	$0.13	$-0.01	$0.36	$0.49*	$0.25
Pro,Anti,& Ver	$-0.01	$0.02	$0.03	$0.03	$0.13	$0.20

Note: * and ** denote significance at the 10% and 5% levels respectively. "w/o" denotes without enhanced consumer attributes.

[10] For brevity, only a comparison of bids for a select set of labels is presented. Statistics for other cases are available from the author.

The table shows that the premium participants are willing to pay for GM Free over Transgenic products is larger across all information treatments when compared to the premium for GM Free over Intragenic. The results of the t-test shows that, for both cases, the null hypothesis of no difference in WTP for GM Free and either Intragenic or Transgenic can be rejected for those participants who received the environmental information treatment.

Table 5 presents a similar analysis comparing products with enhanced consumer attributes produced through Intragenic or Transgenic techniques with their counterparts without enhanced consumer attributes. For nearly all information treatments, the table shows that participants have a higher willingness to pay for products with the enhanced attributes. The average premium across all information treatments for enhanced consumer attributes in Intragenic products was found to be \$0.26 for broccoli, \$0.40 for tomatoes, and \$0.45 for potatoes. The average premium for enhanced consumer attributes in Transgenic products was lower with values of \$0.25, \$0.23, and \$0.27. This provides evidence that consumers do respond to, and value, additional nutritional content in food products, even if it is engineered through genetic techniques.

Table 5

Difference in Mean Bid Prices for Products With and Without Enhanced Attributes: Test of Null Hypothesis of No Difference in Bid Prices between GM Intragenic and Transgenic Labeled Products With and Without Enhanced Attributes

	Intragenic w/ Enhanced Attributes versus Intragenic w/o			Transgenic w/ Enhanced Attributes versus Transgenic w/o		
Information Treatment	Broccoli	Tomatoes	Potatoes	Broccoli	Tomatoes	Potatoes
ALL	\$0.26*	\$0.4**	\$0.45**	\$0.25*	\$0.23*	\$0.27
No info	\$0.32	\$0.60	\$1.17*	\$0.46	\$0.48	\$1.16
Pro	\$0.78**	\$1.02**	\$0.95*	\$0.55**	\$0.61**	\$0.44
Anti	\$0.00	\$0.14	\$0.08	\$-0.08	\$-0.01	\$-0.10
Pro & Anti	\$0.27	\$0.14	\$0.19	\$0.41	\$0.18	\$0.16
Pro,Anti,& Ver	\$0.09	\$0.25	\$0.06	\$-0.06	\$-0.04	\$-0.18

Note: * and ** denote significance at the 10% and 5% levels respectively.
"w/o" denotes without enhanced consumer attributes.

4 Impact of Controversial and Verifiable Information on WTP

Although the data and unconditional analysis presented in the previous section are suggestive of the impact of information on the valuation of various types of genetic modification, it is necessary to undertake regression analysis of the bid prices in order to identify information impacts while controlling for potentially confounding factors. In this section, a multivariate regression model is developed and estimated to analyze the data in a more robust fashion.

Before deriving the econometric model, it is beneficial to summarize several of the pertinent econometric issues that will be addressed in modeling bid prices. The first issue, which is common to all analyses of multiple round auctions, is whether it is appropriate to assume that bids by an individual in two different rounds are independent. While this is a commonly made assumption, it is questionable in the present setting for two reasons. First, it requires the assumption that unmodeled factors affecting bid prices in one round are independent of those in a different round. Secondly, treating each round independently does not permit consideration of potential impacts from the order in which labels were presented to auction participants (i.e. round effects). To err with caution, a system of equations approach is selected to account (and test) for correlation across rounds of bidding.

A second issue, which is often addressed in analysis of auction data, is whether to control for individual effects. While individual effects can be easily included in a standard single equation or system of equations model, they clearly have a drawback in that they restrict correlation across different rounds (or labels) to have a common term. While for some auctions this may be a fair assumption, given the potential diversity of relative preferences for the considered food labels, a general error specification is a more natural starting place for estimation. Hence, a seemingly unrelated regression (SUR) model (Zellner 1962) is selected to account (and test) for correlation across labels.

The final important issue affecting the choice of modeling approach is the common dilemma in experimental auctions of bids of zero. A zero bid for a product presents a censoring problem which, in the case of single equation models, can be easily managed under some assumptions (e.g. a Tobit model). In the case of system of equations with censoring, there are a number of classical estimation techniques that have been proposed, but suffer from a variety of econometric issues and diminished tractability. An alternative, which is selected for this study, is to estimate the model via Bayesian techniques with data augmentation. Hence, in order to address these three relevant econometric issues, Huang's (2001) model is adapted and extended to develop what is best described as a Bayesian SUR Tobit model with commodity specific fixed effects.

Let y_{ij} denote an individual's $i = 1, 2, ..., N$ bid for a food product with label $j = 1, ..., J$ (for the case of no enhanced attribute auctions $J = 4$ and the labels are GM Free, No Label, Intragenic, and Transgenic. For the case of with enhanced attribute auctions $J = 3$ and the labels are Intragenic, GM, and Transgenic). The latent demand of the i^{th} individual for the food product under label j can be expressed as

$$y_{ij}^* = x_{ij}^{'}\beta_j + \varepsilon_{ij}, \quad i = 1, 2, ..., N, \qquad j = 1, 2, ..., J \tag{1}$$

where

$$y_{ij} = \begin{cases} y_{ij}^* & if \;\; y_{ij}^* > 0 \\ 0 & if \;\; y_{ij}^* \leq 0 \end{cases}, \tag{2}$$

y_{ij} is the observed bid, y_{ij}^* is the latent bid, $\varepsilon_i = (\varepsilon_{i1}, ..., \varepsilon_{iJ})' \overset{iid}{\sim} \mathbf{N}(0, \Omega)$.

For an individual i, we can express a system of equations, one equation for each label $j = 1, ..., J$ as

$$\begin{bmatrix} y_{i1}^{*} \\ y_{i2}^{*} \\ ... \\ y_{iJ}^{*} \end{bmatrix} = \begin{bmatrix} x_{i1}^{'} & 0 & ... & 0 \\ 0 & x_{i2}^{'} & ... & 0 \\ ... & .. & ... & ... \\ 0 & 0 & ... & x_{iJ}^{'} \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ ... \\ \beta_J \end{bmatrix} + \begin{bmatrix} \varepsilon_{i1} \\ \varepsilon_{i2} \\ ... \\ \varepsilon_{iJ} \end{bmatrix}. \tag{3}$$

In stacked notation, for each individual i we can express the system of demand equations as

$$y_i^{*} = x_i\beta + \varepsilon_i, \;\; i = 1, 2, ..., N \tag{4}$$

where $y_i^{*} = \left(y_{i1}^{*}, ..., y_{iJ}^{*}\right)^{'}$ is a $J \cdot 1$ vector, $x_i = diag(x_{i1}^{'}, ..., x_{iJ}^{'})$ is a $J \cdot Jk$ matrix, and $\beta = (\beta_1^{'}, ..., \beta_J^{'})'$ is a $Jk \cdot 1$ vector.

Finally, stacking over all N individuals we have a complete system of equations

$$y^{*} = X\beta + \varepsilon.$$

To derive the likelihood function, note that for each y_{ij} there are two possible cases: censored or not censored. Hence, for each individual there are a total of 2^J total combinations of censored and uncensored outcomes. Let the 2^J possible combinations be represented by the $2^J \cdot 1$ vector S_h, $h = 1, 2, ..., 2^J$, as

$$S_h = (\underbrace{0, 0, ..., 0}_{a}, \underbrace{+, +, ..., +}_{J-a})^{'}$$

where '0' denotes censored at zero and '+' denotes not censored. The contribution to the augmented likelihood function for the ith individual characterized by the S_h censoring case is given by

$$L_i^{S_h}(y_i; \beta, \Omega^{-1}) = \int_{-\infty}^{-x_{i1}^{'}\beta_1} ... \int_{-\infty}^{-x_{ia}^{'}\beta_a} L(y_i; \beta, \Omega^{-1}) d\varepsilon_{ia} ... d\varepsilon_{i1} \tag{5}$$

where

$$L(y_i; \beta, \Omega^{-1}) = (2\pi)^{-J/2} \left|\Sigma^{-1}\right|^{1/2} \exp\left(-\frac{1}{2}\left(y_i - X_i\beta\right)' \Omega^{-1} \left(y_i - X_i\beta\right)\right).$$

Finally, we can express the likelihood function that accounts for each of the possible combinations of censoring over all individuals as

$$\prod_{i=1}^{N} \left\{ \prod_{S_h} \left[L_i^{S_h}(y_i; \beta, \Omega^{-1})\right]^{I_i(S_h)} \right\} \tag{6}$$

where $I_i(S_h) = 1$ if for individual i censored regime S_h is observed and $L_i^{S_h}$ gives the contribution to the likelihood function of an individual with censored regime S_h.

Now consider the derivation of the full conditionals. Assuming independent priors of the form

$$\beta \sim \mathbf{N}(\beta_0, V_\beta) \tag{7}$$

$$\Omega^{-1} \sim W(a_\varepsilon, V_\varepsilon) \tag{8}$$

where $\mathbf{N}$ and W denote multivariate normal and Wishart distributions respectively, the conditional posterior distribution for β is given by a standard result

$$\beta|\Omega^{-1}, y \sim \mathbb{N}(D_\beta d_\beta, D_\beta) \tag{9}$$

where

$$\begin{aligned} D_\beta &= \left(X' \left(\Sigma^{-1} \otimes I_N\right) X + V_\beta^{-1}\right)^{-1} \\ d_\beta &= X' \left(\Sigma^{-1} \otimes I_N\right) y + V_\beta^{-1}\beta_0. \end{aligned} \tag{10}$$

The conditional posterior distribution for Ω^{-1} is also straightforward to derive and given by

$$\Omega^{-1}|\beta, y \sim W\left(N + a_\varepsilon, \left[V_\varepsilon^{-1} + \sum_{i=1}^{N}(y_i - X_i\beta)(y_i - X_i\beta)'\right]^{-1}\right).$$

The final step, before estimation of the model can proceed, is to simulate those data points which are censored. This can be done by conditioning and drawing from a truncated normal distribution for censored observations. The complete conditional for censored observations is given by

$$y_{ij}^*|\beta, \Omega^{-1} \sim TN_{[-\infty,0]}(\mu_{j|-j}, \omega_{j|-j}^2) \;\; \forall ij \; s.t. \; y_{ij} = 0 \tag{11}$$

where

$$\begin{aligned} \mu_{j|-j} &= \mu_j + \Omega_{j-j}'\Omega_{-j-j}^{-1}(y_{-j}^* - \mu_{-j}) \\ \omega_{j|-j}^2 &= \omega_{jj}^2 - \Omega_{j-j}'\Omega_{-j-j}^{-1}\Omega_{j-j}, \end{aligned} \tag{12}$$

$\mu = X_i\beta$, μ_j is the jth row element of μ and μ_{-j} is obtained by deleting the jth row element of μ. The matrix Ω_{-j-j} is the $(J-1)\cdot(J-1)$ matrix derived from Ω by eliminating the jth column and row, Ω_{j-j} is the $(J-1)\cdot 1$ vector derived from the jth column of Ω by removing the jth row term.

4.1 Estimation Results

The Bayesian SUR Tobit model developed in the previous section was estimated for both the cases of with and without enhanced attribute products. Instead of estimating a separate model for each food product (broccoli, tomatoes, and potatoes), the model was further stacked over the three commodities and three separate commodity specific effects, one for each commodity, were included. The assumed prior parameters were chosen to impose minimal structure and are $\beta_0 = \mathbf{0}$, $V_\beta = (10e4)\mathbf{I}_J$, $a_\varepsilon = J * k$, and $V_\varepsilon = (10e4)\mathbf{I}_J$. A total of $10,000$ draws from the Gibbs sampler were used following a $1,000$ iterate burnin.

Table 6 presents the posterior means, standard deviations, and the posterior probability of being greater than zero for the regression model estimated using bids on products without enhanced consumer attributes. For readers who are interested, Table 8 in the Appendix presents corresponding estimates of marginal effects (abbreviated M.E.) evaluated at the mean.

The signs of the estimated posterior means of the information treatment dummy variables fall partially in line with expectations. Individuals receiving environmental information are willing to pay a premium, relative to those who received no information, for GM Free products (M.E. \$0.054) and discount both Intragenic and Transgenic foods (M.E. \$-0.120 and \$-0.228 respectively). For individuals who received only industry information, the situation is reversed with higher valuations for Intragenic and Transgenic products (M.E. \$0.120 and \$0.082 respectively) and lower valuations for the GM Free (M.E. \$-0.066). Surprisingly, individuals who received both the pro- and anti-biotechnology perspectives have greater valuations for all four types of products relative to individuals who received no information. But, the impact on the relative valuation of Intragenic versus GM Free and Transgenic versus GM Free is less than when pro-biotech information is received in isolation. This indicates that, in combination, the anti-biotechnology information dampens the augmenting impact of pro-biotechnology information on the GM labels relative to the GM Free, as would be expected. The willingness to pay for all four labels by individuals who received the pro and anti perspectives with verifiable information is lower relative to individuals who received no information. While the marginal impact is similar for each of the four labels, the greatest decrease occurs for the GM Free product.

From the estimates of the posterior means for the demographic variables we can see that individuals who are older, of white ethnicity, have larger households, and have higher incomes are willing to pay more for products under each of the four labels. For individuals who are members of an environmental group, the posterior mean for each label is negative, and, as expected, the marginal decrease in WTP is most pronounced for the Transgenic product and least for the GM Free (M.E. \$-0.174 and M.E. \$-0.592 respectively).

Table 6

Bayesian Estimates of Bid Price Equations for Products Without Enhanced Consumer Attributes (N=92, Obs=1104)

Dep Var	$\mathbf{Y}^{No\ Label}$			$\mathbf{Y}^{GM\ Free}$			$\mathbf{Y}^{Intragenic}$			$\mathbf{Y}^{Transgenic}$		
	$E(\cdot\|y)$	$Std(\cdot\|y)$	$P(\cdot > 0\|y)$	$E(\cdot\|y)$	$Std(\cdot\|y)$	$P(\cdot > 0\|y)$	$E(\cdot\|y)$	$Std(\cdot\|y)$	$P(\cdot > 0\|y)$	$E(\cdot\|y)$	$Std(\cdot\|y)$	$P(\cdot > 0\|y)$
	Information Treatment Dummy Variables (No Information Dummy Omitted)											
Pro	0.116	0.185	0.74	-0.140	0.187	0.23	0.284	0.195	0.93	0.105	0.183	0.79
Anti	-0.119	0.209	0.28	0.191	0.212	0.82	-0.171	0.219	0.21	-0.257	0.207	0.11
Pro & Anti	0.252	0.169	0.93	0.212	0.170	0.89	0.369	0.180	0.98	0.112	0.169	0.75
Pro,Anti,&Ver	-0.108	0.195	0.29	-0.243	0.197	0.11	-0.013	0.205	0.53	-0.112	0.194	0.28
	Demographic Variables											
Gender	-0.130	0.146	0.19	-0.067	0.146	0.33	0.058	0.153	0.65	-0.228	0.145	0.06
Race	0.432	0.176	0.99	0.240	0.179	0.91	0.292	0.183	0.95	0.239	0.173	0.92
Age	0.021	0.004	1.00	0.019	0.004	1.00	0.017	0.004	1.00	0.016	0.004	1.00
Income	0.004	0.002	0.98	0.005	0.002	1.00	0.005	0.002	0.99	0.005	0.002	1.00
Educ	-0.004	0.020	0.42	-0.010	0.021	0.32	0.028	0.022	0.90	0.028	0.020	0.92
Married	-0.137	0.131	0.14	-0.071	0.131	0.30	-0.180	0.136	0.09	-0.159	0.130	0.11
Household	0.139	0.045	1.00	0.178	0.045	1.00	0.095	0.047	0.98	0.086	0.044	0.98
Iowa	-0.182	0.118	0.06	-0.169	0.121	0.08	-0.115	0.125	0.17	0.127	0.118	0.86
Farm	0.014	0.138	0.54	0.105	0.139	0.78	0.095	0.144	0.75	0.131	0.137	0.83
Envi_Mem	-0.495	0.313	0.06	-0.250	0.318	0.22	-0.315	0.328	0.17	-0.628	0.310	0.02
	Opinion Variables											
Informed	0.392	0.213	0.97	0.236	0.214	0.86	0.025	0.220	0.54	0.263	0.212	0.89
Opinion	-0.046	0.160	0.39	0.055	0.162	0.63	0.064	0.166	0.65	-0.114	0.159	0.24
Read_Labels	-0.289	0.154	0.03	-0.091	0.153	0.28	-0.183	0.155	0.12	-0.436	0.148	0.00
	Health Variables											
Smoke	0.381	0.147	1.00	0.437	0.149	1.00	0.274	0.152	0.96	0.262	0.145	0.97
Exercise	0.043	0.140	0.63	0.105	0.141	0.78	0.386	0.146	1.00	0.162	0.138	0.88
Health_Diet	0.055	0.047	0.88	0.075	0.047	0.95	-0.016	0.048	0.37	0.071	0.046	0.94
Health_Phys	-0.047	0.041	0.13	-0.053	0.041	0.10	-0.052	0.043	0.11	-0.080	0.041	0.03
Round	0.115	0.066	0.96	0.148	0.082	0.97	0.282	0.095	1.00	0.218	0.061	1.00

Correlation Coefficients					
$\rho_{No,GMF}$	$\rho_{No,Intra}$	$\rho_{No,Trans}$	$\rho_{GMF,Intra}$	$\rho_{GMF,Trans}$	$\rho_{Intra,Trans}$
0.46	0.51	0.31	0.51	0.13	0.24

The estimates of the opinion variables present an interesting picture. Individuals who typically read labels have lower valuations for all four products, but the marginal effect is most pronounced for the Intragenic and Transgenic products. Those with negative opinions of GM have greater WTPs for both GM Free and Intragenic products, but less for the No Label and Transgenic foods. And those who are more informed about GM are more receptive than their counterparts in particular to Transgenic and No Label foods.

When considering the posterior means for the health variables, it is difficult to draw a clear conclusion regarding the relationship between healthiness and WTP for the four labels. While the signs of the posterior means for smoking, exercise, physical healthiness, and diet healthiness are consistent across the four labels, there is little variation in the magnitude of the marginal effect across the different labels. While a priori one might expect that those individuals who are healthier would be willing to pay a much greater premium for the GM Free (and maybe the Intragenic product), relative to the Transgenic product, the data cannot support this conclusion.

Finally, the round dummy variable and the correlation coefficients were found to have high posterior probabilities of being greater than zero (near 100%). As well, from the correlation coefficients we can see that there is variation across labels. For example, the estimated correlation between no label and intragenic products was found to 0.51 while the correlation between no label and transgenic products is only 0.13. These results support the provided intuitive justification for the utilized modeling approach. Despite the greater modeling burden, there are gains from using a system of equations approach with a general error structure to model multi-round auction data.

Table 7 presents estimation results for the auctions with enhanced consumer attribute products. Table 9 found in the Appendix presents corresponding marginal effects. For the products with enhanced consumer attributes (Table 7), from the estimated posterior means of the information variables it can be seen that, relative to an individual who received no information, individuals who received pro-biotechnology information have a greater willingness to pay for products under each of the three labels. The impact is greatest for the Intragenic product with a marginal effect of $0.14. Conversely, individuals who received only anti-biotechnology information have a lower WTP across each of three labels. In combination, individuals receiving both the pro- and anti-biotechnology information have a lower WTP for the GM and Transgenic products, but higher for the Intragenic product. This indicates that these two perspectives in combination largely counterbalance each other in terms of their impact on valuations, but the positive impact on WTP for Intragenic products still holds. Finally, when verifiable information is injected, valuations for all three products are significantly lower, indicating that verifiable information bolsters the negative impact of environmental information on WTP for genetically modified food products with enhanced consumer attributes.

Table 7
Bayesian Estimates of Bid Price Equations for Products With Enhanced Consumer Attributes
(N=98,Obs=882)

Dep Var	$\mathbf{Y}^{GM}$			$\mathbf{Y}^{Intragenic}$			$\mathbf{Y}^{Transgenic}$		
	$E(\cdot\|y)$	$Std(\cdot\|y)$	$P(\cdot>0)$	$E(\cdot\|y)$	$Std(\cdot\|y)$	$P(\cdot>0)$	$E(\cdot\|y)$	$Std(\cdot\|y)$	$P(\cdot>0)$
	Information Treatment Dummy Variables (No Information Dummy Omitted)								
Pro	0.198	0.256	0.78	0.982	0.267	1.00	0.479	0.341	0.93
Anti	-0.109	0.266	0.34	-0.478	0.279	0.05	-0.387	0.355	0.13
Pro & Anti	-0.085	0.258	0.36	0.152	0.270	0.72	-0.250	0.349	0.24
Pro,Anti,&Ver	-0.718	0.243	0.00	-0.566	0.256	0.01	-0.506	0.325	0.06
	Demographic Variables								
Gender	-0.045	0.164	0.39	0.224	0.173	0.91	0.252	0.220	0.87
Race	-0.419	0.232	0.03	-0.488	0.243	0.02	-0.476	0.305	0.06
Age	0.023	0.006	1.00	0.016	0.006	0.99	0.017	0.008	0.98
Income	-0.008	0.003	0.01	-0.008	0.003	0.01	-0.012	0.004	0.00
Educ	-0.022	0.035	0.27	0.073	0.036	0.98	-0.001	0.048	0.50
Married	-0.072	0.199	0.35	-0.413	0.207	0.03	0.021	0.264	0.53
Household	0.265	0.062	1.00	0.215	0.065	1.00	0.156	0.083	0.97
Iowa	-0.170	0.161	0.14	-0.265	0.170	0.06	0.352	0.224	0.95
Farm	-0.473	0.206	0.01	-0.518	0.221	0.01	-0.298	0.282	0.14
Envi_Mem	-0.323	0.419	0.22	-0.458	0.445	0.15	-0.213	0.562	0.35
	Opinion Variables								
Informed	0.169	0.291	0.72	0.178	0.304	0.72	0.284	0.380	0.77
Opinion	0.448	0.262	0.95	-0.025	0.282	0.46	0.804	0.348	0.99
Read_Labels	0.483	0.184	1.00	0.348	0.194	0.97	0.068	0.249	0.60
	Health Variables								
Smoke	0.308	0.189	0.94	0.201	0.200	0.84	0.154	0.244	0.73
Exercise	0.146	0.164	0.81	0.551	0.176	1.00	0.408	0.224	0.97
Health_Diet	-0.046	0.074	0.27	-0.134	0.078	0.05	-0.112	0.098	0.13
Health_Phys	0.179	0.074	0.99	0.132	0.079	0.95	0.171	0.100	0.96
Round	-0.210	0.110	0.02	0.342	0.138	1.00	0.626	0.159	1.00

Correlation Coefficients		
$\rho_{GM,Intra}$	$\rho_{GM,Trans}$	$\rho_{Intra,Trans}$
0.49	0.46	0.54

The estimates of the demographic variables are fairly consistent across the three labels. Individuals who are environmental group members, have experience in farming, white, and of higher income have lower valuations for products produced through any form of genetic modification, while those who are older or have larger households are more receptive. The signs of the posterior means of the opinion variables also present a fairly consistent picture. Individuals who are more informed about genetic modification or typically read food labels are willing to pay more under each of the three labels. But the signs and magnitudes of the posterior means for those with a negative opinion of genetic modification are reversed from that which would be expected.

As in the estimates for products without enhanced consumer attributes, the signs of the posterior estimates for health variables do not present a clear relation between "healthiness" and willingness to pay for products with enhanced nutritional attributes through genetic modification. Individuals who regularly exercise, have higher self-assessed physical healthiness, or smoke are willing to pay more under each of the three labels, while those with self-assessed healthier diets are willing to pay less. The positive sign of the posterior mean for smoking is interesting, and could be interpreted as meaning that individuals who are less healthy in other aspects of their lifestyle are less concerned with the potential risks from genetic modification.

Finally, as in the case of products without enhanced attributes, it was found that there are significant round effects and correlation across labels. Yet, unlike the results for products without enhanced attributes, the correlation across the labels is nearly consistent (slightly stronger for intragenic and transgenic). This could be interpreted, in contrast to the previous regression, that while a system of equations approach is appropriate a less general error structure (e.g. only random effects) could be sufficient to model bids for this set of labels.

5 The Value of Verifiable Information

While in the previous section it was shown that information has an impact on both absolute and relative valuations of food products produced through different bioengineering methods, these results alone are not sufficient to assess the welfare impact or "value" of information to consumers. The seminal paper by Foster and Just (1989) asserts that information has value to consumers if, from an ex-post perspective, the information has an impact on purchasing behavior. In the following section a simple methodology in the spirit of Foster and Just is developed for estimating the value of information in the context of a market with close substitutes.

Consider a market with $n = 1, 2, ..., N$ consumers who may consume at most one unit of one product from a selection of three alternative A, B, and C. Let P^A, P^B, and P^C denote the respective prices of the three products. Finally, let I_n denote the information set consumer n possesses prior to making his or her purchase decision. In this simple market, consumers choose the product (or none) that maximizes their consumer surplus

$$Surplus_n = \max\left\{\left(WTP^A_{n,I_n} - P^A\right), \left(WTP^B_{n,I_n} - P^B\right), \left(WTP^C_{n,I_n} - P^C\right), 0\right\}. \tag{13}$$

Now, consider the same scenario, but suppose that the consumer is operating under a different information set $I_n^{'}$. Under the new information set, surplus is

$$Surplus_n^{'} = \max\left\{\left(WTP^A_{n,I_n^{'}} - P^A\right), \left(WTP^B_{n,I_n^{'}} - P^B\right), \left(WTP^C_{n,I_n^{'}} - P^C\right), 0\right\}. \tag{14}$$

Using these two equations, we can express the "direct" change in consumer surplus resulting from the different sets of information as

$$\Delta Surplus_n = Surplus_n^{'} - Surplus_n. \tag{15}$$

The problem with this measure of the impact of information, as argued by Foster and Just, is that it leads to the paradox of "blissful ignorance" in that by solely comparing welfare under different "information states", information may have a negative impact on welfare (i.e. the consumer may be better off without the new information). Hence, Foster and Just argue that welfare measures should be assessed under the new information state only. Their proposed measure, the cost of ignorance (COI), compares welfare of informed and uniformed purchases measured in terms of the informed state[11]. Let $Z_{I_n} = \{A, B, C, 0\}$ denote the product that for consumer n yields the highest surplus under information set I_n. Then, from an ex-post perspective, the "indirect" impact of information is

$$\Delta \widetilde{Surplus}_n = \left(WTP_{n,I_n'}^{Z_{I_n}} - P^{Z_{I_n}} \right) - Surplus_n \tag{16}$$

where $WTP_{n,I_n'}^{Z_{I_n}}$ denotes WTP under information set I_n' for the product the individual would have purchased under the previous information set (Z_{I_n}). Finally, the welfare impact of information, the COI, is given by

$$COI_n = \Delta Surplus_n - \Delta \widetilde{Surplus}_n = Surplus_n^{'} - \left(WTP_{n,I_n'}^{Z_{I_n}} - P^{Z_{I_n}} \right). \tag{17}$$

Within the context of the considered market, it can be seen that information has value to consumers iff the information leads to a change in the product purchased.

5.1 Empirical Methodology

To estimate the value of information using the described methodology, several values are required including WTP before and after receipt of information and market prices. In the conducted experimental auctions, participants' WTP was only obtained after receiving information treatments. To proceed, in lieu of making restrictive assumptions[12], the regression model derived in the previous section is used to generate WTP forecasts. This permits controlling for confounding factors that affect WTP other than the information treatment. More explicitly, suppose one wishes to estimate the value of information i. For those individuals with information set I where $i \in I$, a forecast is generated of their WTP under the information set $I \neg i$. As

[11] An incomplete list of studies utilizing the COI or a related variant for analysis of information within the context of food products include Hu, Veeman, and Adamowicz (2005), Mazzocchi, Stefani, and Henson (2004), Teisi and Roe (1998), and Teisi, Bockstael, and Levy (2001).

[12] For example, one could assume that participants who receive an information treatment have relative preferences that are uniformly distributed across the subset of individuals who did not receive the information treatment

well, for those individuals who received information set $I\neg i$, a forecast of their WTP under information set I is generated. Using these forecasts (denoted by $\wedge$), the direct change in surplus from information i for those individuals who received information treatment I and $I\neg i$ can be expressed as

$$\begin{aligned} \Delta Surplus_{n,I,I\neg i} &= Surplus_{n,I} - \widehat{Surplus}_{n,I\neg i} && \text{(18a)} \\ &= \max\left\{ \left\{WTP^Z_{n,I} - P^Z\right\}_{Z=A,B,C}, 0\right\} - \max\left\{ \left\{\widehat{WTP}^Z_{n,I\neg i} - P^Z\right\}_{Z=A,B,C}, 0\right\} \\ \Delta Surplus_{n,I\neg i,I} &= \widehat{Surplus}_{n,I} - Surplus_{n,I\neg i} && \text{(18b)} \\ &= \max\left\{ \left\{\widehat{WTP}^Z_{n,I} - P^Z\right\}_{Z=A,B,C}, 0\right\} - \max\left\{ \left\{WTP^Z_{n,I\neg i} - P^Z\right\}_{Z=A,B,C}, 0\right\}. \end{aligned}$$

The indirect impact of information on consumer surplus for an individual who received treatment I or $I\neg i$ are

$$\begin{aligned} \Delta \widetilde{Surplus}_{n,I,I\neg i} &= \left(WTP^{\widehat{Z}_{n,I\neg i}}_{n,I} - P^{\widehat{Z}_{n,I\neg i}}\right) - \widehat{Surplus}_{n,I\neg i} && \text{(19a)} \\ \Delta \widetilde{Surplus}_{n,I\neg i,I} &= \left(\widehat{WTP}^{Z_{n,I\neg i}}_{n,I} - P^{Z_{n,I\neg i}}\right) - Surplus_{n,I\neg i} && \text{(19b)} \end{aligned}$$

where $\widehat{Z}_{n,I\neg i}$ denotes the forecasted product that would have yielded individual n the greatest surplus under information set $I\neg i$ and $Z_{n,I\neg i}$ denotes the observed product that yielded the greatest surplus under information set $I\neg i$.

Putting the two pieces together, we can express the value of information for each type of individual as

$$\begin{aligned} COI_{n,I,I\neg i} &= \Delta Surplus_{n,I,I\neg i} - \Delta \widetilde{Surplus}_{n,I,I\neg i} = Surplus_{n,I} - \left(WTP^{\widehat{Z}_{n,I\neg i}}_{n,I} - P^{\widehat{Z}_{n,I\neg i}}\right) && \text{(20a)} \\ COI_{n,I\neg i,I} &= \Delta Surplus_{n,I\neg i,I} - \Delta \widetilde{Surplus}_{n,I\neg i,I} = \widehat{Surplus}_{n,I} - \left(\widehat{WTP}^{Z_{n,I\neg i}}_{n,I} - P^{Z_{n,I\neg i}}\right). && \text{(20b)} \end{aligned}$$

Finally, we can express the estimated average value of information i per individual per product as

$$COI_i = \frac{1}{N_I + N_{I\neg i}} \left(\sum_{n=1}^{N_I} COI_{n,I,I\neg i} + \sum_{n=1}^{N_{I\neg i}} COI_{n,I\neg i,I} \right) \tag{21}$$

where N_I and $N_{I\neg i}$ denote the number of individuals in the sample who received treatments I and $I\neg i$ respectively.

For estimating the value of information, three different market scenarios are considered. Scenario 1 is a market with GM Free, Intragenic, and No Label products, scenario 2 is a market with GM Free, Intragenic, and Transgenic products, and scenario 3 is a market with GM, Intragenic, and Transgenic products all with enhanced consumer attributes. For each market scenario, we consider the value of verifiable information in a conflicted information setting (i.e. $I = \{\text{Pro, Anti, Ver}\}$ and $i = \{\text{Ver}\}$). Finally, instead of making assumptions regarding the prices of the three products in each market scenario, one of the prices is fixed while the other two are allowed to vary over an interval[13]. This allows for estimation of the value of information for each case over the spectrum of prices that could be encountered in the market.

Table 10 presents for each scenario the following: (1) the percentage of individuals who switch to purchasing a different product after receipt of the verifiable information, (2) the value of verifiable information (COI measure) to those individuals who switched purchases, and (3) the total value of verifiable information across all individuals (switchers and non-switchers).

From Table 10 we can see that across the three scenarios over the range of considered prices, a small percentage of consumers ranging from an average of 13% to 22% and a maximum of 18% to 26% switch products from receipt of the verifiable information treatment.

Table 10

Value of Verifiable Information about Genetic Modification in a Market with Conflicting Information

Scenario	**Percent Switch**[a]		**Switcher Value**[b]		**Total Value**[c]	
	Mean[d]	**Max**[e]	**Mean**[d]	**Max**[e]	**Mean**[d]	**Max**[e]
1	13%	18%	$0.14	$0.19	$0.04	$0.05
2	15%	23%	$0.13	$0.20	$0.04	$0.06
3	22%	26%	$0.15	$0.23	$0.06	$0.11

[a] Percentage of individuals who purchase a different product after receiving the information.
[b] The value of information (COI) for individuals who switch products.
[c] The value of information (COI) across all individuals (switchers and non-switchers).
[d,e] Denotes the average and maximum values estimated over the price range, respectively.

For those individuals that switch product purchases, the value of information ranges from an average of $0.13 to $0.15 and a maximum of $0.19 to $0.23. This implies that verifiable information has a small (but significant when viewed as a fraction of the product purchase price) value to this subset of consumers. The total value of verifiable information (switchers and non-switchers) ranges from an average of $0.04 to $0.06 and a maximum of $0.05 to $0.11. Again, while these estimates of the value of verifiable information are small, if viewed as a percentage of the purchase price it is evident that the information has moderate value to consumers. As well, if the value of verifiable information is viewed in the context of a repeated choice situation (or even extrapolated to other food products beyond those considered), it is evident that are significant welfare gains to consumers from information campaigns by credible 3rd-party organizations.

[13] For market scenarios 1 and 2, the price of the GM Free product is fixed at $1.80 and the prices for the other two products are allowed to vary over the interval $1.00-$1.80. For market scenario 3, the price of the GM product is fixed at $1.80, and the prices of the Intragenic and Transgenic products are allowed to vary over the intervals $1.00-$2.00 and $1.00-$1.80 respectively. Estimates over alternative price assumptions were performed and are available from the author. There is some sensitivity of the estimate of the value of information resulting from the assumed fixed price, but the magnitude is quite small over the range of reasonable values.

6 Conclusion

While the controversy over the balance between the benefits and hazards of genetic modification continues to unfold in the arenas of politics and public information campaigns, the advancements in intragenic bioengineering presents a new piece to the puzzle. The results of this study indicate that consumers, when presented with positive information, view intragenic food products more positively compared to otherwise equivalent transgenic counterparts. Furthermore, consumers do respond to and value products engineered to have higher nutritional content. These results pose a dilemma for individuals who have historically taken a position of staunch opposition to genetic modification. While intragenics may present a more palatable form of bioengineering when compared to transgenics, if this preference relation translates into market penetration for intragenic foods, there is the potential for an even greater crowding out of conventionally bred crops. While the results of this study presents a mildly positive picture for the potential of intragenics to obtain, at a minimum, a foothold in the food market, the results also indicate that to the victor of the information campaign goes the spoils. While pro-biotechnology information disseminated by agribusiness in isolation has significant positive effects on consumer valuations for GM foods, this effect is largely dampened or reversed by anti-biotechnology information coming from environmental groups. Yet, while the possibility that the abundance of diverging positions on genetic modification may ultimately simply lead to consumer confusion, the results of this study indicates that verifiable information about genetic modification has sizable value to consumers making purchase decisions in a market characterized by close substitutes.

Finally, it is hoped that the experimental procedure refinements and econometric methods employed in this study will serve to advance the literature. By coupling sophisticated experimental procedures with robust econometrics, this study has sought to minimize and control for a number of factors that may bias bid elicitation and subsequent analysis of explanatory factors. As well, it is hoped that the employed Bayesian methods demonstrate the potential for these techniques to model in a straightforward and easily implemented fashion factors that are difficult (and typically omitted) using classical econometric methods.

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7 Figure and Table Appendix

Figure 1

Examples of Auction Food Labels for Products Without Enhanced Attributes

Russet Potatoes (5 lb.)	Russet Potatoes (5 lb.) GM Free Product
Russet Potatoes (5 lb.) Intragenic GM Product	Russet Potatoes (5 lb.) Transgenic GM Product

Figure 2

Examples of Auction Food Labels for Products With Enhanced Attributes

Russet Potatoes (5 lb.) Enhanced levels of Antioxidants and Vitamin C GM Product	Russet Potatoes (5 lb.) Enhanced levels of Antioxidants and Vitamin C Intragenic GM Product	Russet Potatoes (5 lb.) Enhanced levels of Antioxidants and Vitamin C Transgenic GM Product

Table 8
Marginal Effects of Explanatory Variables on Bid Prices for Products Without Enhanced Attributes

Dep Var	$\mathbf{Y}^{No\ Label}$		$\mathbf{Y}^{GM\ Free}$		$\mathbf{Y}^{Intragenic}$		$\mathbf{Y}^{Transgenic}$	
	$E(\cdot\|y)$	$Std(\cdot\|y)$	$E(\cdot\|y)$	$Std(\cdot\|y)$	$E(\cdot\|y)$	$Std(\cdot\|y)$	$E(\cdot\|y)$	$Std(\cdot\|y)$
	Information Treatment Dummy Variables (No Info Dummy Omitted)							
Pro	0.048	0.090	-0.066	0.090	0.120	0.084	0.082	0.132
Anti	-0.084	0.132	0.054	0.066	-0.120	0.150	-0.228	0.198
Pro & Anti	0.108	0.072	0.066	0.054	0.156	0.072	0.060	0.108
Pro,Anti,&Ver	-0.072	0.120	-0.120	0.114	-0.006	0.114	-0.102	0.156
	Demographic Variables							
Gender	-0.060	0.066	-0.018	0.054	0.036	0.090	-0.132	0.084
Race	0.330	0.174	0.120	0.102	0.204	0.150	0.210	0.168
Age	0.012	0.000	0.006	0.000	0.006	0.000	0.012	0.000
Income	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000
Educ	0.000	0.012	-0.006	0.006	0.012	0.012	0.018	0.012
Married	-0.072	0.072	-0.024	0.048	-0.096	0.078	-0.108	0.090
Household	0.060	0.024	0.060	0.018	0.048	0.024	0.054	0.030
Iowa	-0.090	0.060	-0.060	0.042	-0.060	0.066	0.090	0.090
Farm	0.000	0.072	0.030	0.048	0.042	0.072	0.078	0.084
Envi_Mem	-0.474	0.390	-0.174	0.222	-0.288	0.324	-0.592	0.522
	Opinion Variables							
Informed	0.138	0.066	0.060	0.060	-0.006	0.120	0.132	0.108
Opinion	-0.036	0.090	0.012	0.060	0.024	0.084	-0.096	0.132
Read_Labels	-0.138	0.078	-0.030	0.054	-0.090	0.078	-0.270	0.096
	Health Variables							
Smoke	0.150	0.054	0.120	0.042	0.120	0.060	0.150	0.078
Exercise	0.024	0.072	0.036	0.054	0.198	0.084	0.108	0.096
Health_Diet	0.024	0.024	0.024	0.018	-0.006	0.024	0.042	0.030
Health_Phys	-0.024	0.018	-0.018	0.012	-0.024	0.024	-0.048	0.024
Round	0.054	0.030	0.048	0.030	0.114	0.036	0.138	0.036

Table 9
Marginal Effects of Explanatory Variables on Bid Prices for Products With Enhanced Consumer Attributes

Dep Var	$\mathbf{Y}^{GM}$		$\mathbf{Y}^{Intragenic}$		$\mathbf{Y}^{Transgenic}$	
	$E(\cdot\|y)$	$Std(\cdot\|y)$	$E(\cdot\|y)$	$Std(\cdot\|y)$	$E(\cdot\|y)$	$Std(\cdot\|y)$
	Information Treatment Variables (No Info Omitted)					
Pro	0.040	0.056	0.140	0.034	0.136	0.094
Anti	-0.034	0.072	-0.122	0.080	-0.142	0.132
Pro & Anti	-0.026	0.068	0.026	0.050	-0.092	0.122
Pro,Anti,&Ver	-0.226	0.092	-0.142	0.074	-0.182	0.122
	Demographic Variables					
Gender	-0.010	0.040	0.048	0.038	0.084	0.074
Race	-0.086	0.046	-0.080	0.038	-0.138	0.084
Age	0.008	0.002	0.004	0.002	0.010	0.004
Income	-0.002	0.000	-0.002	0.000	-0.006	0.002
Educ	-0.006	0.012	0.020	0.010	-0.002	0.026
Married	-0.018	0.050	-0.082	0.042	0.008	0.086
Household	0.082	0.022	0.058	0.020	0.082	0.044
Iowa	-0.042	0.040	-0.052	0.034	0.118	0.076
Farm	-0.140	0.070	-0.128	0.064	-0.106	0.100
Envi_Mem	-0.118	0.146	-0.140	0.144	-0.098	0.202
	Opinion Variables					
Informed	0.030	0.066	0.026	0.056	0.078	0.112
Opinion	0.088	0.048	-0.012	0.060	0.216	0.084
Read_Labels	0.132	0.056	0.076	0.046	0.024	0.082
	Health Variables					
Smoke	0.068	0.040	0.036	0.038	0.046	0.076
Exercise	0.038	0.042	0.116	0.042	0.136	0.076
Health_Diet	-0.014	0.024	-0.036	0.022	-0.060	0.054
Health_Phys	0.056	0.024	0.036	0.022	0.092	0.056
Round	-0.054	0.030	0.064	0.026	0.188	0.048

8 Information Treatment Appendix

Agricultural Biotechnology Industry Perspective on GM

The following is a collection of statements and information on genetic modification provided by a group of leading biotechnology companies, including Monsanto, Pioneer and Syngenta.

General Information

Genetically modified (GM) plants have the potential to be one of the greatest discoveries in the history of farming. GM crops have lowered food production costs by improving insect and disease resistance and weed control in plants. New genetic engineering techniques could dramatically enhance consumer benefiting attributes of food such as vitamins, antioxidants, flavor, and shelf life. These improvements to plant quality can only be attained through GM, not conventional breeding.

The process of genetic modification takes genes from one organism and places them into another. There are two distinct types of GM used by biotechnology companies. Transgenic GM transfers genes between two unrelated organisms, for example from soil bacteria to corn. Intragenic GM involves transferring genes between two breeds of the same organism, for example, from wild species of corn to a commercial variety of corn.

Scientific Impact

Both transgenic and intragenic techniques are used to produce food products that are approved by the Food and Drug Administration (FDA). Intragenic modification is a genetic technique for significantly speeding up the conventional process of plant cross-breeding, which has been undertaken by farmers and plant breeders for thousands of years. Many industry groups believe intragenics should require minimal FDA testing because no foreign genes or proteins are added to the GM plant. We have only seen the tip of the iceberg of the future potential of GM for improving worldwide health and nutrition through enhanced plants.

Human Impact

The potential exists for GM to dramatically enhance traits that have direct value to consumers, such as increased vitamins and antioxidants, more flavor, longer shelf life, lower pesticide use, and reduced cost of production. Superior GM plants will help reduce worldwide malnutrition and improve the healthiness of foods. The FDA has approved GM food for human consumption, and Americans have been consuming GM foods for a decade. While every food (modified or not) poses some risks, there has never been a documented case of a person getting sick from GM food.

Financial Impact

With the introduction of enhanced nutrition, antioxidants, shelf life, flavors and other consumer-desired attributes using GM technology, consumers will for the first time enjoy the direct benefits of genetic engineering. GM plants have reduced farmers' costs, which mean lower food prices. Worldwide the number of hungry people is declining. GM technology is helping to feed the world and improve worldwide nutrition.

Environmental Impact

Genetic modification of plants has the potential to be one of the most environmentally helpful discoveries ever. GM technology has produced new methods of insect control that reduce chemical insecticide application by 50% or more. GM weed control is providing new methods to control weeds, which are a problem in no-till farming. This means greater crop yields and less environmental damage.

Environmental Group Perspective on GM

The following is a collection of statements and information on genetic modification from Greenpeace, a leading environmental group.

General Information

Genetic modification (GM) takes genes from one organism and places then into another. The process lets scientists manipulate genes in an unnatural way. Inadequate safety testing of GM plants and food products has occurred. Humans and the Earth are being used as guinea pigs for testing whether "Frankenfoods" are safe. GM foods should be banned because their effect on consumers and the environment is unknown and potentially catastrophic! Genetic modification is one of the most risky things being done to your food sources today and should be stopped before more damage is done.

Scientific Impact

All genetic modifications of plants are risky. All GM techniques are relatively new and no one can guarantee that consumers or the environment will not be harmed. The biggest potential hazard of GM foods is the unknown.

Human Impact

Genetically modified foods could pose serious risks to human health. Some foods contain allergens, and the potential exists for allergens to be transferred into a GM food product that no one would suspect. For example, if the genes from a peanut were transferred into a tomato, and someone who is allergic to peanuts eats this GM tomato, he could display a peanut allergy.

Another problem with transgenic foods is a moral issue. Many GM techniques transfer genes across species. We believe it is morally wrong to alter life forms on such a fundamental level.

Financial Impact

GM foods are being pushed onto consumer by big businesses which only care about their own profits and ignore possible negative side effects. These groups are actually patenting new life forms they create with plans to sell for profits. Studies have shown that GM crops may even get lower yields than conventional crops.

Environmental Impact

GM foods could pose major environmental hazards. Little testing of GM plants for environmental impacts has occurred. One potential risk of GM crops is their impact on wildlife, including wild species of plants and insects. A study showed that one type of GM plant killed Monarch butterflies.

Another potential environmental hazard could come from pests that become resistant to new naturally occurring toxic substances engineered into plants to kill pests—insects and worms—or to make a plant resistant to a particular herbicide application. The target pests that get exposed to these new GM crops could quickly develop tolerances and wipe out many of the potential advantages of GM pest resistance.

Independent, 3rd Party, Verifiable Perspective on GM

The following is a statement on genetic modification approved by a third-party group consisting of a variety of individuals knowledgeable about genetically modified foods including: scientists, professionals, religious leaders, and academics. These parties have no financial stake in GM foods.

General Information

The process of genetic modification (GM) takes genes from one organism and places them into another. There are two distinct types of GM used by biotechnology companies. Transgenic GM transfers genes between two unrelated organisms, for example from soil bacteria to corn. Intragenic GM involves transferring genes between two breeds of the same organism, for example from wild species of corn to a commercial variety of the crop. Hence, intragenic modification has much in common with conventional plant breeding.

Scientific Impact

The Food and Drug Administration (FDA) standard for GM food products is based on the principle that they have essentially the same ingredients, although modified from the original plant. Almost all GM crops meet the FDA's substantive equivalent requirement. Hence, they do not require special testing before commercial marketing can occur.

Human Impact

Many scientists see intragenics as having real potential for enhancing consumer attributes of plants such as dramatically increasing vitamin and antioxidant levels, extending shelf life, and reduced chemical pesticide application without concerns about gene transfer across species. These improvements to plants are only possible using genetic modification and not conventional breeding.

All foods present a risk of an allergic reaction to a small fraction of the population. No FDA approved GM food poses any known unique human health risks, but when genes are transferred across species, a new allergen is possible. This is more likely with transgenics than intragenics. While GM crops can result in higher yields and enhanced nutrition, there is no consensus whether GM foods have or will reduce worldwide hunger.

Many people have moral or religious objections to GM. Some groups see intragenics as being more acceptable because genes are transferred between two breeds of the same species.

Financial Impact

GM seeds and other organisms are produced by businesses that seek profits. For farmers to switch to GM crops, they must see benefits from making a change. Consumers must also see benefits from consuming GM foods—lower price or enhanced consumer attributes. However GM technology may lead to changes in the organization of the agri-business industry and farming.

Environmental Impact

The long-term effects of GM on the environment are largely unknown. Bioengineered insect resistance has reduced farmers' applications of environmentally hazardous insecticides, but resistance to this bio-control system will increase over time. More studies are occurring to help assess the impact of bioengineered plants on the environment. Some studies reported harm to Monarch butterflies from GM crops, but other scientists were not able to recreate the results.

Enhanced consumer attributes, such as vitamins, antioxidants, and longer shelf life due to intragenics pose no known environmental hazards.