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# Improving the Nutrient Content of Food through Genetic Modification: Evidence from Experimental Auctions on Consumer Acceptance

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This paper assesses consumers' acceptance of nutritionally enhanced vegetables using a series of auction experiments administered to a random sample of adult consumers. Evidence suggests that consumers are willing to pay significantly more for fresh produce with labels signaling enhanced levels of antioxidants and vitamin C achieved by moving genes from within the species, as opposed to across species. However, this premium is significantly affected by diverse information treatments injected into the experiments.

*Key words*: Bayesian analysis, experimental auction, food products, genetic modification

## Introduction

Daily consumption of fruits and vegetables in the United States is significantly lower than national dietary recommendations, despite extensive information campaigns, outreach efforts, and popular-media attention highlighting the relationship between food choices and health outcomes (Guenther et al., 2006; Kimmons et al., 2009). Fruits and vegetables are promoted in the battle against obesity as a superior alternative to high-caloric foods (e.g., sugar based beverages, calorie-dense processed snacks). They are also a natural source of the vitamins, minerals, and antioxidants that play a critical role in determining health outcomes (e.g, Block, Patterson, and Subar, 1992; Joshipura et al., 2001; Epstein et al., 2001), but the proliferation of foods fortified or enriched with vitamins and minerals (e.g., breakfast cereals) and daily multivitamin tablets has diminished this role (Subar et al., 1998; Berner, Clydesdale, and Douglass, 2001).[1] The emergence of non-food sources of nutrients coupled with the burgeoning success of the functional food market has helped motivate the biotechnology industry to develop new crop varieties engineered for superior nutrient levels, such as potatoes with enhanced levels of antioxidants and vitamin C.

While genetic modification has potential for delivering improved product quality by enhancing nutrient content, since their emergence in the market in the mid-1990s genetically modified (GM) foods have remained domestically and internationally a socially and politically sensitive topic due to their perceived unnatural production. Early GM foods were engineered using "transgenic" methods, in which genes from one species are transferred into a different species (e.g., from soil bacteria into corn). Studies have shown that consumers view these transgenic foods as weakly inferior to similar non-GM alternatives (e.g., Huffman et al., 2003; Noussair, Robin, and Ruffieux, 2004; Lusk et al., 2005; Rousu et al., 2007). The transgenic nature of these genetically modified organisms (GMOs)

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[1] See Woodside et al. (2005) for a review of medical evidence on supplements vs. food sources.

has been one dimension of consumers' and environmental groups' resistance to genetic modification of plants–raising biodiversity, environmental, ethical, and safety concerns–and has been a factor in the larger controversy surrounding GMOs (for reviews of the GM debate see Herdt, 2006; van den Bergh and Holley, 2002).

To counter some of these concerns, new "intragenic" bioengineering methods have been developed that only transfer genes from within the species (e.g., from a wild potato variety into a commercial potato variety), exploiting the natural and induced diversity of species that has evolved over time in diverse geo-climates. The traditional method of slicing genes includes the use of antibiotic markers, which mark the location of a transgene on chromosomes, but this practice has raised public concern. A new gene transfer system has been developed that does not infringe on existing gene splicing patents and does not use antibiotic markers (see Rommens et al., 2004). No "foreign" genetic material is used in this new gene transport system, removing one of the perceived negative attributes of earlier transgenic foods. Moreover, the new method has many features in common with traditional plant breeding methods.

This study examines consumers' willingness to pay for foods that have been enhanced with consumer attributes–vitamins and antioxidants–delivered by transgenic and intragenic GM methods controlling for information effects. The study uses an auction market mechanism for revealing willingness to pay and participants randomly chosen from consumers in two urban areas. Building on the methodology of Rousu et al. (2007), food labels and information treatments are an important part of the research design. As an additional advance in analyzing experimental auction bid-price data, we construct and estimate a Bayesian econometric model of bid prices that simultaneously controls for bid censoring, commodity fixed effects, bidding-round fixed effects, and correlation of unobserved effects across rounds of bidding.

## Experimental Design

In spring 2007, an independent survey agency called a random set of telephone numbers in two cities to solicit participants for our experiments. Participants were chosen from two geographically separated cities to obtain some regional balance in our participants, and they were only told that this was a university project on consumers' assessments of household products and foods. Willing participants were then permitted to chose among three or four starting times on the auction days (March 24 in Harrisburg, Pennsylvania, and April 14 in Des Moines, Iowa; both dates were Saturdays), and they were given instructions on how to reach the lab site or classroom. In our experiments, we disseminate several information treatments randomly within the same session to avoid potentially confounding session effects.

Our methodology incorporated and refined established experimental procedures (Hoffman et al., 1993; Shogren et al., 1994; Lusk et al., 2001; Alfnes and Rickertsen, 2003) and advances made by Rousu et al. (2007). We used adult consumers from two distinct geographic regions that were drawn from a random phone book sample, ensuring that our results are not artifacts of a single geographic region. We paid participants a fixed amount for participating in the experiments, but do not endow participants with products and have them bid to upgrade to another product, because new evidence by Corrigan and Rousu (2006) and Plott and Zeiler (2007) has shown that session monitors in the past may have induced significant endowment effects in bid prices by emphasizing the personal gift nature of in-kind transfers made to participants as part of the experiment. To assess the impact of interested parties (e.g., biotechnology, environmental, and independent scientific groups) attempting to impact market outcomes by strategically using private information (Milgrom and Roberts, 1986), we injected randomized information treatments into the experiments. We used the *n*th-price auction mechanism (Shogren et al., 2001), which has been shown to be a demand revealing mechanism that better engages off-margin bidders. To avoid strategic behavior in bidding in sequential price auctions (Bajari and Hortaçsu, 2003; Guerre, Perrigne, and Vuong, 2000; Corrigan and Rousu, 2006), all bids are collected in a session before any information about the bid levels and distributions are revealed.

We also randomized all food labels to eliminate sequencing effects. Finally, in many previous experiments where information is disseminated to participants (Lusk et al., 2004; Rousu et al., 2007), each "session" receives the same information treatment. In our experiments, we disseminate several information treatments randomly within the same session, thus avoiding potentially confounding session effects.

Upon arrival at the experiment site, participants were alternately assigned to one of two concurrent sessions (related individuals were assigned to different sessions). Each session consisted of nine to seventeen individuals and lasted approximately ninety minutes. Participants were asked to sign a consent form and were paid $45 dollars for their participation. Next, they were asked to complete a short questionnaire soliciting socioeconomic and demographic information and to answer a few questions about agricultural technologies. A total of fourteen sessions (eight in Des Moines and six in Harrisburg) were conducted. With regards to the location for experiments, it should be noted that many experimental studies are now being conducted in settings that are more familiar to consumers (Lusk, Pruitt, and Norwood, 2006). 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.

Participants were informed that they would be engaging in an auction of food products and provided with instructions and examples about the auction method used in the study: the *n*th-price auction. In this type of auction, all individuals who bid higher than the randomly selected "*n*th-price" win the auction and pay the *n*th-price for the commodity. Instead of using the more common Vickrey sealed bid second-price auction mechanism (Vickrey, 1961), the *n*th-price auction was selected based on evidence that it better engages off-margin bidders while still being a demand-revealing mechanism. The Becker and Marschak (1964) mechanism is also demand-revealing (e.g., Wertenbroch and Skiera, 2002), but the random *n*th-price auction has been shown to be more accurate at revealing preferences in experiments, potentially due to the endogenous clearing price (Lusk and Rousu, 2007). As part of the instruction process, participants were told that their preferred strategy should be to bid their true preferences.

During a practice phase, participants engaged in a two-round *n*th-price auction with candy, pens, and pencils to gain experience with the *n*th -price auction. Participants were then told that the auction would consist of four rounds of bidding, but only one round would be binding and it would be chosen after all bids were submitted. This format reduces participants' concerns about exceeding their resources (the $45 dollars plus any cash they brought with them to the experiment) and fixes the idea that despite multiple bidding rounds they are bidding on only one unit of each of the auctioned commodities, eliminating potential demand effects associated with multiple purchases.

Three information perspectives on GMOs and a "no information" baseline were used to construct five information treatments for the experiments. The pro-biotech perspective consists of a collection of mainly positive or optimistic statements on GM provided by a group of leading agricultural biotechnology companies. The anti-biotech perspective consists of a collection of mainly negative or pessimistic statements on GM from leading environmental groups. The third-party perspective (or verifiable information) is a collection of statements representing an objective assessment of GM at the time the experiments were conducted. This perspective was linked to scientists, professions, religious leaders and academics, none of whom had a financial stake in GM foods. To ensure that the volume of information contained in the three perspectives on GMOs was not overwhelming to participants, each perspective was limited to one standard sheet of copy paper and organized under five common headings. The three information perspectives are presented in the appendices. The order of pro- and anti-biotech perspectives was randomized in treatments consisting of more than one perspective. The verifiable perspective was always presented last. Throughout this article, the following terms will be used synonymously to refer to types of information: 1) industry, positive, pro-biotech, 2) environmental, negative, and anti-biotech, and 3) verifiable and third party.

In each round of the auction, participants submitted three separate bids: one bid for each of the three auction commodities. The auction commodities were one pound of broccoli, one pound of

| | |
|---|---|
| Russet Potatoes (5 lb.) | Russet Potatoes (5 lb.)<br><br>GM Free Product |
| Russet Potatoes (5 lb.)<br><br>Intragenic GM Product | Russet Potatoes (5 lb.)<br><br>Transgenic GM Product |

**Figure 1. Examples of Auction Food Labels for Products without Enhanced Nutrients**

| | | |
|---|---|---|
| Russet Potatoes (5 lb.)<br><br>Enhanced levels of Antioxidants and Vitamin C<br><br>GM Product | Russet Potatoes (5 lb.)<br><br>Enhanced levels of Antioxidants and Vitamin C<br><br>Intragenic GM Product | Russet Potatoes (5 lb.)<br><br>Enhanced levels of Antioxidants and Vitamin C<br><br>Transgenic GM Product |

**Figure 2. Examples of Auction Food Labels for Products with Enhanced Nutrients**

beefsteak tomatoes, and five pounds of russet potatoes. Products were presented in plain packaging similar to how they are displayed in a grocery store, and a simple label was affixed. In each bidding round, the three commodities with labels were revealed on a table in the front of the lab. In half of the sessions (3 in PA and 4 in IA), the four food labels (one in each round) were: GM Free, Intragenic GM, Transgenic GM, and Plain. Product name (e.g. Russet Potatoes) and weight were listed on each label. The phrase "Plain" describes a label containing only the product name and weight. Figure 1 presents examples of labels. In the other half of the sessions (seven total), the first three rounds of the auction consisted of products with food labels of either GM, Intragenic GM, or Transgenic GM, but also offered additional information: "Enhanced levels of Antioxidants and Vitamin C." Figure 2 presents examples of these labels. A fourth label treatment, not pertinent to this article, always appeared in the final auction round and would not affect bids in the earlier three rounds.

All three products within a round of bidding had the same food label, and the order in which labels were presented was randomized across sessions. After a set of experimental products was revealed, participants were asked to come to the front of the room and view the products before writing their three bids. These bids were then collected by the session monitor before proceeding to the next round of bidding.

After completion of all bidding rounds, the binding bidding round was selected by drawing a number from an envelope. Bids were then posted and ranked on a whiteboard in the front of the lab (no bids were posted prior to this point). Finally, for each of the three commodities a random $n$ was drawn from an envelope to determine the clearing prices. Winners were then identified. All participants were then asked to complete a short exit questionnaire. Upon completing the questionnaire, non-winners were told that they were free to leave, and winners were told to go to an adjacent room to complete their purchases, exchanging money for goods. Given the incomplete regulatory status of the intragenic foods, we were unable to deliver nutrient-enhanced GM fresh vegetables to winners. As an alternative, winners were informed and given plain-labeled food products, which is similar to procedures followed by others in similar circumstances (e.g., Alfnes

**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 | 15.8 |
| 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 supportive | 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 | 0.04 | 0.21 |
| 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 physical health (1-10 scale) | 7.16 | 1.69 |

and Rickertsen, 2003; Corrigan et al., 2009; Tonsor et al., 2005). Participants' reception to these experiments was very good, and we did not receive any complaints.[2]

## Summary of Data

Table 1 presents basic summary statistics of the auction participants. Participants are 68% female, the mean age is 44 years, mean education is 14.5 years, and mean household income is $51,000. Only 11% of the participants consider themselves well- or extremely well-informed about GM, and 17% report an opinion of GM that is supportive or strongly supportive. 63% report that they often or always read food labels. Regarding lifestyle indicators, 23% report that they smoke and 51% report exercising regularly. Participants self-assessed the healthiness of diet with a mean score of 6.7 on a scale of 1 to 10 and self-assessed their physical health with a mean of 7.2.

Tables 2 and 3 summarize participants' bid prices for fresh produce in the experimental auctions. Table 2 contains the mean and standard deviation (in parentheses) of bid prices for products without enhanced nutrient labels, conditional on information treatments. Table 3 presents similar summary statistics for products with enhanced nutrient labels. Fewer than 8% of placed bids were zeros. For products without enhanced nutrient labels, the mean bid pooled across all information treatments for products labeled GM Free is greater than for Plain-labeled products; similarly, Plain-labeled products had a higher mean bid than products labeled as Transgenic GM. The ordering of mean bid prices for the Plain label and Intragenic GM label is not the same across products. For products with enhanced nutrient labels, mean bid prices for Intragenic GM labeled products pooled across all

[2] Some of the food labels for fresh vegetables were different from the actual genetic make-up of the product. This discrepancy was not perceptible to participants and no winner was misled about the product that he or she received at the end of the experiment. Some call this practice "deception." There is not much research on the effects of this type of deception, and the few studies that have investigated it find small–if any–impact. Ethically, the benefits from this type of deception need to be weighed against the costs. If university students are the participants and they participate repeatedly within the same lab, then the practice is problematic to good research (e.g., Ortmann and Hertwig, 2002). However, when participants are randomly drawn adults from the general population, the impact on future experimental participants is going to be very small. Some argue for debriefing sessions at the end of experiments (Bonetti, 1998), but our experimental design, which was approved by the ISU Institutional Review Board on Human Subjects, did not lend itself to a complete debriefing of non-winners.

**Table 2. Mean Bid Prices for Foods without Enhanced Nutrient Label**

| Broccoli (1 lb.) | | | | Tomato (1 lb.) | | | | Potato (1 lb.) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Plain** | **GMF** | **Intra** | **Trans** | **Plain** | **GMF** | **Intra** | **Trans** | **Plain** | **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) |

*Notes:* Average bid prices are in dollars. Standard deviations are presented in parentheses.

information treatments are greater than for generic GM, which in turn are higher than for Transgenic GM labeled products.

Tables 4, 5, and 6 present differences in mean bid prices across a selection of different labels. Table 4 presents a comparison between bid prices for GM Free vs. Intragenic GM and GM Free vs. Transgenic GM labeled products, without enhanced nutrient labels. Consumers are willing to pay a premium for GM Free over Transgenic GM labeled products under all information treatments. Average premiums under different information treatments range from $0.03 to $0.46 per pound of broccoli, $0.13 to $0.69 per pound of tomatoes, and $0.13 to $0.90 per five pounds of potatoes. In general, participants are willing to pay premiums for GM Free over Intragenic GM labeled products that are smaller, or even negative (e.g., under the pro-biotechnology treatment). Participants receiving anti-biotech information are willing to pay the greatest premium for GM Free labeled products.

A comparison of average bid prices for GM labeled products with and without enhanced nutrient labels are presented in table 5. The first part of table 5 considers products with intragenic labels; differences are positive, implying that consumers value enhanced antioxidants and vitamin C. Premiums are the greatest under the pro-biotech information treatment and least under the anti-biotech treatment. The second part of the table presents mean differences in bid prices for Transgenic GM labeled products with and without enhanced nutrient labels. Here the differences are smaller and–in the case of anti-biotech information and the pro, anti and third-party information treatments–differences are slightly negative but not significantly different from zero. Combined, these results

**Table 3. Mean Bid Prices for Foods with Enhanced Nutrient Label**

| | GMF | Intra | Trans | GMF | Intra | Trans | GMF | 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) |

*Notes:* Average bid prices are in dollars. Standard deviations are presented in parenthesis.

**Table 4. Difference in Mean Bid Prices for Foods without Enhanced Nutrient Label**

| | GM Free w/o EN vs. Intragenic w/o EN | | | GM Free w/o EN vs. Transgenic w/o EN | | |
|---|---|---|---|---|---|---|
| **Info Treatment** | **Broccoli** | **Tomato** | **Potato** | **Broccoli** | **Tomato** | **Potato** |
| 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 |

*Notes:* Asterisk (*) and double asterisk (**) denote variable significant at 10% and 5% respectively.

show that consumers value enhanced nutrition in fresh vegetables but are willing to pay a greater premium when these traits are obtained through intragenics instead of transgenics. The first part of table 6 compares bid prices for Intragenic GM labeled products with enhanced nutrient labels versus Plain Label products without enhanced nutrient labels. Across all treatments, except for anti-biotech, consumers are willing to pay a premium for the Intragenic GM labeled products with enhanced nutrient labels. The second part of table 6 is a comparison between Transgenic GM labeled products with enhanced nutrient labels versus Plain Label products. Here the differences are smaller and

**Table 5. Difference in Mean Bid Prices for Foods with and without Enhanced Nutrient Label**

| | Intragenic w/ EN vs. Intragenic w/o EN | | | Transgenic w/ EN vs. Transgenic w/o EN | | |
|---|---|---|---|---|---|---|
| **Info Treatment** | **Broccoli** | **Tomato** | **Potato** | **Broccoli** | **Tomato** | **Potato** |
| 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 |

*Notes:* Asterisk (*) and double asterisk (**) denote variable significant at 10% and 5% respectively.

**Table 6. Difference in Mean Bid Prices for Foods with Enhanced Nutrient Label and Plain Label Foods**

| | Intragenic w/ EN vs. Plain Label w/o EN | | | Transgenic w/ EN vs. Plain Label w/o EN | | |
|---|---|---|---|---|---|---|
| **Info Treatment** | **Broccoli** | **Tomato** | **Potato** | **Broccoli** | **Tomato** | **Potato** |
| No info | $0.48 | $0.56 | $1.21* | $0.45 | $0.34 | $1.24 |
| Pro | $1.22** | $1.15** | $1.16** | $0.49* | $0.41 | $0.32 |
| Anti | $ – 0.14 | $ – 0.14 | $ – 0.27 | $ – 0.15 | $ – 0.26 | $ – 0.48 |
| Pro & Anti | $0.39 | $0.26 | $0.30 | $0.18 | $ – 0.05 | $0.00 |
| Pro, Anti, & Ver | $0.13 | $0.21 | $0.04 | $ – 0.06 | $ – 0.18 | $ – 0.38 |

*Notes:* Asterisk (*) and double asterisk (**) denote variable significant at 10% and 5% respectively.

negative in the conflicted information setting with anti-, pro-, and verifiable-information. Table 6 provides additional evidence on the positive value placed by consumers on nutrition derived through intragenics.

## Impacts of Controversial and Verifiable Information on WTP

Although the data and unconditional analysis are suggestive of the impact of information on the valuation of various types of GM products, a more rigorous analysis of bid prices is necessary to identify label and information effects. In this section, a multivariate regression model is constructed for this task.

Before deriving the econometric model, it is useful to summarize the issues that need to be incorporated in a model of bid prices. Bids for a given type of produce may be correlated in successive rounds of bidding. While it is common in the experimental economics literature to ignore correlation across rounds, efficiency can be gained by incorporating this information into the estimation procedure. Given the potential diversity of relative preferences for the experimental products, a general error specification is a natural starting place for estimation. Hence, a seemingly unrelated regression (SUR) model (Zellner, 1962) is selected to account for correlation across rounds of bidding.

Zero bids raise special problems in bid price models. A zero bid could represent a participant's protest of GMOs; but more generally, a zero bid for a product presents a censoring problem (i.e., bid prices are restricted to the non-negative interval). In the case of single equation models, censoring can be easily managed (e.g., a Tobit model). In the case of a system of equations with censoring, there are a number of classical estimation techniques that have been proposed, but they suffer from a variety of econometric issues and general intractability, particularly for models with larger numbers of equations and cross-equation correlation of disturbances (e.g., a SUR-Tobit model). A SUR-Tobit model is difficult to estimate because multiple integrals are required for maximum likelihood estimation, requiring simulation algorithms (Huang, Sloan, and Adamache, 1987; Meng and Rubin, 1996; Huang, 1999).

An alternative, selected for this study, is to estimate the model via Bayesian techniques with data augmentation (Albert and Chib, 1993). In this approach the complication of multiple integrals in the SUR-Tobit model is eliminated and replaced with a straightforward Gibbs sampler, which is fast to estimate and easily scaled to larger order systems. To simultaneously address these econometric issues, Huang's (2001) model is adapted and extended to create a Bayesian-SUR-Tobit model of individual bid prices with commodity-specific-fixed effects.

Let $y_{ij}$ denote the bid price by an individual, $i = 1,2,...,N$, for a food product with label $j = 1,2,...,J$ ($J = 4$ for the auctions without enhanced nutrient labels and $J = 3$ for the auctions with enhanced nutrient labels). The latent WTP of the $i^{th}$ individual for the food product under label $j$ can be expressed as:

(1) $$y^*_{ij} = x'_{ik}\beta_j + \varepsilon_{ij}, \quad i = 1,2,...,N, \quad j = 1,2,...,J,$$

where:

(2) $$y_{ij} = \begin{cases} y^*_{ij} & \text{if} \quad y^*_{ij} > 0 \\ 0 & \text{if} \quad y^*_{ij} \leq 0, \end{cases}$$

where $y_{ij}$ is the observed bid price, $y^*_{ij}$ is the latent bid price, and $\varepsilon = (\varepsilon_{i1},...,\varepsilon_{iJ})'^{iid} \sim N(0,\Omega)$. For individual $i$, we can express a system of equations, one equation for each label $j = 1,2,...,J$, as:

(3) $$\begin{bmatrix} y^*_{i1} \\ y^*_{i2} \\ \vdots \\ y^*_{iJ} \end{bmatrix} = \begin{bmatrix} x'_{i1} & 0 & \cdots & 0 \\ 0 & x'_{i2} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & x'_{iJ} \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_J \end{bmatrix} + \begin{bmatrix} \varepsilon_{i1} \\ \varepsilon_{i2} \\ \vdots \\ \varepsilon_{iJ} \end{bmatrix}.$$

In stacked notation, for each individual, $i$, we can express the system of WTP equations as $y^*_i = x_i\beta + \varepsilon_i$, $i = 1,2,...,N$, where $y^*_i = (y^*_{i1},...,y^*_{iJ})$ is a $J$x1 vector, $x_i = diag(x_{i1},...,x_{iJ})$ is a $J$x$k$ matrix, and $\beta = (\beta'_1,...,\beta'_J$ is a $Jk$x1 vector. Finally, stacking over all $N$ individuals we have a complete system of equations $y^* = X\beta + \varepsilon$.

Following Albert and Chib (1993), latent bid prices are model parameters, and the augmented posterior density function for unknown model parameters is proportional to the product of two conditional distributions and the prior:

(4) $$p(\beta,\Omega,y^*|y) \propto p(y|y^*,\beta,\Omega)p(y^*|\beta,\Omega)p(\beta,\Omega).$$

The conditional distribution function for $y$ is directly predicted by the latent bid price outcomes:

(5) $$p(y|y^*,\beta,\Omega) = \prod_{i=1}^{N}\prod_{j=1}^{J}\{I(y^*_{ij} > 0)I(y_{ij} = y^*_{ij}) + I(y^*_{ij} \leq 0)I(y_{ij} = 0)\},$$

and the conditional distribution function for $y^*$ is proportional to:

$$(6)\qquad p(y^*|\beta,\Omega) \propto \prod_{i=1}^{N}\{|\Omega|^{-N/2}\exp[-\frac{1}{2}\sum_{i=1}^{N}(y_i^* - x_i\beta)\Omega^{-1}(y_i^* - x_i\beta)]\}.$$

Priors for the unknown model parameters, $\beta$ and $\Omega$, are assumed to be independent:

$$(7)\qquad \begin{array}{l} \beta \sim N(\beta_0, V_\beta) \\ \Omega^{-1} \sim W(a_\varepsilon, V_\varepsilon) \end{array},$$

where $N$ and $W$ denote the multivariate normal and Wishart distributions. The conditional posterior distributions for $\beta$ and $\Omega^{-1}$ are given by standard results:

$$(8)\qquad \beta|\Omega^{-1}, y \sim N(D_\beta d_\beta, D_\beta),$$

where

$$(9)\qquad \begin{array}{l} D_\beta = (X'(\Omega^{-1} \otimes I_N)X + V_\beta^{-1})^{-1} \\ d_\beta = X'(\Omega^{-1} \otimes I_N)y + V_\beta^{-1}\beta_0 \end{array},$$

and

$$(10)\qquad \Omega^{-1}|\beta, y \sim W(N + a_\varepsilon, [V_\varepsilon^{-1} + \sum_{i=1}^{N}(y_i - X_i\beta)(y_i - X_i\beta)]^{-1}).$$

Finally, the conditional posterior for latent bids is a multivariate truncated normal given by:

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

where:

$$(12)\qquad \begin{array}{l} \mu_{j|-j} = \mu_j + \Omega'_{j-j}\Omega_{-j-j}^{-1}(y_{-j}^{*'} - \mu_{-j}) \\ \omega_{j|-j}^2 = \omega_{jj}^2 - \Omega'_{j-j}\Omega_{-j-j}^{-1}\Omega'_{j-j} \end{array},$$

where $\mu = X_i\beta$, $\mu_j$ is the $j^{th}$ row element of $\mu$, and $\mu_{-j}$ is obtained by deleting the $j^{th}$ row element of $\mu$. The matrix $\Omega_{-j-j}$ is derived from $\Omega$ by eliminating the $j^{th}$ column and row and $\Omega_{j-j}$ is the vector derived from the $j^{th}$ column of $\Omega$ by removing the $j^{th}$ row term. Iteratively sampling from the conditional posterior distributions for $\beta$, $\Omega^{-1}$, and $y^*$ yields a set of draws from the joint pdf.

## Econometric Results

We separate observations of bid prices into one set without enhanced nutrient labels and one with enhanced nutrient labels and fit the Bayesian-SUR-Tobit model developed in the previous section to these two groups separately. Instead of estimating a separate model for each food product (fresh broccoli, tomatoes, and potatoes), the model is further stacked over the three commodities, and a commodity-specific fixed effects is added for each commodity. These dummy variables are accompanied in each of the models by the socio-demographic variables presented in table 1, including individual characteristics (e.g., income, education), personal opinions and knowledge regarding genetic modification, and several health status indicators. Key values of parameters in the priors $\beta_0 = 0, V_\beta = (10e4)I_j$, $a_\varepsilon = J^*k$, and $V_\varepsilon = (10e4)I_j$, allowing the econometric results to be dominated by the sample information and not the priors. Following a 1,000 iteration burn-in, a total of 10,000 draws from the Gibbs sampler were used in estimation.

Following the tradition of Bayesian econometrics, we present empirical results for the posterior mean of key parameters and their standard deviations and posterior probability of the estimated parameter being greater than zero (Koop, Poirier, and Tobias, 2007). Table 7 presents estimates of the bid price model for commodities without enhanced nutrients. A table of corresponding marginal effects (abbreviated M.E.) is presented in the appendices as table A1.

The signs of the estimated posterior means of the information treatment dummy variables are consistent with expectations. Individuals who receive anti-biotech information are willing to pay a premium for the GM Free label (M.E. \$0.054) and discount both the Intragenic GM and Transgenic GM labels (M.E. \$-0.120 and \$-0.228). For individuals who receive only pro-biotech information, the situation is reversed, with higher WTP for Intragenic and Transgenic GM labels (M.E. \$0.120 and \$0.082) and lower WTP for the GM-Free label (M.E. \$-0.066).

Individuals who receive pro- and anti-biotech information treatments have greater WTP for all four types of labels. However, the impact on relative WTP for Intragenic GM vs. GM Free and Transgenic GM vs. GM Free labels is less than when participants receive pro-biotech information in isolation. This indicates that, in combination, the anti-biotech information dampens the augmenting impact that pro-biotech information has on WTP for GM labels relative to GM Free. Individuals who received the combined pro, anti, and third party perspectives show reduced WTP for all four labels. While the marginal impact is similar for each of the four labels, the largest reduction occurs for the GM Free label.

We can also see that individuals who are older, white, have larger households, and have higher household incomes are willing to pay more for foods with each of the four labels. Individuals with affiliations to environmental groups have a negative posterior mean for each label; as expected, and the decrease in WTP among this group is most pronounced for the Transgenic GM label and least for the GM Free label (M.E. \$-0.592 and \$-0.174).

Results for the opinion variables present an interesting picture. Individuals who typically read food labels–signaling an interest in the nutrient content of foods–have lower WTP for all four labels, but the marginal effect is most pronounced for Intragenic and Transgenic GM labels. Individuals who are more informed about GM coming into the experiments are willing to pay more than their counterparts for Transgenic GM label and Plain label foods in particular. However, individuals with a positive opinion of GM coming into the experiments have a posterior mean close to zero across the four labeling treatments, indicating that the information treatments, in part, confounded prior opinions of GM.

Results for the healthy attitude proxies are mixed. While the signs of the posterior means for smoking (a negative attitude), regular exercise (a positive attitude), and highly rated healthiness of diet (a positive attitude) are consistent across the four food labels, there is little variation in the magnitude of the marginal effect across the different products.

Finally, results show a significant first-round bidding or framing effect. Specifically, participants bid relatively more in the first round for some labels. Our results also show that error terms in the bid price equations are positively correlated. For example, the estimated correlation between error terms for rounds with the Plain and Intragenic GM labels is 0.51 and between rounds with Plain and Transgenic GM labels is 0.31. Despite the greater modeling burden, taking account of the cross-label/round error correlations raises the efficiency of estimation.

Table 8 summarizes the econometric model of bid prices for food products with enhanced nutrient labels (corresponding marginal effects are presented in table A2 in the appendices).

**Table 7. Bayesian Estimates of Bid Price Equations for Products without Enhanced Nutrient Label (N=92, Obs=1,104)**

| | $Y^{PlainLabel}$ | | | $Y^{GMFree}$ | | | $Y^{Intragenic}$ | | | $Y^{Transgenic}$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variables** | **Mean** | **Stdev** | **Pr** | **Mean** | **Stdev** | **Pr** | **Mean** | **Stdev** | **Pr** | **Mean** | **Stdev** | **Pr** |
| 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 1 Label | 0.115 | 0.066 | 0.96 | 0.148 | 0.082 | 0.97 | 0.282 | 0.095 | 1.00 | 0.218 | 0.061 | 1.00 |

Inter-Round Correlation Coefficients

| $\rho_{Plain,GMF}$ | $\rho_{Plain,Intra}$ | $\rho_{Plain,Trans}$ | $\rho_{GMF,Intra}$ | $\rho_{GMF,Trans}$ | $\rho_{Intra,Trans}$ |
|---|---|---|---|---|---|
| 0.46 | 0.51 | 0.31 | 0.51 | 0.13 | 0.24 |

*Notes:* Mean, Stdev, and Pr respectively denote the posterior mean, $E(\cdot|y)$, posterior standard deviation, $Std(\cdot|y)$, and posterior probability of being greater than zero, $Pr(\cdot > 0|y)$.

The posterior mean is positive across all three labels for individuals receiving the pro-biotech information treatment, with the greatest relative increase for the Intragenic GM label. Individuals who receive anti-biotech information have reduced WTP for all three labels. In combination, individuals receiving both the pro- and anti-biotech information have a lower WTP for the GM and Transgenic GM labels, but higher for the Intragenic GM label. 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 the Intragenic GM label still holds marginally. Finally, when verifiable information is introduced, valuations for all three labels are lower, indicating that verifiable information bolsters the negative impact of anti-biotech information on WTP for GM food products with enhanced consumer attribute labels.

Individuals who are members of environmental groups, have experience in farming, are white, or have higher household incomes have lower WTP for all three GM labels. Consumers who are older or have larger households have a higher WTP. Consistent with the results for products without enhanced nutrient labels, individuals who were informed about GM before the experiments or typically read food labels are willing to pay more for each of the three labels. Interestingly, individuals with a favorable prior opinion towards GM are willing to pay more for both the GM and Transgenic GM labels, but the posterior is flat and centered at zero for the Intragenic GM label. This indicates that prior perceptions toward GM did not carry over into valuations of the Intragenic GM with enhanced nutrition label.

As in the estimates for products without enhanced nutrient labels, the signs of the posterior estimates for the healthy attitude variables do not present a clear relation with WTP. Surprisingly, individuals who regularly exercise or smoke are willing to pay more for each of the three labels, but those with self-assessed healthier diets are willing to pay less. However, individuals who have higher self-assessed physical healthiness are willing to pay more under each of the three labels.

Finally, as in the case of products without enhanced nutrient labels, a significant first-round label effect and correlation of error terms across rounds of bidding/labels occurs. The correlation coefficients across the different labels is approximately 0.5, which is large and consistent with the cross-label correlations in bid prices for products without enhanced nutrient labels.

## Discussion

In the effort to improve health outcomes in the United States, current policy objectives focus on encouraging consumption of healthy alternatives, including fruits, vegetables, and whole grains. In addition to typically being lower-calorie options compared to alternatives, fruits and vegetables in particular make important dietary contributions to overall health quality and may reduce potential health risks. One potential strategy for increasing both potency and consumption of these foods is improving the nutritional value and appeal of fruits and vegetables. By departing from fortification approaches, biotechnology companies have developed new “healthier” varieties via controversial genetic methods that would not be feasible using standard plant breeding techniques. Our experimental evidence indicates that potential exists for genetically modified foods containing enhanced vitamin and antioxidant content to find acceptance among consumers, with several important caveats.

Our experiments indicate that information brought to the public’s attention by interested parties attempting to influence market outcomes plays an important role in determining acceptance of GM foods with enhanced nutrients. While pro-biotechnology information in isolation has a strong augmenting impact on WTP, the premium consumers are willing to pay declines significantly in a crowded information environment with positive, negative, and verifiable information. Additionally, experiments indicate that the very nature of the engineering process has an effect on consumer WTP for nutritionally enhanced foods. Consumers appear to be more accepting of nutrition enhancements achieved using intragenics, which is arguably closer to conventional plant breeding methods, compared to transgenics, where “foreign” genetic material outside of the species is used, indicating

**Table 8. Bayesian Estimates of Bid Price Equations for Products with Enhanced Nutrient Label (N=98, Obs=882)**

| | $Y^{GM}$ | | | $Y^{Intragenic}$ | | | $Y^{Transgenic}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variables** | **Mean** | **Stdev** | **Pr** | **Mean** | **Stdev** | **Pr** | **Mean** | **Stdev** | **Pr** |
| | 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 1 Label | -0.210 | 0.110 | 0.02 | 0.342 | 0.138 | 1.00 | 0.626 | 0.159 | 1.00 |
| | Inter-Round Correlation Coefficients | | | | | | | | |
| | $\rho_{GM,Intra}$ | | | $\rho_{GM,Trans}$ | | | $\rho_{Intra,Trans}$ | | |
| | 0.49 | | | 0.46 | | | 0.54 | | |

*Notes:* Mean, Stdev, and Pr respectively denote the posterior mean, $E(\cdot|y)$, posterior standard deviation, $Std(\cdot|y)$, and posterior probability of being greater than zero, $Pr(\cdot > 0|y)$.

that intragenics may be a more appealing product development path for biotechnology companies attempting to bring enhanced food products to market.

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## References

Albert, J. H. and S. Chib. "Bayesian Analysis of Binary and Polychotomous Response Data." *Journal of the American Statistical Association* 88(1993):669–679.

Alfnes, F. and K. Rickertsen. "European Consumers' Willingness to Pay for U.S. Beef in Experimental Auction Markets." *American Journal of Agricultural Economics* 85(2003):396–405.

Bajari, P. and A. Hortaçsu. "The Winner's Curse, Reserve Prices, and Endogenous Entry: Empirical Insights from eBay Auctions." *RAND Journal of Economics* 34(2003):329–355.

Becker, M. H. D. and J. Marschak. "Measuring Utility by a Single-Response Sequential Method." *Behavioral Science* 9(1964):226–232.

Berner, L. A., F. M. Clydesdale, and J. S. Douglass. "Fortification Contributed Greatly to Vitamin and Mineral Intakes in the United States, 1989-1991." *Journal of Nutrition* 131(2001):2177–2183.

Block, G., B. Patterson, and A. Subar. "Fruit, Vegetables, and Cancer Prevention: A Review of the Epidemiological Evidence." *Nutrition and Cancer* 18(1992):1–29.

Bonetti, S. "Experimental Economics and Deception." *Journal of Economic Psychology* 19(1998):377–395.

Corrigan, J. R., D. P. T. Depositario, R. M. Nayga, X. Wu, and T. P. Laude. "Comparing Open-Ended Choice Experiments and Experimental Auctions: An Application to Golden Rice." *American Journal of Agricultural Economics* 91(2009):837–853.

Corrigan, J. R. and M. C. Rousu. "The Effect of Initial Endowments in Experimental Auctions." *American Journal of Agricultural Economics* 88(2006):448–457.

Epstein, L. H., C. C. Gordy, H. A. Raynor, M. Beddome, C. K. Kilanowski, and R. Paluch. "Increasing Fruit and Vegetable Intake and Decreasing Fat and Sugar Intake in Families at Risk for Childhood Obesity." *Obesity Research* 9(2001):171–178.

Guenther, P. M., K. W. Dodd, J. Reedy, and S. M. Krebs-Smith. "Most Americans Eat Much Less than Recommended Amounts of Fruits and Vegetables." *Journal of the American Dietetic Association* 106(2006):1371–1379.

Guerre, E., I. Perrigne, and Q. Vuong. "Optimal Nonparametric Estimation of First-Price Auctions." *Econometrica* 68(2000):525–574.

Harrison, G. W. and J. A. List. "Field Experiments." *Journal of Economic Literature* 42(2004):1009–1055.

Herdt, R. W. "Biotechnology in Agriculture." *Annual Review of Environment and Resources* 31(2006):265–295.

Hoffman, E., D. J. Menkhaus, D. Chakravarti, R. A. Field, and G. D. Whipple. "Using Laboratory Experimental Auctions in Marketing Research: A Case Study of New Packaging for Fresh Beef." *Marketing Science* 12(1993):318–338.

Huang, C. J., F. A. Sloan, and K. W. Adamache. "Estimation of Seemingly Unrelated Tobit Regressions via the EM Algorithm." *Journal of Business & Economic Statistics* 5(1987):425–430.

Huang, H. "Estimation of the SUR Tobit model via the MCECM algorithm." *Economics Letters* 64(1999):25–30.

———. "Bayesian Analysis of the SUR - Tobit Model." *Applied Economics Letters* 8(2001):617–622.

Huffman, W. E., J. F. Shogren, M. C. Rousu, and A. Tegene. "Consumer Willingness to Pay for Genetically Modified Food Labels in a Market with Diverse Information: Evidence from

Experimental Auctions." *Journal of Agricultural and Resource Economics* 28(2003):481–502.

Joshipura, K. J., F. B. Hu, J. E. Manson, M. J. Stampfer, E. B. Rimm, F. E. Speizer, G. Colditz, A. Ascherio, B. Rosner, D. Spiegelman, and W. C. Willett. "The Effect of Fruit and Vegetable Intake on Risk for Coronary Heart Disease." *Annals of Internal Medicine* 134(2001):1106 –1114.

Kimmons, J., C. Gillespie, J. Seymour, M. Serdula, and H. M. Blanck. "Fruit and Vegetable Intake Among Adolescents and Adults in the United States: Percentage Meeting Individualized Recommendations." *Medscape Journal of Medicine* 11(2009):26.

Koop, G., D. J. Poirier, and J. L. Tobias. *Bayesian Econometric Methods*. New York, NY: Cambridge University Press, 2007.

Lusk, J. L., M. S. Daniel, D. R. Mark, and C. L. Lusk. "Alternative Calibration and Auction Institutions for Predicting Consumer Willingness to Pay for Nongenetically Modified Corn Chips." *Journal of Agricultural and Resource Economics* 26(2001):40–57.

Lusk, J. L., L. O. House, C. Valli, S. R. Jaeger, M. Moore, J. Morrow, and W. B. Traill. "Effect of Information about Benefits of Biotechnology on Consumer Acceptance of Genetically Modified Food: Evidence from Experimental Auctions in the United States, England, and France." *European Review of Agricultural Economics* 31(2004):179–204.

Lusk, J. L., M. Jamal, L. Kurlander, M. Roucan, and L. Taulman. "A Meta-Analysis of Genetically Modified Food Valuation Studies." *Journal of Agricultural and Resource Economics* 30(2005):28–44.

Lusk, J. L., J. Pruitt, and B. Norwood. "External Validity of a Framed Field Experiment." *Economics Letters* 93(2006):285–290.

Lusk, J. L. and M. C. Rousu. "Market Price Endogeneity and Accuracy of Value Elicitation Mechanisms." In J. A. List, ed., *Using Experimental Methods in Environmental and Resource Economics,* Cheltenham, UK: Edward Elger Publishing, 2007.

Meng, X.-L. and D. B. Rubin. "Efficient Methods for Estimation and Testing with Seemingly Unrelated Regressions in the Presence of Latent Variables and Missing Observations." In D. A. Berry, K. M. Chaloner, and J. K. Geweke, eds., *Bayesian Analysis in Statistics and Econometrics,* New York: John Wiley & Sons, 1996.

Milgrom, P. and J. Roberts. "Relying on the Information of Interested Parties." *RAND Journal of Economics* 17(1986):18–32.

Noussair, C., S. Robin, and B. Ruffieux. "Do Consumers Really Refuse to Buy Genetically Modified Food?" *Economic Journal* 114(2004):102–120.

Ortmann, A. and R. Hertwig. "The Costs of Deception: Evidence from Psychology." *Experimental Economics* 5(2002):111–131.

Plott, C. R. and K. Zeiler. "Exchange Asymmetries Incorrectly Interpreted as Evidence of Endowment Effect Theory and Prospect Theory?" *American Economic Review* 97(2007):1449–1466.

Rommens, C. M., J. M. Humara, J. Ye, H. Yan, C. Richael, L. Zhang, R. Perry, and K. Swords. "Crop Improvement through Modification of the Plant's Own Genome." *Plant Physiology* 135(2004):421–431.

Rousu, M. C., W. E. Huffman, J. F. Shogren, and A. Tegene. "Effects and Value of Verifiable Information in a Controversial Market: Evidence from Lab Auctions of Genetically Modified Food." *Economic Inquiry* 45(2007):409–432.

Shogren, J. F., M. Margolis, C. Koo, and J. A. List. "A Random nth-Price Auction." *Journal of Economic Behavior & Organization* 46(2001):409–421.

Shogren, J. F., S. Y. Shin, D. J. Hayes, and J. B. Kliebenstein. "Resolving Differences in Willingness to Pay and Willingness to Accept." *American Economic Review* 84(1994):255–270.

Subar, A. F., S. M. Krebs-Smith, A. Cook, and L. L. Kahle. "Dietary Sources of Nutrients among US Adults, 1989 to 1991." *Journal of the American Dietetic Association* 98(1998):537–547.

Tonsor, G. T., T. C. Schroeder, J. A. Fox, and A. Biere. "European Preferences for Beef Steak Attributes." *Journal of Agricultural and Resource Economics* 30(2005):367–380.

van den Bergh, J. C. J. M. and J. M. Holley. "An Environmental-Economic Assessment of Genetic Modification of Agricultural Crops." *Futures* 34(2002):807–822.

Vickrey, W. "Counterspeculation, Auctions, and Competitive Sealed Tenders." *Journal of Finance* 16(1961):8–37.

Wertenbroch, K. and B. Skiera. "Measuring Consumers? Willingness to Pay at the Point of Purchase." *Journal of Marketing Research* 39(2002):228–241.

Woodside, J. V., D. McCall, C. McGartland, and I. S. Young. "Micronutrients: Dietary Intake v. Supplement Use." *Proceedings of the Nutrition Society* 64(2005):543–553.

Zellner, A. "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias." *Journal of the American Statistical Association* 57(1962):348–368.

## Appendix A: Environmental Group Perspective on GM

*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.

## Appendix B: Biotechnology Industry Perspective on GM

### *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.

## Appendix C: Independent, 3rd Party, Verifiable Perspective on GM

*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 varieties of the same organism, for example, from wild species of corn to a commercial variety. 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.

**Table A1. Marginal Effects of Explanatory Variables on Bid Prices for Products Without Enhanced Nutrient Label (N=92, Obs=1,104)**

| | $Y^{PlainLabel}$ | | $Y^{GMFree}$ | | $Y^{Intragenic}$ | | $Y^{Transgenic}$ | |
|---|---|---|---|---|---|---|---|---|
| **Dep Var** | **Mean** | **Stdev** | **Mean** | **Stdev** | **Mean** | **Stdev** | **Mean** | **Stdev** |
| | Information Treatment Dummy Variables (No Information 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 1 Label | 0.054 | 0.030 | 0.048 | 0.030 | 0.114 | 0.036 | 0.138 | 0.036 |

*Notes:* Mean and Stdev denote the posterior mean, $E(\cdot|y)$, and posterior standard deviation, $Std(\cdot|y)$.

**Table A2. Marginal Effects of Explanatory Variables on Bid Prices for Products with Enhanced Nutrient Label (N=98, Obs=882)**

| | $Y^{GM}$ | | $Y^{Intragenic}$ | | $Y^{Transgenic}$ | |
|---|---|---|---|---|---|---|
| **Dep Var** | **Mean** | **Stdev** | **Mean** | **Stdev** | **Mean** | **Stdev** |
| | Information Treatment Dummy Variables (No Information Dummy 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 1 Label | -0.054 | 0.030 | 0.064 | 0.026 | 0.188 | 0.048 |

*Notes:* Mean and Stdev denote the posterior mean, $E(\cdot|y)$, and posterior standard deviation, $Std(\cdot|y)$.