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A Meta-Analysis of Genetically Modified Food Valuation Studies

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A plethora of research in recent years has been devoted to estimating consumer demand for genetically modified food, an important piece of information needed to create appropriate public policy. To examine this body of work, a meta-analysis was conducted of 25 studies that, in aggregate, report 57 valuations for GM food. Findings indicate as much as 89% of the variation in existing value estimates for genetically modified food can be explained by an econometric model that controls for (*a*) the characteristics of the sample of consumers studied, (*b*) the method for eliciting consumers' valuation, and (*c*) characteristics of the food being valued. Each of these factors has a statistically significant effect on estimated premiums for non-GM food. Results of this study effectively summarize the extant literature on consumer demand for genetically modified food and permit the creation of some stylized facts that are not conditional on the results of one particular study. This paper also illustrates the effect of methodological choices on valuation estimates and reports a model which allows researchers and policy makers to quickly generate valuation measures for use in marketing or cost/benefit analysis.

Key words: biotechnology, consumer acceptance, genetically modified food, willingness to pay

Introduction

Use of biotechnology in food production is one of the most controversial subjects in modern agriculture. A key piece of information needed to fully understand the controversy and create appropriate public policy is an estimate of consumer demand for genetically modified (GM) food. For example, Fulton and Giannakas (2004) showed that consumer aversion to GM foods has an important impact on welfare implications of introducing GM crops and on the welfare effects of labeling GM food. They found that when GM foods are unlabeled, an increase in consumer aversion to GM foods decreases agricultural producers' welfare and life-science companies' profits. Other studies have illustrated the impact of consumer aversion to GM foods on trade. Using a general equilibrium model, Nielsen, Thierfelder, and Robinson (2003) concluded that producer welfare critically hinges on consumer acceptance of GM food. Bureau, Marette, and Schiavina's (1998) theoretical analysis suggests the welfare effects of non-tariff trade barriers on GM food in places such as the European Union are increasing in consumer aversion to GM food.

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Estimates of consumer willingness to pay (WTP) can be used to parameterize the aforementioned models to determine the welfare effects of public policies. The intense amount of research into consumer WTP for GM food is a reflection of the need for and usefulness of information regarding consumer demand for GM food. However, existing studies to date have used a myriad of different procedures, different types of food products, and different subject pools to estimate consumer demand for GM food. As a result, it has become difficult to effectively summarize the burgeoning literature on consumer demand for GM food and develop stylized facts. Furthermore, because of the divergent protocols employed in different studies, it is difficult to determine the extent to which particular methodological choices (e.g., hypothetical versus non-hypothetical valuation, student versus non-student subject pools, etc.) might drive valuation estimates of demand for GM foods versus true underlying preferences or food product characteristics.

The purpose of this study is to conduct a meta-analysis of studies that have reported consumer willingness-to-pay (WTP) or willingness-to-accept (WTA) values for GM food and to determine the effects of the characteristics of the studied consumers, methods of value elicitation, and food product characteristics on valuation estimates. The goal is to generate a set of findings about consumer WTP/WTA for GM food that are not conditional on the particulars of a single study, and to provide researchers and policy makers with a concise summary of the extant work. Because of the current nature of the topic and the ongoing research being conducted in the area, we do not claim to provide a comprehensive literature review of valuation studies on GM food. However, we have collected a reasonably large and representative sample of such studies for analysis. The data set is comprised of 25 separate studies that collectively provide 57 estimates of consumers' values for GM food.

In the next section, we discuss our method of selecting papers for inclusion in this analysis and describe the data collected from the selected studies. Detailed results of the analysis are then presented. The final section provides concluding remarks and offers helpful suggestions for future research.

Methods

An extensive search for published articles relating to consumer acceptance of and demand for GM food was conducted in the EconLit, Business Source Premier, and Agricola databases. The search was then extended to AgEcon Search, a database of working papers related to agricultural economics. Additionally, we contacted several researchers known to be actively working in this area and requested copies of their most recent working papers. Once this list of papers was compiled, several criteria were utilized to determine whether to include the study in this analysis. First, the study had to report a valuation estimate (WTP or WTA value) for GM food relative to non-GM food or vice versa. Several papers, although focused on consumer acceptance or purchasing behavior related to GM food, failed to meet this criterion (e.g., Moon and Balasubramanian, 2001; Frewer, Howard, and Shepherd, 1998; Gaskell et al., 1999). While this selection criterion eliminated a number of useful and interesting studies, our desire was to assemble a compilation of studies that utilized a common dimension of consumer acceptance. Second, there were cases where multiple papers from the same authors employed identical data sets. In these cases, only one of the studies was included in this analysis.

Table 1. Summary of GM Food Valuation Studies Selected for Analysis

No.	Study	Data Collection Year	Location of Study	Sample Description	Elicitation Format
1	Buhr et al. (1993)	1992	Ames, IA	Students	Experiment
2	Noussair, Robin & Ruffieux (2002)	1999	Grenoble, France	Random sample	Experiment
3	Boccaletti & Moro (2000)	1999	Northern Italy	Random sample	Phone
4	Lusk, Roosen & Fox (2003)	2000	United States United Kingdom Germany France	Random sample	Mail survey
5	Lusk et al. (2001)	2000	Manhattan, KS	Students	Experiment
6	Baker & Burnham (2001)	2000	United States	Random sample	Mail survey
7	Burton et al. (2001)	2000	Manchester, UK	Random sample	In-person survey
8	Noussair, Robin & Ruffieux (2004)	2000	Grenoble, France	Random sample	Experiment
9	Loureiro & Hine (2002)	2000	Colorado	Grocery shoppers	In-person interview
10	James & Burton (2003)	2000	Western Australia	Random sample	Mail survey
11a	Chern et al. (2003)[a]	2000	Columbus, OH As, Norway Tsukba, Japan Taipei, Taiwan	Students	In-person survey
12	Huffman et al. (2003)	2001	Des Moines, IA and St. Paul, MN	Random sample	Experiment
13	Rousu et al. (2003)	2001	Des Moines, IA and St. Paul, MN	Random sample	Experiment
14	Chen & Chern (2001)	2001	Columbus, OH	Random sample	Mail survey
15	West et al. (2002)	2001	Canada	Random sample	Phone
16	Lusk et al. (2002)	2001	Starkville, MS	Students	In-person survey
17	McCluskey et al. (2003)	2001	Matsumoto City, Japan	Grocery shoppers	In-person interview
18	Lusk (2003)	2001	Mississippi	Random sample	Mail survey
19	Grimsrud et al. (2003)	2002	Liertoppen, Norway	Grocery shoppers	In-person interview
11b	Chern et al. (2003)[a]	2002	United States United States Norway Norway	Random sample	Phone
20	Lusk et al. (2004a)[b]	2002	Lubbock, TX Long Beach, CA Jacksonville, FL Reading, England Grenoble, France	Random sample of women	Experiment
21	Tonsor & Schroeder (2003)	2002	London, England Frankfurt, Germany Paris, France	Grocery shoppers	In-person interview
22	Li et al. (2003)	2002	Beijing, China	Grocery shoppers	In-person interview
23	Moon & Balasubramanian (2003)	2002	United Kingdom	Panel of consumers	Online survey
24	VanWechel et al. (2003)	2003	Fargo, ND	Students	Experiment
25	Bugbee & Loureiro (2003)	2003	Western United States	Random sample	Mail survey

Notes: Percentage premium for non-GM food is generally calculated as: [(WTP for non-GM) - (Price of GM)]/(Price of GM) * 100. Appendix table A1 provides the assumptions made in calculating the percentage premiums for each study.

[a] The study by Chern et al. (2003) appears twice in this listing. That analysis was a multiple-country assessment with consumer data collected in 2000 for GM vegetable oil (No. 11a) and in 2002 for GM salmon (No. 11b).

[b] A portion of these data have been published in Lusk et al. (2004b).

Table 1. Extended

No.	Valuation Method	Nature of Elicitation Question	Type of Valuation	Product	Tangible Consumer Benefit?	% Premium for Non-GM
1	Auction	Real	WTP	Pork sandwich	Yes	-15.44
2	Auction	Real	WTP	Cornflakes	No	29.63
3	Payment card	Hypothetical	WTP	General	No	1.06
					Yes	-6.63
4	Conjoint choice	Hypothetical	WTP/WTA	Beef steak	No	38.94
						74.24
						90.24
						109.65
5	Auction	Real	WTP	Corn chips	No	13.00
6	Conjoint ranking	Hypothetical	WTP/WTA	Cornflakes	No	39.84
7	Conjoint choice	Hypothetical	WTP/WTA	General	No	168.83
8	Auction	Real	WTP	Cookie	No	51.01
9	Payment card	Hypothetical	WTP	Potato	No	5.55
10	Conjoint choice	Hypothetical	WTP/WTA	General–Plant	No	18.20
				General–Animal		21.05
11a	Conjoint choice	Hypothetical	WTP/WTA	Vegetable oil	No	56.00
						62.00
						36.50
						19.00
12	Auction	Real	WTP	Vegetable oil	No	15.39
				Corn chips		16.13
				Potato		16.67
13	Auction	Real	WTP	Vegetable oil	No	5.26
				Corn chips		10.29
				Potato		12.00
14	Dichotomous choice (DC)	Hypothetical	WTP	Vegetable oil	No	6.50
				Cornflakes		14.50
				Salmon		21.50
15	Conjoint choice	Hypothetical	WTP/WTA	Tomato	Yes	-67.00
				Potato chips		-63.00
				Chicken		-24.00
16	Conjoint choice	Hypothetical	WTP/WTA	Corn chips	No	11.33
					Yes	-0.33
17	Semi-double-bound DC	Hypothetical	WTA	Noodles	No	60.34
18	Double-bound DC	Hypothetical	WTP	Golden rice	Yes	-19.54
19	Semi-double-bound DC	Hypothetical	WTA	Bread	No	49.87
11b	Conjoint choice	Hypothetical	WTP/WTA	Salmon (feed)	No	41.00
				Salmon (meat)		53.00
				Salmon (feed)		54.00
				Salmon (meat)		67.00
20	Auction	Real	WTA	Cookie	No	40.00
						80.00
						20.00
						160.00
						784.00
21	Conjoint choice	Real	WTP/WTA	Beef steak	No	101.61
					No	29.58
					No	32.36
22	Double-bound DC	Hypothetical	WTP	Rice	Yes	-38.00
				Soybean oil	No	-16.30
23	Payment card	Hypothetical	WTP	Breakfast cereal	No	27.97
			WTA			95.97
24	Auction	Real	WTP	Potato chips	No	8.60
				Cookie		6.70
				Muffin		11.00
25	Double-bound DC	Hypothetical	WTP/WTA	Tomato	Yes	-12.37
				Beef		-32.60

The selection process resulted in 25 studies. A listing is provided in table 1, with the studies sorted in chronological order according to the date when the data were collected.[1]

Once the set of studies had been identified, focus was directed to identifying how these 25 studies differed according to a variety of measures related to: (*a*) the characteristics of the sample of consumers studied, (*b*) the method for eliciting consumers' valuation of GM food, and (*c*) characteristics of the food being valued. With respect to the characteristics of the sample of consumers studied, we recorded the location of the study and noted whether the sample was comprised of students, grocery shoppers, or randomly recruited subjects. Summary statistics are reported in table 2. The majority (49%) of valuations were obtained from U.S. participants. European consumers represented 33% of the valuations, and consumers in Asian countries accounted for 9%. Another 9% of the observations were from countries such as Canada and Australia. As shown in table 2, almost 20% of the valuations were based on student samples, and about 14% were elicited from grocery shoppers. In addition, the sample sizes associated with each valuation estimate were recorded.

Several variables (defined in table 2) were created to measure the degree to which the studies varied in the methods used to elicit consumers' values for GM food—in particular, whether the study was conducted in-person (either by interview or experiment), by mail, or by phone. The exact method of value elicitation was also recorded, which included several types of conjoint analysis, contingent valuation, and experimental auction (as shown in table 1). Because of the findings stemming primarily from the environmental valuation literature that individuals tend to overstate the amount they are willing to pay in hypothetical valuation tasks as compared to when real money is on the line (e.g., see the literature review by List and Gallet, 2001), we also recorded whether the valuation task was hypothetical or non-hypothetical. There was a good deal of overlap in these variables. For example, all contingent valuation studies were hypothetical and all auction studies were non-hypothetical. Accordingly, an attempt was made to create variables that captured essential features of the methodological choice while minimizing redundancies.

As shown in table 2, two variables were created—*In-person* and *Non-hyp*—to capture the primary features of the elicitation method. *In-person* identifies whether the valuation was elicited with a researcher face-to-face with the consumer. In-person valuations, which made up about 58% of the valuations in this study, included all valuations from auction studies, some of the contingent valuations, and some of the conjoint valuations. The *Non-hyp* variable identifies whether the valuations were elicited in a real or hypothetical situation. All auction valuations were non-hypothetical, as were a few of the conjoint-choice experiment valuations; these valuations made up approximately 37% of the total sample of valuations. The last variable measured with regard to elicitation method was whether the valuation measure was WTP or WTA. A large number of empirical studies have shown that while neoclassical economic theory predicts WTP should be approximately equal to WTA, WTA typically exceeds WTP several fold (e.g., see the literature review by Horowitz and McConnell, 2002). Some elicitation methods, such as conjoint analysis, do not make a distinction between WTP and WTA.

[1] We excluded a few studies that estimated consumer WTP for rBST milk because WTP for "rBST-free" milk confounds WTP for "hormone-free" and "GM-free." Prior research (e.g., Lusk, Roosen, and Fox, 2003) has found that consumers differentiate between hormone use and GM use.

Table 2. Summary Statistics and Definitions of Variables

Variable	Definition	Mean
US	1 if data from United States; 0 otherwise	0.491 (0.504)
Europe	1 if data from Europe; 0 otherwise	0.333 (0.476)
Asia	1 if data from China, Japan, or Taiwan; 0 otherwise	0.087 (0.285)
Other	1 if data from location other than U.S., Europe, or Asia [a]; 0 otherwise	0.087 (0.285)
Student	1 if sample comprised of students only; 0 otherwise	0.193 (0.398)
Shopper	1 if sample comprised of grocery shoppers only; 0 otherwise	0.140 (0.350)
In-person	1 if value elicited in-person via interview or experiment; 0 if by mail or phone	0.579 (0.498)
Non-hyp	1 if valuation task involved actual purchase; 0 if hypothetical	0.368 (0.487)
WTA	1 if valuation is willingness to accept; 0 if willingness to pay, or either	0.140 (0.350)
Fresh	1 if product valued was fresh fruit, vegetable, rice, or unspecified [b]; 0 otherwise	0.192 (0.398)
Processed	1 if product valued was bread, cereal, chips, cookie, muffin, or noodles	0.386 (0.491)
Oil	1 if product valued was oil; 0 otherwise	0.140 (0.350)
Meat	1 if product valued was GM or GM-fed meat; 0 otherwise	0.281 (0.453)
Benefit	1 if product had a direct tangible benefit to the consumer; 0 otherwise	0.281 (0.453)
Premium	Percentage premium for non-GM food	41.966 (109.683)
Premium2	Percentage premium for non-GM food, excluding one extreme outlier	28.715 (46.378)

Notes: Numbers in parentheses are standard deviations. Except for *Premium2*, number of observations = 57.
[a] Other locations include Canada and Australia.
[b] Only four valuations in the sample applied to general unspecified foods. Due to the low number of observations in this unspecified category, they were pooled with fresh foods.

Thus, a dummy variable was created to identify whether the valuation was from a study that strictly elicited WTA.[2]

Finally, several variables were created to describe the good valued in each of the studies, including the food type and whether the GM food provided any direct benefit, such as enhanced nutrition, to the consumer. As shown in table 2, most of the valuations related to processed foods, with 28% of valuations corresponding to meat products. The

[2] Several studies explicitly provided consumers with positive and/or negative information on biotechnology, whereas some studies provided neutral information, and still others seemingly provided no information to subjects at all. In the analysis that follows, we attempted to control for these potential differences in information in estimated valuation premiums by: (*a*) averaging values across information treatments in studies that introduced positive and negative information, and (*b*) using values elicited prior to "information shocks." Although one might argue that dummy variables could be constructed to identify the effect of information on premiums for non-GM food, most of the studies reported in table 1 did not explicitly identify whether or what type of information was provided to subjects. Only two of the studies reported in table 1 actually focused on the effects of information.

remaining valuations were about equally spit between oil and fresh fruits and vegetables. *Benefit*, the last variable created pertaining to product characteristics, indicates whether the valued GM food was identified as having a direct, tangible benefit to the consumer, such as increased nutrition or shelf life.

Ideally, it would be informative to collect demographic information from the studies. However, previous studies did not use identical scales or techniques to control for demographic variables. For example, with respect to income, some studies used a dummy variable for "high" versus "low," others used income ranges, others used point estimates of income, and still other studies did not report statistics on income at all. The point here is that because the data on demographics are not reported in a uniform fashion across studies (when they are reported), they cannot be pooled. It would also have been informative to collect data not just on the point estimate of WTP/WTA, but on the estimated variability of the valuation, such as the 95% confidence intervals. Unfortunately, many studies did not report such information. Consequently, this study focuses solely on mean valuation estimates without regard for the precisions with which they were measured.

To identify the effect of the aforementioned variables on the premium for non-GM food, multiple regression procedures are utilized where the dependent variable is the percentage premium for non-GM food over GM food, and independent variables are the dummy variables defined in table 2. Because the studies listed in table 1 differ (often drastically) with respect to their sample sizes, weighted least squares regressions are also estimated, where valuations are weighted by the number of observations used to generate the estimate. Intuitively, this procedure allows valuation estimates generated from larger sample sizes to have a proportionately larger effect on estimated coefficients than valuation estimates generated from smaller sample sizes.

Results

The final column in table 1 reports the percentage premiums for non-GM food over GM food for each of the valuation studies. Unfortunately, many of the studies did not report their valuation estimates in percentage terms. Consequently, we calculated the percentage premium for non-GM food over GM food implied by the data reported in the studies. In general, the percentage premium for non-GM food was calculated as: { [(value for non-GM) – (Price of GM)]/(Price of GM)} *100. For studies employing an experimental design, we used the mid-point of the experimental design as the price of GM food. For studies in which values were elicited for non-GM food in the absence of a design that controlled for the price of GM food, we utilized market prices for GM food (often this price was reported in the respective paper). For studies that separately elicited values for GM and non-GM food, we calculated the percentage premium as: { [(value for non-GM) – (value for GM)]/(value for GM)} *100. Appendix table A1 details the procedures used to calculate each of the percentage premiums reported in text table 1.

The percentage premiums for non-GM food range from a low of -67% (i.e., consumers valued the GM food over the non-GM food) to a maximum of 784%. The maximum premium of 784% was generated from a study by Lusk et al. (2004a) with French consumers. The next highest premium was only 168%, a value reported by Burton et al. (2001) in a study with English consumers. The maximum premium is roughly 4.7 times greater than the next highest value. Thus, the maximum value from the Lusk et al. (2004a) study

appears to be an extreme outlier. Because this value is abruptly "out of line" with the other premiums reported in table 1, in what follows we complement our analysis using the entire data set with a separate analysis excluding the single outlier. The simple-average premium for non-GM foods across all the valuation studies is 42% including all valuations, and 29% excluding the outlier. When studies are weighted by the number of observations used to generate the respective WTP estimates, the weighted-average WTP is 28% including all valuations, and 23% excluding the outlier. Thus, the first finding from this study is that consumers, worldwide, appear somewhat averse to GM foods and value non-GM foods over GM foods. However, as will be seen from the discussion below, this finding is mitigated by a number of factors.

Table 3 presents the primary results of this study. Results are reported from both weighted and unweighted ordinary least squares regressions.[3] In addition to these models, random effects models were estimated that accounted for correlation in WTP estimates within the study. However, for two of the models reported in table 3, the random effects estimates could not be computed because the initial estimate of the variance of the study-specific error was negative, which suggests the data are not supportive of a random effects specification (Greene, 2000). In the two models where we were able to compute the random effects estimates, results of Breusch-Pagan Lagrange multiplier tests indicate the hypothesis that the variance of the study-specific error is zero cannot be rejected, implying ordinary least squares is the appropriate model. As a result of these findings, the ordinary least squares estimates are reported in table 3.

For sake of interpretation, the constant (table 3) represents the percentage premium for a random sample of U.S. consumers, where a hypothetical WTP value was elicited via mail or phone for a meat product with no direct benefit to the consumer. A good model fit is evidenced by the F-statistics, which indicate the estimated models are statistically significant, and the R^2 values are strikingly high. In fact, when the outlier is removed, the R^2 values range from 0.75 (unweighted regression) to 0.89 (weighted regression). It is remarkable that the set of variables defined in table 2 explain as much as 89% of the variation in valuations for GM food when one considers the extreme diversity of the manner in which the studies were conducted as well as the geographic locations from which the values were derived (e.g., from Starkville, Mississippi, to Beijing, China). Because of the precision of the models, it might be possible for practitioners in need of preliminary or initial valuation estimates to utilize the equation in table 3 prior to conducting their own separate analyses. This is similar to the "benefits transfer" approach taken in environmental valuation and cost/benefit analysis, where estimated benefits from one subject pool are often used to make inferences about other individuals' values. In discussion below, this issue is examined further by considering the out-of-sample forecasting properties of the models.

Because of the appeal of the weighted least squares regression excluding the outlier (i.e., this model weights estimates based on their sample sizes and it is less sensitive to a single observation), we focus our attention on interpreting this model. However, it is important to recognize that while the other models reported in table 3 are less significant

[3] All of the regressions pool data from the WTP and WTA studies. It might be argued that it would be more effective to estimate separate regressions for WTP and WTA, as these represent two theoretically distinctive measures. However, in this analysis, there are only eight (seven if we remove the outlier) observations from WTA studies. Thus, a comparable model using only WTA observations cannot be estimated. If we estimate a model using only the WTP observations and test whether the coefficients are different than the pooled WTP/WTA model, we cannot reject the hypothesis the coefficients are the same.

Table 3. Effects of Sample Characteristics, Method of Value Elicitation, and Food Type on Premium for Non-GM Food: Weighted and Unweighted Least Squares Regressions (dependent variable = % premium for non-GM food over GM food)

	All Data		Excluding Extreme Outlier	
Variable	Unweighted	Weighted[a]	Unweighted	Weighted[a]
Constant[b]	14.894	35.360	39.994***	45.038***
	(34.038)	(22.223)	(9.064)	(7.664)
	[28.714]	[13.209]	[7.495]	[7.196]
Europe	80.116**	41.884	39.880***	29.312***
	(31.544)	(22.698)	(8.508)	(7.839)
	[44.567]	[18.561]	[11.299]	[14.137]
Asia	19.355	15.677	-3.331	1.340
	(63.451)	(42.007)	(16.811)	(14.473)
	[44.658]	[33.923]	[17.424]	[23.262]
Other	2.986	-14.881	-14.731	-22.244
	(51.950)	(29.434)	(13.762)	(10.134)
	[25.519]	[18.179]	[10.622]	[12.665]
Student	-20.572	-57.828	-14.098	-26.582
	(51.267)	(45.080)	(13.565)	(15.603)
	[23.805]	[41.162]	[17.624]	[35.565]
Shopper	-99.005	-115.391**	-53.106***	-72.688***
	(56.222)	(47.430)	(14.993)	(16.485)
	[58.006]	[54.261]	[29.020]	[47.759]
In-person	66.486	100.198**	53.401***	62.462***
	(66.152)	(46.871)	(17.508)	(16.258)
	[39.050]	[52.279]	[37.164]	[54.220]
Non-hyp	-15.210	-23.611	-38.589***	-40.144***
	(50.667)	(40.671)	(13.437)	(14.021)
	[36.342]	[30.763]	[26.774]	[38.948]
WTA	124.353**	75.821***	44.777***	58.614**
	(48.495)	(23.409)	(13.234)	(8.109)
	[89.443]	[39.508]	[18.729]	[22.711]
Processed	-44.370	-47.801**	-37.623***	-41.322***
	(41.915)	(23.255)	(11.092)	(8.008)
	[21.775]	[12.208]	[10.971]	[12.548]
Oil	-40.834	-57.198	-44.078***	-49.145***
	(56.424)	(39.297)	(14.927)	(13.526)
	[24.471]	[20.558]	[16.233]	[16.803]
Fresh	-24.578	-36.252	-25.116**	-28.084**
	(44.056)	(27.099)	(11.654)	(9.333)
	[21.854]	[18.135]	[13.680]	[12.803]
Benefit	-36.875	-40.961	-51.069***	-49.209***
	(40.528)	(27.012)	(10.737)	(9.304)
	[21.423]	[17.425]	[9.518]	[10.262]
In-Sample[c] R^2	0.39	0.57	0.75	0.89
Out-of-Sample[c] R^2	0.06	0.40	0.54	0.72
F-Statistic	2.38**	4.91***	10.95***	29.82***
No. of Observations	57	57	56	56

Notes: Double and triple asterisks (*) denote statistical significance according to conventional OLS standard errors at the 0.05 and 0.01 levels, respectively. Numbers in parentheses ( ) are conventional standard errors obtained from the OLS variance-covariance matrix. Numbers in brackets [ ] are jackknife standard errors obtained from delete-one cross-validation.

[a] Estimation weighted by sample size that generated valuation estimate.

[b] The constant represents percentage premium for a random sample of U.S. consumers, where a hypothetical willingness-to-pay valuation was elicited via mail or phone for a meat product with no direct benefit to the consumer.

[c] The in-sample R^2 is calculated in the conventional fashion as the squared correlation between actual values and in-sample predicted values. The out-of-sample R^2 is calculated as the squared correlation between actual values and out-of-sample predicted values obtained from delete-one cross-validation.

and have fewer significant variables, there are no sign reversals or inconsistencies in interpretation of statistically significant variables in the weighted least squares model excluding the outlier.

In the weighted least squares model excluding the outlier, all variables except *Asia*, *Other*, and *Student* are statistically significant (table 3). Results indicate that European consumers have valuations for non-GM food 29% higher than U.S. consumers. This finding is consistent with the stance of the European government and its associated food labeling and trade policies relative to those of the United States (see the discussion in Lusk et al., 2004a). The finding that student valuations are not different from the general population is somewhat unexpected. Studies using student subjects (e.g., Lusk et al., 2001) have cautioned quite heavily against extrapolating their results to the broader population; however, the results here suggest such extreme caution may be unwarranted. If this result is robust, it potentially suggests valuation work can be carried out in a much less costly manner than is done by most practitioners. Harrison and Lesley (1996) arrived at a similar conclusion by showing that behavioral responses of students to WTP questions could be used to accurately predict median WTP of the general population.

When valuations are elicited from shoppers, results indicate they are significantly lower than when elicited from the general population. This result may be due to the environment in which the valuations are elicited. Lusk and Fox (2003) provide a discussion on why valuations might differ in store environments as compared to non-retail environments. Overall, this result provides motivation for conducting valuation work in a store setting, as this is the environment in which consumers will actually be making food purchases. The coefficient on the *In-person* variable indicates that conducting valuations in-person tends to increase premiums for non-GM food. This result may be due to a Hawthorn-type effect where individuals behave differently because they know they are being observed or because subjects try to please the researcher with their response. Alternatively, individuals may put more cognitive effort into their response when face-to-face with a researcher as opposed to a response given when sitting in the comfort of their own homes.

Consistent with the extant literature on hypothetical bias (e.g., see List and Gallet, 2001), our findings show that premiums elicited in a non-hypothetical context are significantly lower than premiums which are hypothetical. More specifically, making the valuation task non-hypothetical lowers the premium for non-GM food by 40% as compared to when commitments are purely hypothetical.

When considering how a given research design will affect valuations, it is important to jointly interpret the *Shopper*, *In-person*, and *Non-hyp* variables. For example, if one utilizes an experimental auction in a lab setting, then *Shopper* = 0, *In-person* = 1, and *Non-hyp* = 1, and the net effect of this methodological choice is: 62% – 40% relative to the baseline category. As another example, if a contingent valuation study is conducted in a store setting, then *Shopper* = 1, *In-person* = 1, and *Non-hyp* = 0, and the anticipated net effect of this methodological choice is: -73% + 62% relative to the baseline category.

The weighted regression result for the final study design variable, *WTA*, indicates that eliciting a WTA valuation as compared to a WTP valuation tends to increase non-GM premium estimates by approximately 59%. This finding is consistent with the extensive body of literature comparing WTP to WTA (Horowitz and McConnell, 2002).

The remaining variables in the model pertain to characteristics of the valued good. As observed from table 3, GM meat products are the least desired GM food. Consumers appear to be least concerned with GM oil, with premiums for non-GM oil 49% lower than premiums for non-GM meat. This result is highly intuitive; oil made from GM corn and soybeans does not actually contain any GM ingredients, as current applications of biotechnology do not alter fat cells in plants. Results also indicate that when benefits are provided to consumers, they are more accepting of GM food. In particular, adding a direct benefit to a GM food reduces the premium for non-GM food by 49%. This result suggests the so-called "second generation" of biotechnology might be more warmly received by the public than the "first generation," which provides direct benefits only to agricultural producers.

The results discussed thus far correspond quite well to generally accepted phenomena that have been identified in studies completely unrelated to GM food. For example, our results provide evidence that hypothetical WTP is greater than non-hypothetical WTP, a finding consistent with the meta-analysis of List and Gallet (2001). Further, our study confirms that WTA exceeds WTP, supporting findings reported in the meta-analysis conducted by Horowitz and McConnell (2002). Nevertheless, one might challenge the reliability of our results due to the relatively low sample size, and question how robust these results are to the inclusion/exclusion of certain studies. This issue is important from the "benefits transfer" perspective previously mentioned. How accurate is our model in generating out-of-sample forecasts?

To answer these questions, a delete-one cross-validation exercise was conducted. This task was accomplished by deleting one observation, re-estimating the model, and using the model estimates to predict the WTP premium for the deleted observation. Carrying out this procedure for every observation in the sample generates 57 (or 56 when excluding the outlier) out-of-sample predictions. To assess how well our model performed out of sample, an out-of-sample R^2 statistic was calculated. The conventional R^2 statistic is the squared correlation between observed and predicted values, where the predicted values are generated from a model estimated using all the data, *including* the observation being predicted. Here, the out-of-sample R^2 statistic is calculated as the squared correlation between observed and predicted values, but where the predicted values are generated from a model estimated *excluding* the observation being predicted. The out-of-sample R^2 statistics for each model are reported at the bottom of table 3. As would be expected, the out-of-sample R^2 is lower than the in-sample R^2. However, in the two models excluding the outlier, the out-of-sample R^2 remains high. For example, the weighted least squares model excluding the outlier explains 72% of the variation in out-of-sample WTP for non-GM food.

To reinforce these findings, figure 1 plots predicted (out-of-sample) values against actual values for the unweighted model excluding the outlier. Points along the 45° line indicate perfect predictions. Consistent with the out-of-sample R^2 calculations, figure 1 shows that most points fall within reasonable proximity to the 45° line. As observed from figure 1, the model performs most poorly for the four largest actual WTP values. Overall, these results support our contention that practitioners in need of valuation estimates may find it helpful to simply utilize the equation in table 3 rather than going through the time and expense of conducting their own separate analyses. A caveat to this statement is the specific case when it is expected that actual WTP for non-GM foods exceeds 100%.

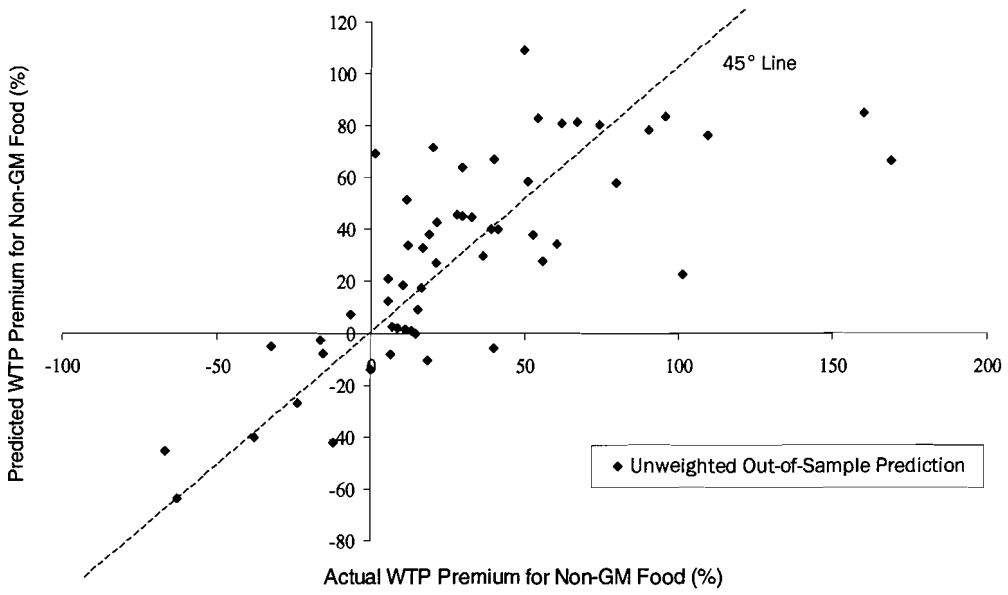

Figure 1. Comparison of actual willingness-to-pay premiums to out-of-sample predictions

In addition to determining the out-of-sample performance of our model, the stability of our parameter estimates across the cross-validation subsamples was investigated. Following Efron and Tibshirani (1993), standard errors of the model parameters were calculated using the delete-one jackknife method. Let $\hat{\theta}_i$ denote a particular parameter's value from a model estimated when the ith observation is deleted. The jackknife estimate of the standard error is specified as

$$\left[\frac{n-1}{n}\sum\left(\hat{\theta}_i - \sum\hat{\theta}_i/n\right)^2\right]^{1/2},$$

where n is the number of delete-one observations (Efron and Tibshirani, 1993). The jackknife standard errors are reported in brackets beneath the model parameters in table 3. Overall, the jackknife standard errors are comparable to the conventional OLS standard errors, and using the jackknife standard errors instead of the conventional ones to determine statistical significance changes few of the implications. However, the variables *Shopper*, *In-person*, and *Non-hyp* are only marginally significant using the jackknife standard errors. For example, in the unweighted model excluding the outlier, these three variables are only statistically different from zero at the $p = 0.07$, 0.15, and 0.15 levels, respectively. Despite this result, the signs of the coefficients on *Shopper* and *Non-hyp* are negative and the signs of the coefficients on *In-person* are positive for all 56 of the jackknife subsamples, regardless of which observation was deleted. That is, the signs of these variables are robust to the exclusion or inclusion of any particular observation.

Conclusions

Although a number of studies have been conducted to investigate consumer demand for GM food, it is difficult to assimilate the findings of the extant literature. This paper conducts a meta-analysis of 25 studies that collectively report 57 valuations for GM food. Across all studies, consumers on average placed anywhere from a 42% (unweighted average using all data) to a 23% (weighted average excluding one outlier) higher value for non-GM food relative to GM food. However, a number of factors significantly affected this value estimate. In particular, European consumers placed a higher value on non-GM food than consumers from North America. Somewhat surprisingly, valuation studies employing student samples generated valuation estimates on par with studies using more representative samples.

Examining the influence of the method of value elicitation on estimated premiums for non-GM food, we found: (*a*) non-hypothetical premiums were lower than hypothetical premiums, (*b*) premiums estimated using the WTA value measure exceeded premiums estimated using the WTP value measure, and (*c*) conducting the valuation task in-person generated lower premiums for non-GM food as compared to when the valuation was elicited over the phone or by mail. The product being analyzed was also found to significantly affect valuations. In particular, consumers placed the lowest values on GM meat products and the highest values on GM oil—i.e., GM meat products were least acceptable and GM oil was most acceptable. GM products that provided tangible benefits, such as increased nutrition to consumers, significantly decreased premiums for non-GM food.

The appeal of these findings is that they do not hinge on the findings of a single study; they are based cumulatively on a variety of different studies by different authors in different locations evaluating different foods and using different methods. Clearly, more research is needed to fully understand consumer acceptance of GM food, but we are encouraged by the ability of our model to effectively summarize the extant literature. In fact, our model was able to explain over 89% of the variation in existing premium estimates for non-GM over GM food. The model also performed well when predicting out of sample. The correlation between actual WTP premiums and out-of-sample predicted WTP premiums was 0.85. As such, if researchers are interested in quickly obtaining a single valuation measure, the model provided in this paper is likely to generate a reasonable preliminary valuation estimate.

These WTP estimates are needed, for example, to determine the welfare implications of labeling policies. Analytical results reported by Fulton and Giannakas (2004) indicate that high consumer WTP for non-GM food is one of the key criteria needed to increase both consumer and producer welfare in the movement by the United States toward a mandatory labeling policy. Results of our model imply consumer WTP likely is not sufficiently high to make a mandatory labeling policy a "win-win" outcome in the United States. Our model predicts that WTP for a non-GM processed food without any direct benefit over a GM processed food is 26% if the elicitation method is non-hypothetical and carried out in-person. This relatively low level of aversion to GM foods might be one explanation for the failure of the United States to adopt mandatory labeling policies for GM food. Our model further predicts that Europeans are willing to pay, on average, 29% more for non-GM food than U.S. consumers, ceteris paribus—making labeling policies and non-tariff trade barriers more likely in the European Union than in the United

States, as supported by the models of Fulton and Giannakas (2004), and Bureau, Marette, and Schiavina (1998).

This analysis leads us to conclude that previous research has effectively identified *what* consumers' valuations are, given a particular valuation method. However, based on our finding that valuations are significantly affected by elicitation method, a more complicated issue rests in informing policy makers as to which valuation estimates are the best suited for use in cost/benefit analysis. It seems appropriate to suggest that non-hypothetical valuations should be preferred over hypothetical, but similar arguments are harder to make in choosing WTP over WTA, in-person over anonymous, in-store over in-house, and/or processed over fresh food. Other areas of fruitful research lie in explaining *why* consumers have a particular valuation estimate, predicting how these valuations might change, and determining the effect of public policies on valuations.

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Appendix

Table A1. Methods Used to Determine Percentage Premiums for Non-GM Food

No.	Study	Method for Determining Percentage Premiums for Non-GM Food
1	Buhr et al. (1993)	Estimated premium calculated as a weighted average of mean bids from round 10 in experiments II and III in the original paper. The estimate includes data from both endowment treatments. The base price of GM pork sandwich is assumed to be $2.
2	Noussair, Robin & Ruffieux (2002)	Estimated premium calculated from mean bids in period 3 when food labels were projected.
3	Boccaletti & Moro (2000)	Estimated premiums calculated by using the summary statistics in table 3 of the original paper to construct an interval-censored log likelihood function and maximizing this function with respect to the mean premium level. Data across all four columns in the lower part of table 3 are averaged to calculate the premium for GM foods with a benefit.
4	Lusk, Roosen & Fox (2003)	Estimated premiums calculated using average premiums in table 5 of the original paper. The price of GM steak is assumed to be $8.50, the mid-point of the prices used in the experimental design.
5	Lusk et al. (2001)	Estimated premium calculated by averaging mean bids from rounds 4 and 5 for 1st and 2nd price auctions. The price of a 1-ounce bag of GM chips is assumed to be $0.50.
6	Baker & Burnham (2001)	Estimated premium calculated using aggregate model estimates in table 3 of the original paper. The price of GM cornflakes is assumed to be $3.50, the mid-point of the prices used in the experimental design.
7	Burton et al. (2001)	Estimated premium calculated as a weighted average of percentage premiums reported in table 8 of the original paper.
8	Noussair, Robin & Ruffieux (2004)	Estimated premium calculated using average bids for "GMO-free" and "with GMOs" from period 2 as reported in table 2 of the original paper.
9	Loureiro & Hine (2002)	Estimated premiums calculated using premiums reported in table 5 of the original paper. The price of GM potatoes is assumed to be $1.
10	James & Burton (2003)	Estimated premiums calculated using statistics in table 6 of the original paper. Premiums calculated by averaging the WTP estimates across 45-year-old men and women. Premiums for animals calculated as the difference between WTP for plants and animals and WTP for plants.
11a	Chern et al. (2003)[a]	Estimated premiums calculated as the mid-point of the range of percentage premiums listed in table 3 of the original paper.
12	Huffman et al. (2003)	Estimated premiums calculated from mean bids from all information treatments in table 3 of the original paper.
13	Rousu et al. (2003)	Estimated premiums calculated from mean bids from the "mandatory GM label treatment" in table 2 of the original paper.
14	Chen & Chern (2001)	Estimated premiums calculated as the mid-point of the range of percentage premiums listed in table 4 of the original paper.
15	West et al. (2002)	Estimated premiums taken directly from the text of the original paper.
16	Lusk et al. (2002)	Estimated premiums calculated using premiums reported in table 2 of the original paper. The price of GM corn chips is assumed to be $3, the mid-point of the prices used in the experimental design.

(continued . . .)

Table A1. Continued

No.	Study	Method for Determining Percentage Premiums for Non-GM Food
17	McCluskey et al. (2003	Estimated premium calculated using model estimates in table 4 of the original paper in conjunction with mean summary statistics reported in tables 1 and 2 of the original paper.
18	Lusk (2003)	Estimated premium calculated using the linear model with cheap talk. The price of non-GM rice is assumed to be $0.70, the mid-point of the prices used in the experimental design.
19	Grimsrud et al. (2003)	Estimated premiums taken directly from the text of the original paper.
11b	Chern et al. (2003) [a]	Estimated premiums taken directly from the text of the original paper.
20	Lusk et al. (2004a) [b]	Estimated premiums calculated using median round 5 bids reported in table 2 of the original paper. The price of GM cookies is assumed to be $0.25.
21	Tonsor & Schroeder (2003)	Estimated premiums calculated using estimates reported in table 5 of the original paper. The price of GM beef is assumed to be $8.625, the average price level used in the experimental design.
22	Li et al. (2003)	Estimated premium taken directly from the text of the original paper.
23	Moon & Balasubramanian (2003)	Estimated premiums calculated by using the summary statistics from the payment card questions in table 6 of the original paper to construct an interval-censored log likelihood function and maximizing this function with respect to the mean premium level.
24	VanWechel et al. (2003)	Estimated premiums taken directly from the text of the original paper. Estimates are for bids prior to an information shock.
25	Bugbee & Loureiro (2003)	Estimated premiums calculated as weighted average of WTP and WTA as reported in table 6 of the original paper.

Note: Refer to text table 1 for summary descriptions of these 25 studies.

[a] The study by Chern et al. (2003) appears twice in this listing. That analysis was a multiple-country assessment with consumer data collected in 2000 for GM vegetable oil (No. 11a) and in 2002 for GM salmon (No. 11b).

[b] A portion of these data have been published in Lusk et al. (2004b).