Willingness to Pay For Irradiated Food: A Non Hypothetical Market Experiment

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Abstract

This paper focuses on estimating consumers' willingness to pay for and willingness to accept irradiated food using a non-hypothetical experiment utilizing real food products (i.e., irradiated ground beef), real cash, and actual exchange in a market setting. Single-bounded and one and one-half bounded models are developed using dichotomous choice contingent valuation experiments. Our results indicate that average willingness to pay values range from 75.43 to 78.51 cents per pound while average willingness to accept values range from 69.49 to 81.63 cents per pound of irradiated ground beef.

Keywords: food safety, irradiated food, willingness to pay.

Introduction

Despite the fact that food has never been as safe as it is today, food safety remains a major issue. The Centers for Disease Control and Prevention (CDC, 2000) estimated that 76 million people get sick, more than 300,000 are hospitalized, and 5,000 Americans die each year from foodborne illness. Although the developments related to the adoption of Hazard Analysis Critical Control Point (HACCP) and other safety standards may have helped reduce the incidence of foodborne illness in the U.S., infections with *Salmonella*, *E. coli O157:H7*, *Campylobacter*, and *Listeria* remain and are alarmingly an ever present phenomenon. To really make a difference, new approaches for prevention are needed. One such approach is the use of food irradiation technology. Food irradiation is a food safety technology that can eliminate disease-causing germs from foods. Like pasteurization of milk, and pressure cooking of canned foods, treating food with ionizing radiation can kill bacteria and parasites that would otherwise cause foodborne disease. Food is irradiated in a special processing facility where it is exposed to an electron beam or x-ray, generated from electricity or gamma rays produced from cobalt 60. Careful monitoring ensures that the food receives the prescribed amount of irradiation to destroy harmful bacteria. Based on hundreds of studies, the World Health Organization, the Food and Drug Administration (FDA), the U.S. Department of Agriculture (USDA), and the Centers for Disease Control and Prevention (CDC) have endorsed the safety of irradiated food. The CDC conducted a study of the potential benefit of irradiating meat and poultry in the U.S. They estimated that irradiating 50 percent of meat and poultry will result in the prevention of nearly 900,000 cases of infection, 8,500 hospitalizations, and 350 deaths each year (Tauxe 2001).

Despite these benefits, the use of this technology as an important food safety tool that could complement rigorous safety programs is still limited. This paper focuses on an important component of its acceptance: estimating consumers' willingness to pay (WTP) and willingness to accept (WTA) irradiated food using a non-hypothetical market experiment with real products (i.e., irradiated ground beef), cash, and actual exchange. Irradiated food has many of the intangible characteristics of the hypothetical goods that are the subject of marketing research and non-market valuation while still being available for actual consumption and purchase (Shogren et al. 1994). The analysis is conducted using Single-Bounded (SB) and One and One-Half Bounded (OOH) dichotomous choice contingent valuation experiments. Our results indicate that average willingness to pay values range from 75.43 to 78.51 cents per pound, while average willingness to accept values range from 69.49 to 81.63 cents per pound of irradiated ground beef.

The Empirical Framework

Although statistical information could be maximized using an open-ended WTP or WTA question, this ignores considerations of an individual's cognitive capacity (Hanemann and Kanninen 1994). Individuals often cannot simply state their WTP or WTA off the top of their head. The closed-ended dichotomous choice format comes closer to how individuals think and what they can answer. Consequently, we used the dichotomous choice with follow-up contingent valuation experimental methodology in this paper and estimated a single-bounded (SB) and one and one-half bounded (OOH) model.

Assume that an individual's utility function is well behaved and defined over market commodities, q and x, respectively, where x is a bundle of commodities other than q. Let the individual's income, y, her characteristics, s, and the stochastic component of preference is ε. Define an indirect utility function for an individual as $v(p,q,y,s,\varepsilon)$. If an individual is confronted with the possibility of securing a change from q^0 to $q^1>q^0$ and this change costs \$ A. If she regards this change as an improvement, then $v(p,q^1,y-A,s,\varepsilon) \geq v(p,q^0,y,s,\varepsilon)$. The probability that an individual would accept the change at cost \$ A is, therefore,

(1) $$\Pr\{\text{response is "yes"}\} = \Pr\left\{v(p,q^1,y-A,s,\varepsilon) \geq v(p,q^0,y,s,\varepsilon)\right\}.$$

An equivalent way to express this same outcome uses the compensating variation measure, which is the quantity C that satisfies

(2) $$v(p,q^1,y-C,s,\varepsilon) = v(p,q^0,y,s,\varepsilon).$$

Thus $C=C(p,q^0,q^1,y,s,\varepsilon)$ is her maximum WTP for the change from q^0 to q^1. In general it is assumed that the respondent knows this C, but it is unknown to the analyst. The respondent will not answer "yes," if her maximum WTP value is smaller than the cost of the change, i.e., $C < A$. Therefore an equivalent condition to (1) is

(3) $$\Pr\{\text{response is "no"}\} = \Pr\left\{C(p,q^0,q^1,y,s,\varepsilon) < A\right\}.$$

The analyst treats C as a random variable, with an assumed cumulative distribution function, $G_C(\cdot)$, and probability density function, $g_C(\cdot)$. By construction, we interpret $G_C(\cdot) = \Pr\{\text{response is "no"}\}$, and the probability of yes response is

(4) $$\Pr\{\text{response is "yes"}\} = 1 - G_C(A).$$

An individual's random WTP can be formulated by assuming $G_C(A) = G(z)$ as a standard normal cumulative density function (cdf) with $\mathrm{E}\{C\} = \mu = X\beta$, and $\mathrm{Var}(C)=\sigma^2$; then a standardized variate $z = \dfrac{A-\mu}{\sigma}$, and $G_C(A) = G(z) = G\left(\dfrac{A-\mu}{\sigma}\right)$. Equation (4) can be rewritten as

(5) $\Pr\{\text{response is "yes"}\} = 1 - G\left(\frac{A-\mu}{\sigma}\right) \equiv 1 - \Phi\left(\frac{A-\mu}{\sigma}\right)$. By the symmetry property of normality, this equates to $\Phi\left(\frac{\mu - A}{\sigma}\right)$ which is a probit model with an intercept term of $\frac{\mu}{\sigma}$ and a bid coefficient of $\frac{1}{\sigma}$. Therefore the model is

(6) $\Pr\{\text{response is "yes"}\} = \Phi\left(\frac{\mu}{\sigma} - \frac{A}{\sigma}\right) \equiv \Phi(\alpha - \beta A)$.

Note that, we can rewrite the right hand side of equation (1) as follows;

$$\Pr\{\text{response is "yes"}\} \;=\; \Pr\left\{v(p, q^1, y - A, s, \varepsilon) - v(p, q^0, y, s, \varepsilon) \geq 0\right\}$$

$$\Pr\{\text{response is "yes"}\} \;=\; \Pr\left\{\Delta v(p, q^0, q^1, y, A, s, \varepsilon) \geq 0\right\}$$

If $\Delta v(\cdot)$ equals zero, then an individual will be indifferent to the proposed improvement. From equations (2) and (6), we suppress *A* with *C*, obtain $\alpha - \beta C = 0$, and an individual maximum WTP is

(7) $WTP = -\frac{\alpha}{\beta}$.

Hence, the WTA is formulated as:

$\Pr\{\text{response is "yes"}\} \;=\; \Pr\left\{v(p, q^0, y + A, s, \varepsilon) \geq v(p, q^1, y, s, \varepsilon)\right\}$, where \$ *A* is the amount offered to the respondent (Hanemann 1984).

Experimental Method

We conducted face-to-face WTP/WTA experiments to a total of 484 consumers at selected stores of the regional supermarket chain in Austin, Houston, San Antonio, and Waco, Texas from March-June 2002, using real products, cash, and actual product exchange in a supermarket setting. About 57 percent of the sample are female, 54 percent are white, and 45 percent have incomes between $30,000 and $75,000 per year. Our sample is representative of the Texas and U.S. population in terms of income, employment status, and marital status. Our sample, however, includes more women and Hispanics. This was expected since the study targets shoppers in the family who tend to be female in cities with relatively high Hispanic population.

We conducted a two-day pretest on our experimental design at a local supermarket in College Station, Texas. On the first day, the research protocol was the same as that used for the actual experiments, except for the questions about the bid values. An open-ended question on bid values was given to respondents who are willing to pay a premium for irradiated ground beef. Each respondent quoted a bid value, which was then recorded and compared with a predetermined value. If it was higher than the predetermined value, the respondent got a package of irradiated ground beef, otherwise he/she got a package of regular ground beef. After the end of the day, those quoted values were used to select the optimal bid values and sample sizes for each bid using the Bid Distribution with Equal Area Bid Selection (DWEABS) model (Cooper 1993). The DWEABS uses an iterative procedure to select the optimal bid values as well as the sample sizes corresponding to each bid that minimizes the mean square error of the welfare measure. Pretest data and total sample sizes are required as inputs for DWEABS model to calculate optimal bid values and sample sizes corresponding to each bid. On the second day, the dichotomous choice with follow-up experimental design (presented below) was pre-tested with the specific bid values calculated from the DWEABS model. Some minor modifications were made in the experimental design based on the results of the pre-tests.

After the pre-tests, the WTP and WTA experiments were carried out in supermarkets using real products (i.e., ground beef) and cash. About 13-15 respondents per store were randomly selected each for the WTP experiment and the WTA experiment.

WTP Experiment: After information about food irradiation was provided[1], we gave each WTP respondent a pound of non-irradiated ground beef and cash (representing first bid value randomly picked from one of the bid values calculated from the DWEABS model) as a gift for participating in the study. The respondent was then asked his/her willingness to exchange the pound of non-irradiated ground beef and the cash for a pound of irradiated ground beef. If the respondent accepted the bid, the cash amount was recorded as his/her WTP first-bid value, and the exchange was made. However, if the respondent rejected the bid, he/she was again asked his/her willingness to exchange a pound of non-irradiated ground beef and a half value of the cash (representing second bid value) for a pound of irradiated ground beef. If the answer was "yes," the cash amount was recorded as his/her WTP second-bid value and the exchange was made.

WTA Experiment: We also conducted a WTA experiment partly to determine how our WTP values will differ from WTA values. The difference between WTP and WTA has been widely studied. Previous studies have shown that WTA is usually substantially larger than WTP, and almost all have indicated that the WTA/WTP ratio is much higher than what economic

[1] Each respondent received two sets of information: Info I and Info II. Info I is about the nature and benefits of food irradiation, and Info II is about the two different processes of food irradiation. Both information are presented in Figures I and II.

intuition would predict (Kahneman, Knetsch, and Thaler). Our WTA experimental design was similar to that of the WTP experiment except that the items to be exchanged were reversed. We gave each WTA respondent a pound of irradiated ground beef as a gift for participating in the study. The respondent was then asked his/her willingness to exchange the pound of irradiated ground beef for a pound of non-irradiated ground beef and some cash (representing first-offer value randomly picked from one of the offer values calculated from the DWEABS model). If the respondent accepted the offer, the cash amount was recorded as the WTA first-offer value and the exchange was made. However, if the respondent rejected the offer, he/she was again asked his/her willingness to exchange a pound of irradiated ground beef for a pound of non-irradiated ground beef and cash amount double the first-offer value. If the answer was "yes," the cash amount was recorded as his/her WTA second-offer value and the exchange was made.

Empirical Models

The dichotomous choice contingent valuation models are discrete dependent variables that are measured on a nominal or ordinal scale. Both the SB and OOH models are estimated using maximum likelihood (Maddala 1983; Amemiya 1985; Greene 2000).

Single-Bounded (SB) Model

Only the first dichotomous choice question is used in the SB model. The log-likelihood function is:

(8) $$\ln L^s(\alpha,\beta) = \sum_{i=1}^{n}\left\{d_i^{yes}\ln\left(\Phi\left(\alpha-\beta A_i\right)\right)+d_i^{no}\ln\left(1-\Phi\left(\alpha-\beta A_i\right)\right)\right\},$$

where $d_i^{yes}=1$ if the *ith* response is "yes" and 0 otherwise, while $d_i^{no}=1$ if the *ith* response is "no" and 0 otherwise; the $\Phi(\cdot)$ is a normal cdf defined previously (Hanemann, Loomis, and Kanninen). The maximum likelihood estimator, denoted $\hat{\theta}\equiv(\hat{\alpha},\hat{\beta})$, is the solution to the equation $\frac{\partial \ln L(\hat{\theta})}{\partial\theta}=0$. The asymptotic variance-covariance matrix of $\hat{\theta}$ is given by the Cramer-Rao lower bound,

(9) $$V\left(\hat{\theta}\right)=\left[-E\left(\frac{\partial^2 \ln L(\hat{\theta})}{\partial\theta\,\partial\theta'}\right)\right]^{-1}$$

One-and-One-Half Bounded (OOH) Model

In this paper, we modified the concept of double-bounded model, as suggested by Cameron and Quiggin (1994), by asking the second bid question only to respondents who answered "no" to the first bid question. The follow-up question was not asked if the respondent answered "yes" to the first bid question. Hanemann and Kanninen (1996) argued that even if there is gain in efficiency in doubled-bounded method, there is evidence that some of the responses to the second bid are inconsistent with the responses to the first bid due to the fact that two separate overlapping sets of bids are asked. For example, imagine a scenario a) if a respondent answers "no" to 80-cent bid but she answers "yes" to a 40-cent bid; scenario b) if the respondent answers "yes" to 20 cent-bid and she answers "yes" to 40-cent bid. Seeing that the probability of accepting 40-cent bid is conditioned by the first bid question, the calculated probability of accepting 40 cents offer from the two scenarios differs. This finding is supported by the McFadden and Leonard (1993) study.

Second, the inconsistency arises from response effect. The respondent answers the first bid question in a neutral manner. However, Altaf and DeShazo argued that if the respondent is asked by a second follow-up question with a lower or an upper bid, that he might not react to the second question in a neutral manner because he feels that the second bid question is an attempt in bargaining. Therefore, the response to the second bid can be biased. Cooper and Hanemann (1995) found, through a simulation analysis, that the OOH provides parameter estimates much closer in efficiency to those associated with the double bounded than the SB format. Thus, they argue that it may offer most of the statistical advantages of the double-bounded format without the response effects.

The log-likelihood of the OOH model is:

$$\ln L = \sum_{i=1}^{N} \{(I_1)\log\left[\int_{-\infty}^{z_1} \phi(z_1)dz_1\right] + (1-I_1)(I_2)\log\left[\int_{-\infty}^{z_1}\int_{z_2}^{\infty} g\left(z_1, z_2\right)dz_1 dz_2\right]$$
$$+(1-I_1)(1-I_2)\log\left[\int_{-\infty}^{z_1}\int_{-\infty}^{z_2} g\left(z_1, z_2\right)dz_1 dz_2\right],$$

(10) where $\phi(.)$ is a standard normal density function,

$I_1 = 1$ if the answer to the first bid is yes, 0 otherwise,

$I_2 = 1$ of the answer to the second bid is yes, 0 otherwise.

Equation (10) is treated as a bivariate function (Cameron and Quiggin 1994).

Results

Table 1 exhibits the parameter estimates of the WTP and WTA SB models. These were estimated using equation (8) above. Results indicate that the expected WTP equals 76.96 cents with Krinsky and Robb's (1986) confidence bound between 62.42 and 99.10, while the expected WTA equals 81.56 cents with Krinsky and Robb's confidence bound between 68.23 and 103.60.

Table 1. Estimation Results for Single Bounded Models

	WTP		WTA	
Variable	Coefficient	P-value	Coefficient	P-value
Constant	0.7216	0.0007	-0.9672	0.0001
Bid	-0.0094	0.0002	0.0112	0.0001
Income	0.0001	0.9742	0.0001	0.6825
Estimated WTP and WTA	76.9698		81.5664	
90 % Confidence interval*	62.4257 - 99.1025		68.2352 - 103.6013	

*Calculated using Krinsky and Robb's Monte Carlo simulation technique.

Table 2 presents the parameter estimates of the OOH models, estimated using equation (10). Let WTP^1 (WTA^1) and WTP^2 (WTA^2) be the point estimates of WTP (WTA) from the first part and the second part of the OOH model. The estimated WTP^1 from the first part of the model is 75.43 cents per pound while the estimated WTP^2 is 78.51 cents per pound. As expected, the WTP value from SB model lies between the two point WTP estimates from the

OOH model. Similarly, the estimated WTA^1 is 81.63 while the estimated WTA^2 is 69.49. The WTA value from SB model also lies between the two WTA values from the OOH model.

Table 2. Estimation Results for One-and-One-Half Bounded Models

	WTP		WTA	
Variable	Coefficient	P-value	Coefficient	P-value
Constant1	0.7831	0.0001	-0.9561	0.0001
Bid1	-0.0103	0.0001	0.0112	0.0001
Income1	0.0001	0.9059	0.0001	0.7457
Constant1	0.9163	0.0001	-0.4505	0.0513
Bid2	-0.0119	0.0300	0.0066	0.0001
Income2	0.0001	0.7285	0.0001	0.9295
Rho	0.9989	0.0001	0.9952	0.0334
Estimated WTP^1 and WTA^1	75.4390		81.6348	
90 % Confidence interval*	61.9490 - 95.2519		67.9633 - 104.4328	
Estimated WTP^2 and WTA^2	78.5153		69.4905	
90 % Confidence interval*	55.8523 - 210.8033		34.4698 - 92.3521	

*Calculated using Krinsky and Robb's Monte Carlo (1986) simulation technique.

Table 3 summarizes the WTP and WTA values from the SB and OOH models. The pervasiveness of high WTA/WTP ratios has sustained interest in the WTP-WTA divergence issue for at least 3 decades. Horowitz and McConnell extensively reviewed and analyzed WTP/WTA studies and revealed an average WTA/WTP ratio of 7.17 for all goods (minimum 0.74 and maximum 112.67), a 10.41 ratio for public or non-market goods, a 10.06 ratio for health and safety goods, and a 2.92 ratio for ordinary private goods. They also found that ratios in real experiments are not significantly different from hypothetical experiments. Our WTA/WTP ratios in both the SB (1.05 ratio) and the OOH (1.08 for first bid and 0.89 ratio for second bid) models are significantly lower than average WTA/WTP ratios analyzed by Horowitz and McConnell (2002). Hanemann (1991) pointed out that large empirical divergences between WTP and WTA may be indicative not of some failure in the survey methodology but of substitution effects. But our results are in sharp contrast to the findings of Shogren et al., using the Vickrey auction, which reported differences between WTP and WTA in the range of threefold to fivefold for a number of pathogens. Consequently, they concluded that for non-market goods with imperfect substitutes (a good similar to ours which provides reduced risk from food-borne pathogens), WTP and WTA measures are significantly different, even after repeated market participation. It is not clear why our WTA/WTP ratios are lower but it may be due to the nature of the experiments we conducted using real products, cash, and actual exchange in a market setting. In addition, the elicitation questions used in our study are closed-ended, which are considered incentive compatible (IC) and tend to yield lower WTA/WTP ratios than non-closed-ended questions (Horowitz and McConnell 2002). Also, the respondents in our survey are from the "general public" in a real market environment, not college undergraduates that many experiments use.

Table 3. Summary of WTP and WTA Estimates from the Models

	Single Bounded Model		One and One-Half Bounded Model			
	WTP	WTA	WTP[1]	WTA[1]	WTP[2]	WTA[2]
Point Estimate	76.969	81.566	75.439	81.634	78.515	69.490
WTA/WTP Ratio	1.059		1.082		0.885	

Concluding Remarks

Despite all the efforts to make our food supply safe, there were 66 recalls for Listeria or E. coli contaminated beef, pork and poultry in 2002, totaling approximately 60 million pounds of meat - nearly three times as much as the prior year. The largest of these recalls involved about 27 million pounds of food product and cost $81 million, not including litigation costs (Food Irradiation Update 2003). While the HACCP Rule for all meat and poultry plants currently in place requires that certain standards be met throughout the industry, it does not explicitly promote any particular antibacterial intervention and thus allows the plant some flexibility in its compliance decisions. Food irradiation can lower the risk to plants of being non-compliant with the regulation and also could reduce the costs associated with product recall and increase the value of beef if consumers value the additional risk reduction by applying the technologies (Fingerhut et al. 2001). The realization of these benefits of food irradiation, however, would depend on consumers' acceptance of the technology.

Scant information, however, is available related to consumers' WTP or WTA irradiated foods. Our findings suggest that consumers are willing to accept and pay more for irradiated food. Our results indicate that average willingness to pay values range from 75.43 to 78.51 cents per pound while average willingness to accept values range from 69.49 to 81.63 cents per pound of irradiated ground beef. The USDA estimates that irradiated ground beef will cost 13 to 20 cents more per pound than non-irradiated ground beef because of the additional handling and packaging, the cost of irradiation itself, and post-irradiation testing for pathogens (Food Irradiation Update 2003). At these cost estimates, our WTP and WTA estimates easily cover the additional costs for commercial scale irradiation.

These results imply that consumers are willing to bear the cost associated with food irradiation and that food processors and retailers could consider selling irradiated ground beef. Fingerhut et al. (2001) also found strong consumer preference in their study of beef treated by irradiation. They suggested that food irradiation technology might be the most appropriate technology for some beef packers to invest in, provided that consumer concern about irradiation technology can be reduced. In fact, albeit still relatively small in numbers, more and more retailers are now selling irradiated ground beef. The number of supermarket stores that offer irradiated meat products has increased dramatically from 84 in mid-June 2000 to about 7,000 stores from some 50 retail-chains in April 2003. In addition, some 2,000 restaurants, including those belonging to a major fast food chain, are now serving irradiated meat in the U.S. More efforts are still needed though in educating consumers about the irradiation process to increase their acceptance of this technology. Consumer acceptance of the irradiation can be influenced by knowledge and information about the technology (Bruhn 1995; Lusk, Fox, and McIlvain 1999; Aiew, Nayga, and Nichols 2003).

Given our subject pool, the next step should be to apply our methodology across a larger cross-section of the U.S. population, both geographically and socio-economically. In addition, the La Chatelier principle suggests that our WTP estimates represent a measure of the upper end of the distribution of food safety preferences (Hayes et al. 1995). Hence, future research should explore other design features or alternative elicitation methods to further test the robustness of our findings. For example, future research should assess whether our results can be confirmed with experimental auction exercises or actual supermarket trials. Future research should also evaluate the possible effect of the "novelty" of the product on consumers' willingness to pay. In our study, some subjects may have been willing to pay more for irradiated ground beef because it is new and that they would like to try it. This is sometimes referred to in the literature as "preference learning". Preference learning or novelty effects exist if subjects' are willing to pay a high premium for a good because they wanted to learn about an unfamiliar good they had not previously consumed. If this is the motive, then we hypothesize that the willingness to pay will likely decline as the novelty wears off. It is also possible that some consumers have a negative WTP for irradiated foods. Very few in our sample indicated a negative WTP but future studies should not neglect this possibility.

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