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ABSTRACT

This study examines consumer willingness to pay for irradiated beef products. About 58 percent of the respondents are willing to pay a premium for irradiated beef. An ordered probit with sample selection model was estimated. Standard errors of the marginal effects of the ordered probit model were estimated using the bootstrap method. Our findings suggest that females and those who think that improper handling contributes to food poisoning are more likely to pay a premium of 50 cents per pound of irradiated beef than others. Those who trust the irradiation technology are also more likely to pay a premium of between 5 to 25 cents per pound for irradiated beef. Supply chain implications are discussed.

Keywords: Consumer Behavior, Food Chain, Food Irradiation, Willingness to Pay

INTRODUCTION

The Centers for Disease Control and Prevention estimates that 76 million people get sick, more than 300,000 are hospitalized, and 5,000 Americans die each year from foodborne illness. Research over the past 40 years has shown, however, that food irradiation can decrease the incidence of foodborne illness and disease. Despite this benefit, food irradiation has been the focus of much controversy for years. Proponents of irradiation claim that it will improve food safety by reducing harmful bacteria. Opponents, on the other hand, raise concerns about its long term health effects, nutrient loss, and worker safety at irradiation facilities (Sapp et al., 1995). The debate intensified recently when the U.S. government approved the use of irradiation to kill E. coli 0157:H7 and other harmful bacteria in ground beef and other raw meat. The US Department of Agriculture and the Food and Drug Administration are also expected to decide soon whether to allow the process to be used on sandwich meats, hot dogs, and similar packaged food products.

This article reports findings from a survey that examined the factors affecting consumers' willingness to pay for irradiated beef products using an ordered probability model with sample selection. The second and third sections discuss the survey methodology and the overview of the empirical model used in the analysis. The fourth section presents the findings. The fifth section presents the concluding remarks and discusses the supply chain implications of the findings.

DATA

Personal intercept interviews were conducted at three cities in Texas in spring 2001: Austin, Houston, and San Antonio. About 100 persons were randomly chosen in selected HEB stores, a regional supermarket chain based in Texas, in each of these cities. These cities were chosen because of the diversity of their population base. A total of 300 consumers participated in the study. However, due to non-responses in some of the questions, only data from 270 consumers were used in the analysis. The survey questionnaire included questions related to consumers' willingness to pay for irradiated beef products. Respondents were asked how much they would pay more per pound for irradiated beef products knowing that food irradiation can help eliminate the threat of foodborne illness or disease. As an incentive, respondents were provided $5 HEB coupons.

EMPIRICAL MODEL

The empirical framework for the analysis coincides with principles of general systems theory, which takes a holistic approach to explaining relationships between psycho-social and consumer characteristics and human behavior (Jackson and Noel 1992). In this framework, it is assumed that consumers' decisions on willingness to pay for irradiated beef products are made in two stages. First, consumers decide whether or not to pay a price premium on irradiated beef, and second, once the product is deemed desirable, they decide how much more money they are willing to pay for irradiated beef products. In accordance with previous research, these two decisions are assumed to be effected by factors related to consumers' (1) prior knowledge of food irradiation, (2) level of trust on the technology/process, (3) attitudes and concerns about the technology/process, (4) perceived risks of eating irradiated foods, and (5) demographics.

The list and definitions of the variables used in the models are exhibited in Table 1. Two variables were included to reflect consumers' prior knowledge or familiarity with the technology (*familiar, impt, label,* and *aware*). Malone (1990) found that prior knowledge of irradiation significantly affected willingness to purchase irradiated food. It is hypothesized that respondents who are more familiar with food irradiation are more likely to pay more for irradiated beef products. The variables included to reflect consumers' level of trust on the technology and the various entities are *negative, neutral, govt, univ, med* and *trust*. Trust has received much attention recently in both business-management and economics literature. Supply chain strategic alliances have been analyzed in terms of the trust or lack of trust among parties. However, little work has been done to determine the effect of consumers' level of trust and their willingness to accept products produced from technologies (Batista, Morrow, and Trejo 2000).

Table 1. Variable definitions and their descriptive statistics

Variable	Variable Definition	Mean	Std. Dev.	Min	Max
PAY	1 if individual is willing to pay more for irradiated beef; 0 otherwise	0.578	0.495	0	1
FEMALE	1if female; 0 otherwise	0.596	0.492	0	1
FREQSHOP	1 if individual grocery shops at least twice a week; 0 otherwise	0.626	0.485	0	1
FAMILIAR	1 if individual is familiar with food irradiation; 0 otherwise	0.478	0.500	0	1
IMPT	Perceived importance of food irradiation on food safety	9.067	1.866	1	10
LABEL	1 if labeling of irradiated foods is important to individual; 0 otherwise	0.589	0.493	0	1
NEGATIVE	1 if individual considers food irradiation label as a symbol of warning and avoid it; 0 otherwise	0.233	0.424	0	1
NEUTRAL	1 if individual has a neutral reaction to food irradiation labels; 0 otherwise	0.122	0.328	0	1
HANDLING	Perceived contribution of improper handling to food poisoning	9.182	1.616	1	10
PRICE	Degree of price increase concerns due to food irradiation	6.167	3.100	1	10
AWARE	1 if individual considers herself/himself sufficiently informed about the food irradiation process; 0 otherwise	0.126	0.332	0	1
GOVT	1 if individual trusts government the most to endorse food irradiation; 0 otherwise	0.256	0.437	0	1
UNIV	1 if individual trusts university researchers and scientists the most to endorse food irradiation; 0 otherwise	0.237	0.426	0	1
MED	1 if individual trusts medical organizations the most to endorse food irradiation; 0 otherwise	0.185	0.389	0	1
TRUST	1 if individual trusts irradiated products; 0 otherwise	0.600	0.491	0	1
IMMRISK	1 if individual thinks that consuming irradiated food causes immediate health risk ; 0 otherwise	0.211	0.409	0	1
FUTRISK	1 if individual thinks that consuming irradiated food causes only future health risk; 0 otherwise	0.448	0.498	0	1
AGE1	1 if individual's age is from 18 to24; 0 otherwise	0.111	0.315	0	1
AGE2	1 if individual's age is from 25 to 34; 0 otherwise	0.204	0.404	0	1
AGE4	1 if individual's age is at least 55; 0 otherwise	0.193	0.395	0	1
CHILDREN	1 if individual has children under 18 in household; 0 otherwise	0.430	0.496	0	1
BLACK	1 if individual is African-American; 0 otherwise	0.104	0.305	0	1
HISP	1 if individual is Hispanic; 0 otherwise	0.200	0.401	0	1
OTHRACE	1 if individual is not Caucasian, African-American, or Hispanic; 0 otherwise	0.111	0.315	0	1

MARRIED	1 if individual is married; 0 otherwise	0.574	0.495	0	1
HIGHSCHL	1 if individual has at most some high school education; 0 otherwise	0.111	0.315	0	1
COLLEGE	1 if individual has at most some college education; 0 otherwise	0.396	0.490	0	1
GRAD	1 if individual has at a graduate degree; 0 otherwise	0.178	0.383	0	1
PARTTIME	1 if individual is employed part time; 0 otherwise	0.156	0.363	0	1
UNEMPLOY	1 if individual is unemployed; 0 otherwise	0.196	0.398	0	1
INCOME2	1 if individual's household income is between \$30,000-\$49,999; 0 otherwise	0.315	0.465	0	1
INCOME3	1 if individual's household income is between \$50.000-\$99,999; 0 otherwise	0.137	0.345	0	1
INCOME4	1 if individual's household income is at least \$100,000; 0 otherwise	0.126	0.332	0	1
SANANTON	1 if individual was interviewed in San Antonio; 0 otherwise	0.341	0.475	0	1
HOUSTON	1 if individual was interviewed in Houston; 0 otherwise	0.319	0.467	0	1

The variables *handling, price, immrisk*, and *futrisk* are the variables included to represent consumers' attitudes and concerns regarding food safety and the technology. Consumers' perceived risks have been found to affect the acceptance or rejection of new technologies (Sapp, Harrod, and Zhao 1995). Previous polls have showed that consumers are concerned about the proven safety of food irradiation (Weise Research Associates 1984; Food Marketing Institute 1988).

The demographic and individual consumer characteristics included in the models are gender, frequency of grocery shopping, age, presence of children, ethnicity, marital status, education, employment, and income. It is common practice to incorporate participants' demographics into consumer willingness to pay models. Blackburn et al. (1994), Fox (2000), Fox et al. (1998), Nayga (1996), Roosen et al. (1998), Shogren et al. (1994), and Lusk et al. (1999), among others, have all included demographic variables in their models. In addition to these variables, dummy variables for the different survey locations are included in the model. With the exception of a higher percentage of Hispanics, people with graduate degrees, and the unemployed, the sample is representative of the national population.

ESTIMATION

The respondents were initially asked whether or not they would be willing to pay a price premium for irradiated beef. About 58 percent of the respondents indicated that they would be willing to pay a premium for irradiated beef. These respondents were in turn asked how much they are willing to pay more per pound of irradiated beef. Respondents were provided various choices represented in cents per pound instead of an open-ended question. Hence, the responses can be ordered by the level of willingness to pay a premium in cents per pound. An actual figure is observed only if the individual decides to pay a price premium. In addition, since numerous respondents indicated that they would not pay a premium for irradiated beef, combining this group of consumers with those who are willing to pay a premium will produce sample selection bias. Since the decision to pay a premium or not is based on individual self-selection, it is likely that those individuals who are willing to pay more for irradiated beef have systematically different characteristics from those who are not willing to pay more for irradiated beef. This sub-sample heterogeneity is econometrically problematic when unobserved characteristics are distributed differently across those who are willing and those who are not willing to pay a premium for irradiated beef. These unobserved variables may influence both the binary willingness to pay decision and the amount the individuals are willing to pay a premium. Hence, an ordered probit model with sample selection is used to estimate the model discussed above. The ordered probit model involves a qualitative dependent variable for which the categories have a natural order or ranking that reflects the magnitude of some underlying continuous variable or index. This model is based on the following specification:

$$
\begin{aligned}
y_i^* &= \beta' x_i + \varepsilon_i,\ \varepsilon_i \sim N[0,1], \\
y_i &= 0 \text{ if } y \le \mu_0, \\
&\quad 1 \text{ if } \mu_0 < y \le \mu_1, \\
&\quad 2 \text{ if } \mu_1 < y \le \mu_2, \\
&\quad \dots \\
&\quad J \text{ if } y > \mu_{J-1}.
\end{aligned}
\tag{1}
$$

The variable y^* is an unobservable index and x is a vector of independent variables. The observed counterpart to y^* is y. The μ's are unknown "threshold" parameters that are estimated along with the other parameters in the model. In this study, J is equal to 7, with y values specified as:
y = 0 if willingness to pay a price premium is equivalent to 5 cents per pound;
y = 1 if willingness to pay a price premium is equivalent to 10 cents per pound;
y = 2 if willingness to pay a price premium is equivalent to 15 cents per pound;
y = 3 if willingness to pay a price premium is equivalent to 25 cents per pound;
y = 4 if willingness to pay a price premium is equivalent to 30 cents per pound;
y = 5 if willingness to pay a price premium is equivalent to 40 cents per pound;
y = 6 if willingness to pay a price premium is equivalent to 50 cents per pound; and
y = 7 if willingness to pay a price premium is equivalent to 100 cents per pound.
The question was phrased as "how much more would you pay per pound for irradiated beef products if you knew that they help eliminate the threat of food borne bacteria".

The probabilities of observing y, given x can be expressed as:

$Pr(y=0) = \Phi(-\beta'x)$,
$Pr(y=1) = \Phi(\mu_1-\beta'x) - \Phi(-\beta'x)$
$Pr(y=2) = \Phi(\mu_2-\beta'x) - \Phi(\mu_1-\beta'x)$
$Pr(y=3) = \Phi(\mu_3-\beta'x) - \Phi(\mu_2-\beta'x)$
$Pr(y=4) = \Phi(\mu_4-\beta'x) - \Phi(\mu_3-\beta'x)$
$Pr(y=5) = \Phi(\mu_5-\beta'x) - \Phi(\mu_4-\beta'x)$
$Pr(y=6) = \Phi(\mu_6-\beta'x) - \Phi(\mu_5-\beta'x)$
$Pr(y=7) = 1 - \Phi(\mu_6-\beta'x)$

From these probabilities, the likelihood function can be written as:

$L = \prod_{y=1}Pr(y=1) \prod_{y=2}Pr(y=2)\ldots. \prod_{y=7}Pr(y=7)$

Making appropriate substitutions, L can be written as:

$L = \prod_{y=1}\Phi(-\beta'x) \prod_{y=2}[\Phi(\mu_1-\beta'x) - \Phi(-\beta'x)]\ldots. \prod_{y=7}[1 - \Phi(\mu_6-\beta'x)]$

In log form, the log-likelihood function becomes:

$\ln L = \sum_{y=1}\log[\Phi(-\beta'x)] + \sum_{y=2}\log[\Phi(\mu_1-\beta'x) - \Phi(-\beta'x)] + \ldots + \sum_{y=7}\log[1 - \Phi(\mu_6-\beta'x)]$

The marginal effects of the independent variables on the probabilities are not identical to the coefficient estimates and depend on the values of all independent variables. The marginal effects of the variables are calculated for each of the probabilities:

$$\partial \mathrm{Prob}[\text{cell } j]/\partial x_i = \left[f\left(\mu_{j-1} - \beta' x_i\right) - f\left(\mu_i - \beta' x_i\right)\right] \times \beta \qquad (2)$$

where f(.) is the standard normal density. For dummy variables, the marginal effects are computed as the difference of the two resulting probabilities when the dummy variable takes its two values 0 and 1. Standard errors of the marginal effects are calculated using the 500 independent bootstrap samples, each consisting of 270 data values drawn with replacement from the data used in the analysis.

The model is extended to handle sample selection by adding a selection mechanism:

$$\begin{aligned} d &= \alpha' z_i + u_i, \\ u_i, \varepsilon_i &\sim N_2[0,0,1,1,p], \\ d_i &= 1 \text{ if } d > 0 \text{ and } 0 \text{ otherwise,} \end{aligned} \qquad (3)$$

i.e., the univariate probit model applies to d_i (1 if respondent is willing to pay a price premium and 0 if not), and, finally, y_I is observed if and only if d_I =1. If □ and u are correlated, estimation of the ordered probit model ignoring d will suffer from biases similar to those in the regression case. In the sample selection model, [□,u] are assumed to have a bivariate standard normal distribution with correlation p. Estimates are obtained by maximum likelihood.

EMPIRICAL RESULTS

The results for the binary willingness to pay probit equation are reported in Table 2. Specifically, results indicate that female respondents are about 28 percent more likely to pay more for irradiated beef than males. Indeed, when the data are cross-tabulated between gender and the decision to pay a price premium, the numbers indicate that 63.5 percent of those who are willing to pay a price premium are females. In addition, 61.5 percent of the female respondents, which comprise about 60 percent of the whole sample, are willing to pay a price premium compared to only 52.3 percent of the male respondents. This result may be related to Nayga's (1997) finding that females are more nutrition and health conscious than males. This finding, however, is not consistent with previous consumer studies on food irradiation. Sapp et al. (1995) found that males had a higher opinion about food irradiation but were not statistically more likely to eat irradiated foods than were women. Schutz et al. (1989) also found that women showed a higher level of concern about food irradiation than did men. These studies, however, may no longer represent current market conditions.

Table 2. Parameter estimates of the probit equation

Variable	Coefficient	Standard Error	Marg. Effect
Constant	-2.277*	0.884	-0.871
FEMALE	0.728*	0.224	0.278
FREQSHOP	-0.216	0.221	-0.083
FAMILIAR	-0.184	0.225	-0.07
IMPT	0.011	0.060	0.004
LABEL	-0.192	0.217	-0.073
NEGATIVE	-0.748*	0.278	-0.286
NEUTRAL	-0.232	0.297	-0.089
HANDLING	0.241*	0.069	0.092
PRICE	-0.092*	0.034	-0.035
AWARE	0.508	0.352	0.194
GOVT	-0.245	0.264	-0.094
UNIV	0.497*	0.279	0.19
MED	-0.070	0.293	-0.027
TRUST	1.239*	0.242	0.474
IMMRISK	-0.151	0.286	-0.058
FUTRISK	-0.365	0.225	-0.14
AGE1	0.035	0.362	0.013
AGE2	-0.224	0.276	-0.086
AGE4	0.235	0.311	0.09
CHILDREN	-0.388*	0.235	-0.148
BLACK	0.248	0.357	0.095
HISP	0.841*	0.308	0.322
OTHRACE	0.607*	0.331	0.232
MARRIED	0.100	0.229	0.038
HIGHSCHL	-0.011	0.381	-0.004
COLLEGE	-0.309	0.260	-0.118
GRAD	-0.307	0.311	-0.118
PARTTIME	0.240	0.293	0.092
UNEMPLOY	0.154	0.297	0.059
INCOME2	0.014	0.232	0.005
INCOME3	0.097	0.353	0.037
INCOME4	0.347	0.350	0.133
SANANTON	0.077	0.258	0.029
HOUSTON	0.432*	0.262	0.165
% RIGHT PREDICT.	78.1		

Those who would consider a food irradiation label as a symbol of warning are about 29 percent less likely to pay a price premium for irradiated beef than those who consider food irradiation an assurance of safety and quality. Indeed, the survey data indicate that 68.3 percent of the respondents who would consider a food irradiation label as a symbol of warning are not willing to pay a premium. Respondents who think that improper handling of food contributes to outbreaks of food poisoning are about nine percent more likely to pay more for irradiated beef. This result is of some importance since Schafer found that motivation to practice safe handling behavior requires a belief that the individual could be personally harmed by not doing so, and that new behavior could have a positive impact on preventing foodborne disease.

Those who are concerned that prices will increase due to irradiation are 3.5 percent less likely to pay more for irradiated beef than others. Those who trust university researchers and scientists the most to endorse food irradiation are 19 percent more likely to pay a premium for irradiated beef than others. Respondents who trust the food irradiation technology are about 47 percent more likely to pay more for irradiated beef than those who do not trust food irradiation. Survey data show that roughly 76 percent of the respondents who trust food irradiation are willing to pay a premium and about 79 percent of the respondents who are willing to pay a premium trust the technology. About 45.6 percent of the total sample indicated that they trust the technology and they are willing to pay a price premium for irradiated beef.

Interestingly, respondents with children under 18 years of age are about 15 percent less likely to pay a premium for irradiated beef than those without children in their household. The reason for this result is not clear. It is possible that fear of irradiation health effects overrides concerns for foodborne illnesses for those respondents with children in their household. However, when we calculated the cross-tabulation between the variables "negative" and "trust" versus the variable "children", we found that of those individuals who consider food irradiation label as a symbol of warning (which comprise about 23 percent of the sample), only 41 percent have children under 18. And only 22 percent of those who have children under 18 in their households (which comprise 43 percent of the sample) consider food irradiation label as a symbol of warning. This is an important topic for future research because children are at relatively high risks of foodborne illnesses and associated complications because of their undeveloped immune systems, lower body weights, and limited control over food safety.

Hispanics and those of other races (i.e., Asian-Americans and Pacific Islanders) are about 32 and 23 percent more likely to pay a premium for irradiated beef than whites, respectively. Respondents in Houston are 16.5 percent more likely to purchase irradiated beef compared to respondents from Austin. In terms of the marginal effects, the trust variable has the highest effect on the probability of paying a premium for irradiated beef. This may reflect the importance of education campaigns that inform consumers about the nature and benefits of food irradiation.

In the ordered probit equation, only five variables are included in the model due to the statistical insignificance of the other variables also included in the binary probit equation. The marginal effects of these variables and the corresponding bootstrapped standard errors are exhibited in Table 3. As expected, the magnitudes of the marginal effects of each variable are not identical across the different categories and the first few cases have the opposite signs from the estimated coefficients. Results, based on the statistically significant marginal effects, show that females are about nine percent more likely to pay a premium of 50 cents per pound for irradiated beef than males. The willingness to pay a premium of 50 cents per pound for irradiated beef is also higher for those who think that improper handling contributes to outbreaks of food poisoning. Consistent with prior expectations, those who trust irradiated beef are more willing to pay a premium for irradiated beef than those who do not trust irradiated beef. However, this is only true for premiums up to 25 cents per pound. Beyond 25 cents per pound premium, results imply that these individuals are no longer willing to pay that extra premium for irradiated beef. Interestingly as well, respondents in Houston are more likely to pay a premium of 50 cents per pound for irradiated beef than do respondents in Austin.

Table 3. Marginal effects and bootstrapped standard errors of ordered probit equation

Variable	y=0	y=1	y=2	Y=3	y=4	y=5	y=6	Y=7
Constant	-0.022 (0.040)[I]	-0.131 (0.158)	-0.060 (0.067)	-0.201 (0.195)	0.091 (0.095)	0.032 (0.035)	0.257 (0.248)	0.034 (0.091)
FEMALE	-0.008 (0.012)	-0.047 (0.038)	-0.021 (0.016)	-0.071 (0.053)	0.032 (0.025)	0.011 (0.009)	0.091* (0.045)	0.012 (0.013)
HANDLING	-0.003 (0.005)	-0.020 (0.015)	-0.009 (0.007)	-0.031 (0.023)	0.014 (0.010)	0.005 (0.003)	0.039* (0.021)	0.005 (0.006)
TRUST	0.020* (0.010)	0.120* (0.046)	0.055* (0.027)	0.183* (0.111)	-0.083* (0.036)	-0.029* (0.017)	-0.235* (0.111)	-0.031 (0.042)
SANANTON	-0.002 (0.010)	-0.010 (0.035)	-0.005 (0.014)	-0.016 (0.044)	0.007 (0.021)	0.003 (0.007)	0.020 (0.051)	0.003 (0.014)
HOUSTON	-0.011 (0.016)	-0.066 (0.047)	-0.030 (0.023)	-0.101 (0.066)	0.045 (0.031)	0.016 (0.011)	0.129* (0.055)	0.017 (0.020)

[I] Numbers in parentheses are the bootstrapped standard errors of the marginal effects.

CONCLUDING REMARKS AND IMPLICATIONS FOR THE SUPPLY CHAIN

Despite the high level of safety in the US food supply, microbiological hazards exist. Illnesses and death due to foodborne pathogens costs society billions of dollars due to lost productivity and medical expenses. Processing by irradiation enhances food safety through the reduction of potential pathogens in raw meat and poultry products, thus reducing the likelihood of illness from cross contamination or inadequate cooking. Our study investigated consumers' willingness to pay a premium for irradiated beef. Our results indicate that close to 60 percent of our respondents have indicated a willingness to pay a premium for irradiated beef. This is consistent with recent Centers for Disease Control estimates. Our findings also reveal the profile of consumers who are most likely to pay more for irradiated beef: females, those who consider food irradiation as an assurance of safety and quality, those who think that improper handling contributes to food poisoning, those who are less concerned about price increases due to food irradiation, those who trust university researchers/scientists the most to endorse food irradiation, those who trust the irradiation technology, those without children under 18 years of age in their household, Hispanics, Asian-Americans, and Pacific Islanders.

Regarding the amounts of premium consumers are likely to pay, our findings suggest that females, those who think that improper handling contributes to food poisoning, and our Houston respondents are more likely to pay a premium of 50 cents per pound of irradiated beef than others. Those who trust the irradiation technology are also more likely to pay a premium of between 5 to 25 cents per pound for irradiated beef.

The food industry is now an interconnected system with a large variety of complex relationships. Hence, business strategies must now focus not only on traditional economical and technological aspects of food demand but also on issues such as safety and healthfulness of food products. The results of this study provide information important to not only food retailers but also to other players in the supply chain (i.e., manufacturers, processors, distributors, and producers) because production and distribution systems in the supply chain must comply with consumer demand and regulatory issues such as food safety. For example, the general findings of this study can be used as a guide by the supply chain/network in targeting specific consumers. Distribution and marketing efforts could be directed at consumers who are willing to buy and pay a premium for irradiated beef products. A secondary strategy could be to target and educate those consumers who are less willing to purchase irradiated beef products to increase exposure of the product as well as to broaden the consumer base. Hence, the information derived from this study could help the supply chain respond to anticipated or expected market/demographic changes in the future. Although the results of this study are US specific, they may have some important implications and applications to other countries that are experiencing similar consumer demand issues.

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