Attitudes, Acceptance, and Consumption: The Case of Beef Irradiation

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Food contamination by microorganisms, such as pathogenic bacteria and parasites, causes serious public-health problems and economic losses. According to the U.S. Public Health Service, each year pathogenic bacteria cause 6.5 to 8.1 million cases of diarrhea diseases in the U.S. Moreover, there are about 9000 deaths as a result of diarrhea diseases related to pathogenic bacteria (Farkas 1998; Lee 1994). The consequent economic loss is enormous due to medical costs, loss of productivity, loss of business, and possible legal-action costs (Farkas 1998; Todd 1989; Buzby 1996). Sometimes the economic consequence of a food-contamination-related disease outbreak can be so tremendous that it can destroy a product brand name and cause the closure of several companies (Adams 2000).

The problem of food contamination is especially severe with food products of animal origin (Farkas 1998). In past decades, multiple outbreaks of *E. coli* illnesses, principally resulting from consuming hamburger meat, caused many deaths and permanent injuries (Adams 2000), and have shaken the American public's confidence in the safety of their food supply. And among all kinds of meat and meat products, beef contamination has caused the most severe public-health problem and perhaps the greatest economic loss. The number of outbreaks, incidents, and recall of beef is much higher than that of other kinds of meat. In 1998, out of a total of 44 recalls of meat products, at least 25 were related to beef while only 8 were related chicken.

Food-poisoning events due to contamination by microorganisms have aroused public's concerns about food safety. The adequacy and capacity of traditional food processing and preserving technology to guarantee a safe food supply are questioned, and efforts have been made to invent new food processing and preservation technology. One of the many alternatives proved to be effective in reducing food contamination is irradiation. According the Food and Drug Administration (FDA) of the United States and the World Health Organization (WHO), irradiation can effectively kill microorganisms in food and hence reduce contamination. Furthermore, if conducted properly, it will not adversely affect the nutritional quality of food.

In response to the multiple outbreaks of *E. coli* illnesses, food-safety experts and food processors began to consider meat irradiation. The National Food Processors Association (NFPA) and the American Meat Institute (AMI) have been instrumental in the advancement of the approval of meat irradiation (Adams 2000). The FDA approved in December 1997 the use of irradiation to kill harmful bacteria in beef (Adams 2000), and fifteen months later the USDA published its proposed rule, in February 1999. The approval of beef irradiation by the FDA was followed by the American meat industry's keen interest in learning about the technology; most major suppliers and users have tested at least some of their ground beef products to gain an understanding of the effects of the process (Adams 2000).

Efforts have been made at an international level by the Food and Agricultural Organization of the United Nations (FAO), WHO, and the International Atomic Energy Authority (IAEA) to promote food irradiation (Henson 1995). In the United States, however, promotion of the application of food irradiation has not accomplished much due to consumer resistence. Now it is widely recognized that promotion of food irradiation can be successful only when consumer acceptance is enhanced. But enhancement of acceptance can be effective only when we have information on consumer desire for food irradiation and understand the factors affecting their acceptance of this food-processing technology. This study analyzes consumer assessment of the desirability of beef irradiation, using data from a nationwide consumer survey. Efforts are also made to investigate consumer attitudes toward irradiated beef and to address the issue of inconsistent responses in the survey.

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Econometric model

Consumer assessment of the desirability of a good or service is inherently ordered, such as ranking from "not desired" to "very desired." In this study, consumer assessment of the desirability of beef irradiation is measured using five scales from "not necessary at all" to "very necessary." Taking the categorical and ordered nature of the dependent variable into consideration, an ordered probit model is appropriate for this study (Maddala 1984). We follow Greene in the development of the framework.

The ordered probit model is based on a latent regression model. Let y_i^* be a latent response variable related to the categorical response of the ith respondent, then, a latent regression model can be specified as

1) $y_i^* = x_i \beta + \varepsilon_i$,

where x_i is a vector of explanatory variables; β is a vector of regression parameters to be estimated; and ε_i is the disturbance term which is independently, identically, and normally distributed with a zero mean and unit variance. Let y_i be an indicator variable which can take different integer values depending on consumer response; the relationship between y_i and y_i^* can then be specified as

$$
\begin{aligned}
y_i &= 0 \text{ if } y_i^* < \mu_1, \\
&= 1 \text{ if } \mu_1 \le y_i^* < \mu_2, \\
2) \quad &= 2 \text{ if } \mu_2 \le y_i^* < \mu_3, \\
&= 3 \text{ if } \mu_3 \le y_i^* < \mu_4, \\
&= 4 \text{ if } \mu_4 \le y_i^*,
\end{aligned}
$$

where the μs, a vector of unknown parameters to be estimated with β, are the categorical thresholds determining what value of y_i a given value of y_i^* will map into. It is assumed that $\mu_1 < \mu_2 < \mu_3 < \mu_4$ so the probability that y_i falls in any of the categories is nonnegative (Greene 1993).

Suppose the respondents in the survey were given the opportunity to choose from a set of integers ranging from 0 to 1000 to indicate their assessment of the desirability of a good or a service, with 0 indicating not desirable at all and 1000 indicating most desirable. The responses can be widely scattered. When they were asked to choose one category from the given five alternative categories, the best they can do is to select the category that best represents their perceived desirability of the good or service.

At least conceptually, the more choices, the more accurate the stated measurement; having fewer choices implies potential censoring. Hence Eequation (2) exhibits a form of censoring (Greene 1993). With the desirability of beef irradiation denoted by 0, 1, 2, 3, or 4, the probability that y_i will take any of these values can be expressed as

$$
\begin{aligned}
\text{pr}(y_i = 0) &= \Phi(\mu_1 - x_i \beta), \\
\text{pr}(y_i = 1) &= \Phi(\mu_2 - x_i \beta) - \Phi(\mu_1 - x_i \beta), \\
3) \quad \text{pr}(y_i = 2) &= \Phi(\mu_3 - x_i \beta) - \Phi(\mu_2 - x_i \beta), \\
\text{pr}(y_i = 3) &= \Phi(\mu_4 - x_i \beta) - \Phi(\mu_3 - x_i \beta), \\
\text{pr}(y_i = 4) &= \Phi(x_i \beta - \mu_4),
\end{aligned}
$$

where Φ denotes the standard normal cumulative-distribution function. The ordered probit is usually estimated using the maximum-likelihood method. With the probability distribution so specified, the log-likelihood function for the ordered probit model can be expressed as

$$
\begin{aligned}
\ln L = &\sum_{y_i=0} \ln(\Phi(\mu_1 - x_i \beta)) \\
&+ \sum_{y_i=1} \ln(\Phi(\mu_2 - x_i \beta) - \Phi(\mu_1 - x_i \beta)) \\
4) \quad &+ \sum_{y_i=2} \ln(\Phi(\mu_3 - x_i \beta) - \Phi(\mu_2 - x_i \beta)) \\
&+ \sum_{y_i=3} \ln(\Phi(\mu_3 - x_i \beta) - \Phi(\mu_2 - x_i \beta)) \\
&+ \sum_{y_i=4} \ln(\Phi(x_i \beta - \mu_4)),
\end{aligned}
$$

where $\sum_{y_i=j}$ is the summation over the observations where the indicator variable "y" takes the value of j, j = 0, 1, 2, 3, 4. Parameter estimates are obtained by maximizing the log-likelihood function with respect to β and μ. Maximizing the likelihood function is straightforward and the maximum-likelihood estimators of the parameters have the asymptotic desirable properties.

Data and Survey

After the FDA's approval of beef irradiation in 1997, it became necessary to evaluate the feasibility of the adoption of this food-processing technology. An essential piece of information is consumer evaluation of the desirability of the use of irradiation to treat beef, because consumer acceptance is the key to the success of the adoption of a new food-processing technology. A nationwide telephone survey of 740 households on their assessment of beef irradiation was conducted in December 1997 and January

1998, aiming to obtain information on consumer perceptions of beef irradiation, their attitudes toward irradiated beef, and their willingness to pay for beef irradiation. To enhance the reliability of the survey, primary grocery shoppers of households were requested to complete the survey. Vegetarians were excluded from the survey. More than 93% of the respondents had the experience of purchasing beef at grocery stores. The respondents were asked questions in several broad sections. The data used in this study was mostly collected from the sections designed to obtain information on consumer assessment of the desirability of beef irradiation and their attitudes toward irradiated beef.

The survey results show that consumer desire for beef irradiation is strong. About 56% of the respondents think beef irradiation is necessary, more than 19% are either indifferent or unsure about their assessment, and roughly 25% think it is unnecessary. Acceptance of irradiated beef is also rather encouraging. About 55% would buy irradiated beef at the current market price for non-irradiated beef, around 31% would not buy it, and roughly 14% were unsure whether they would buy it or not. On the other hand, consumer attitudes toward irradiated beef are not so optimistic. When asked how they would react to a beef product labeled as irradiated, more than 30% of the respondents would consider it as a symbol of warning and avoid the product, less than 21% would consider it as assurance of quality

and safety and buy it, the rest would either be indifferent or unsure about their attitudes. The results show that consumption of irradiated beef may not substantially increase total demand for beef. Of those who would buy irradiated beef at the current market price, only about 5% would eat beef more often as a result of consuming irradiated beef. As for consumer willingness to pay, of those who would consume irradiated beef, about 60% were willing to pay a higher price for the product, roughly 32% were not willing to do so, and the rest were uncertain.

Of those who would consider a beef product labeled as irradiated as a symbol of warning and would avoid the product, more than 34% considered beef irradiation necessary. Furthermore, of those who would not buy irradiated beef at the current market price, about 39% indicated that beef irradiation is necessary. This is surprising, because if a consumer considers a label of irradiation as a symbol of warning and wants to avoid consuming irradiated beef, then he should not consider beef irradiation necessary.

Empirical Model and Estimation Results

An ordered probit model is specified to explore factors affecting consumer assessments of the desirability of beef irradiation. Table 1 presents a detailed description and summary statistics of the explanatory variables. Consumer demographic factors such

Table 1. Description and Mean Values of the Explanatory Variables.

Variable	Description	Mean (Exclusive model)	Mean (Exclusive model)
Age	Respondents' actual age.	48.4345	48.8903
Male	1 = male, 0 = female.	0.3122	0.3103
College	1 = have college education, 0 other wise.	0.3209	0.3025
Employed	1 = employed, 0 otherwise.	0.4301	0.4404
Lowinc	1 = less than $50,000, 0 otherwise.	0.4520	0.4545
Highinc	1 = $75,000 or more, 0 otherwise.	0.1463	0.1379
White	1 = white people, 0 otherwise.	0.8100	0.8025
Regulation	1 = considering the food safety regulations are neither adequate nor effectively enforced, 0 otherwise.	0.1943	0.2351

as age, gender, and education have been found to affect information acquisition in previous studies. Information acquisition may affect consumer perception about attitudes toward new food-processing technology. Hence demographic characteristics are hypothesized to be important factors affecting consumer assessment of food irradiation in this study. In addition to a set of demographic characteristics commonly used in food-consumption studies, a dummy variable representing consumers' lack of confidence in the adequacy and enforcement effectiveness of food-safety regulations is included in the model. The reason is that lack of confidence in the food-safety regulations may reflect lack of trust in the authoritative institutions formulating and enforcing the regulations. Lack of trust in food-safety authorities may affect consumer acceptance of food irradiation.

As stated before, response inconsistency has been found in the survey. How to treat those inconsistent responses in empirical estimation depends on the nature of the inconsistency, or on the driving force behind the inconsistency. But we are not quite sure about exactly what caused the response inconsistency. There are various plausible explanations for the inconsistency, such as frivolous response or misunderstanding of the relevant questions. In previous studies where no specific cause was identified to be responsible the response inconsistency, those inconsistent responses were excluded from the estimation (Ryan and San Miguel 2000). Ryan and San Miguel argued that if the demographic and economic characteristics of those giving inconsistent responses were not statistically different from that of the rest of the sample, exclusion of the inconsistent responses would not cause much trouble. In this study, those who have given inconsistent responses and the rest of the sample do not differ statistically regarding their demographic and economic characteristics. Hence we estimated a model in which the inconsistent responses were excluded (exclusive model). However, for the sake of comparison, we also estimated a model in which the inconsistent responses were included (inclusive model).

In the survey, some respondents were uncertain about their assessment or refused to answer the assessment question. These responses were dropped; the total observations in the inclusive model therefore is fewer than 740. The estimation results of both the inclusive model and the exclusive model are presented in Table 2. The results show that some factors have statistically significant effects in the exclusive model but not in the inclusive model, and vise versa. There are more variables statistically significant in the exclusive model than in the inclusive model and the value of the pseudo R^2 of the exclusive model is greater than that of the inclusive model, implying that the exclusive model is more appropriate.

Age is found to have a statistically significant

Table 2. Ordered Probit Estimation of Consumer Assessment of the Desirability of Beef Irradiation.

Variable	Coefficients and t-values (Exclusive model)	Coefficients and t-values (Inclusive model)
Constant	1.8948 (7.84)***	1.5467 (7.89)***
Age	-0.0051 (-1.76)*	-0.0071 (-3.05)***
Male	-0.2160 (-1.96)**	-0.1486 (-1.56)
College	-0.2317 (-1.87)*	-0.1202 (-1.17)
Employed	-0.0917 (-0.80)	-0.1631 (-1.76)*
Lowinc	0.1571 (1.32)	0.1310 (1.34)
Highinc	0.3152 (1.99)**	0.2286 (1.71)*
White	-0.0511 (-0.39)	-0.1429 (-1.34)
Regulation	0.0089 (.069)	-0.1305 (-1.34)
N	458	638
Pseudo R^2	0.0147	0.0128

t-values are in parentheses.
* denotes significant at the 0.1 level, ** denotes significant at the 0.05 level, *** denotes significant at the 0.01 level.

negative effect on consumer assessment of the desirability of beef irradiation. The effect may be due to age-related difference in attitudes toward health risk. It is assumed in previous studies that the rate of depreciation for good health increases with age; consequently, older consumers tend to be more risk-averse to food-safety issues than are younger individuals (Grossman 1972). The negative effect of age on attitudes toward risk have been discussed in previous studies. Ott and Maligaya (1989) found that older supermarket shoppers were more concerned about pesticide use in food production than were younger shoppers, while Misra and Huang (1991) observed a positive relationship between age and perceived risk of chemical residues in food. As for the assessment of beef irradiation, older consumers, being more risk-averse, are less likely to consider it necessary, due to imperfect information, especially the ungrounded message from advocates that consumption of irradiated food may do harm to health.

Gender is found to have a statistically significant negative effect on consumer assessment of the desirability of beef irradiation in the exclusive model, with female respondents being more likely to consider beef irradiation necessary. But gender effect is not statistically significant in the inclusive model. The gender effect may be due to task assignment within the household. In the United States, the majority of the main meal planners are females. As main meal planners of the household, they tend to pay more attention to food safety and hence may tend to consider it necessary to irradiate beef to enhance its safety level.

Education is found to have a negative effect on consumer assessment of the desirability of beef irradiation in the exclusive model, but not in the inclusive model. On the other hand, employment status is found to have a negative effect in the inclusive model, but not in the exclusive model. Income is found to have a positive effect in both the exclusive model and the inclusive model.

Conclusion

Despite scientific evidence for and professional attestation to the benefits and safety of the food irradiation, consumers in the United Sates are resistant to the adoption of this food-processing technology. Consumer resistance to food irradiation is affected by perceptions about this food-processing technol-
ogy. Hence gaining consumer acceptance requires a thorough understanding of factors affecting consumer perceptions about food irradiation. The information obtained in this study helps us better understand consumer attitude toward beef irradiation. Furthermore, knowledge about individual characteristics affecting consumer assessment of the desirability of beef irradiation is useful in enhancing consumer acceptance. Such knowledge can be used to effectively tailor needed information to specific groups of consumers with particular socioeconomic and demographic characteristics. Effective channeling of correct and needed information to consumers can help to dispel their ungrounded concerns about and remove their negative perception of beef irradiation, and hence reduce their resistance to beef irradiation.

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