Acceptance of Irradiated Beef and its Effect on Beef Consumption

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There is a growing body of scientific evidence attesting to the effectiveness of irradiation in killing harmful substances such as parasites and bacteria in food. Hence, food irradiation can enhance the safety level of food. Furthermore, if conducted properly, irradiation does not adversely affect the nutritional quality of food. The benefits of food irradiation are well recognized and efforts have been made at an international level by the World Health Organization (WHO) and Food and Agricultural Organization (FAO) to promote food irradiation.

In order to enhance the safety level of beef products, the U.S. Food and Drug Administration (FDA) approved in December 1997 the use of irradiation to kill bacteria and parasites in beef. The decision is primarily in response to the outbreaks of E. coli illness—principally due to consumption of hamburger beef—in the United States in the past decade, which have resulted in many deaths and permanent injuries. The approval of the FDA is based upon the recognition that beef irradiation is both effective and safe: effective in killing harmful substances in beef, and safe in that consumption of irradiated beef would not result in radioactivity related health problems.

Beef has been a staple food of American consumers for centuries. However, beef consumption has decreased gradually but steadily over the past two decades while consumption of chicken meat has increased substantially. Some researchers (Capps and Schmitz 1991) have attributed the decrease in beef consumption to structural changes in meat demand partly due to health consideration of nutrition contents of food, especially the fact that beef is very high in cholesterol. Some researchers (Anderson and Shugan 1991) think that market demand for use convenience has played a role in meat consumption. However, whether food-poisoning accidents such as E. coli illness substantially affect beef consumption remains largely unknown. Furthermore, no previous study has investigated whether beef irradiation, although effective in enhancing the safety level of beef, can increase the consumption of beef.

Promotion of irradiated beef has not accomplished much in the United States. The low rate of consumer acceptance is commonly considered to be a key factor in the unsuccessfulness of efforts to promote irradiated food. Enhancing consumer acceptance can be an effective method for promoting irradiated food, and enhancement of consumer acceptance can be effective only when we understand the factors that affect consumer acceptance. Insights about the factors affecting consumer acceptance can help to better understand and exploit the market for irradiated beef. This study explores factors influencing consumer acceptance of irradiated beef and investigates whether consumption of irradiated beef can increase the total market demand for beef.

Econometric Models

The filter approach was used to obtain information on consumer acceptance of irradiated beef and on the effect of consumption of irradiated beef on total beef demand. The advantage of the filter approach has been discussed thoroughly in many studies (Sterngold, Warland, and Herrmann 1984; Huang, Kan, and Fu 1999). First, respondents were asked whether or not they would purchase irradiated beef ("participation") if irradiation would reduce the number of beef recalls but not change its taste or price. Conditional on his participation in the consumption of irradiated beef, a respondent was then asked whether he would consume beef more frequently ("consumption"). Hence it is implied that for some consumers it is a one-stage binary-choice decision, while for others it is a two-stage decision process. If a consumer decides not to participate in the consumption of irradiated beef, his decision is

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over. If a consumer decides to participate, he then goes on to make the decision whether or not to eat beef more frequently as a result.

Taking the nature of the data into consideration, a bivariate probit model with censoring is a candidate for this study. Bivariate probit models with censoring have been used to analyze data with partial observability. Meng and Schmidt discussed a bivariate probit model that exhibits a form of partial observability and Huang, Kan, and Fu (1999) extended the model to include a probit and a censored ordered probit to analyze consumer demand for food safety. Boyes, Hoffman, and Low (1989) developed a model consisting of a credit-granting and a loan-default equation to assess the probability of loan default, where only applicants who receive credits are observed either defaulting or repaying a loan. We follow Boyes, Hoffman, and Low (1989) in developing a bivariate censored probit model.

Let $y_1 = 1$ if a consumer would participate in the consumption of irradiated beef, 0 otherwise; and $y_2 = 1$ if a consumer would consume beef more frequently as a result of participating in the consumption of irradiated beef, 0 otherwise. For a specific consumer, y_2 is observed only when $y_1 = 1$. Two equations, representing participation in the consumption of irradiated beef and beef consumption frequency respectively, can be specified as

$$(1)\quad \begin{aligned} y_1 &= x_1\beta_1 + \varepsilon_1 \\ y_2 &= x_2\beta_2 + \varepsilon_2 \end{aligned}$$

where x_1 and x_2 are two vectors of explanatory variables, β_1 and β_2 are two vectors of parameters to be estimated, and ε_1 and ε_2 are the disturbance terms. The disturbance terms are jointly distributed as standard normal bivariate with a correlation coefficient ρ and a zero mean.

According to Boyes, Hoffman, and Low (1989) and Greene (1997), with the participation and consumption equations so specified the probabilities that y_1 and y_2 will take a value of 0 or 1 can be expressed as

$$(2)\quad \begin{aligned} &y_1 = 1\text{: prob}(y_1 = 1) = \Phi(\beta_1' x_1) \\ &y_1 = 0\text{: prob}(y_1 = 0) = 1 - \Phi(\beta_1' x_1) \\ &y_2 = 0, y_1 = 1\text{: prob}(y_2 = 0, y_1 = 1) = \Phi_2(\beta_1' x_1, -\beta_2' x_2, -\rho) \\ &y_2 = 1, y_1 = 1\text{: prob}(y_2 = 1, y_1 = 1) = \Phi_2(\beta_1' x_1, \beta_2' x_2, \rho) \end{aligned}$$

where $\Phi(.)$ denotes the univariate standard normal cumulative distribution function (CDF), and Φ_2 denotes the bivariate standard normal CDF. Based on these probabilities, the log-likelihood function for a sample of N observations can be expressed as

$$(3)\quad \begin{aligned} \ln L(\beta_1, \beta_2, \rho) = \sum_{i=1}^{N} & y_{i1}\, y_{i2} \ln\Phi_2(\beta_1' x_1, \beta_2' x_2, \rho) \\ & + y_{i1}(1 - y_{i2})\ln[\Phi(\beta_1' x_1) - \Phi_2(\beta_1' x_1, \beta_2' x_2, \rho)] \\ & + (1 - y_{i1})\ln[1 - \Phi(\beta_1' x_1)]. \end{aligned}$$

Estimates of the parameters can be obtained by maximizing the log-likelihood function with respect to β_1 and β_2. The joint-estimation approach, by accounting for potential correlation ρ between the two equations, corrects for possible sample-selection bias and gains-estimation efficiency over separate estimation of the two equations (Boyes, Hoffman, and Low 1989). However, if ρ is not statistically different from zero, the joint estimation approach may not offer any estimation gains.

Survey, Data, and Empirical Model

The data are from a nationwide telephone survey of U.S. consumers by the Survey Research Center of the University of Georgia. The survey was conducted in December 1999 and January 2000, three years after the approval of beef irradiation by the FDA. It was primarily designed to assess consumers' perception about and attitudes toward beef irradiation; consumers' acceptance of irradiated beef and their willingness to pay for beef irradiation; and consumption of meat products, including beef, chicken, and seafood. The survey instrument was designed by a group of agricultural economists and survey-design experts after a careful review of relevant literature on food irradiation.

In order to enhance the reliability of the information obtained from the survey, primary grocery shoppers of the households were requested to answer the questions. Vegetarians were excluded from the survey because the underlying good is meat products. More than 99% of the respondents ate meat at least once a week and more than 93% of them had the experience of purchasing beef in a grocery store.

Information was obtained on consumer willingness to consume irradiated beef. The respondents were told that, with respect to food poisoning, beef was not as safe as chicken, and in 1998 the number of recalls of beef products was more than three times as high as the number of chicken recalls. When asked whether they would buy irradiated beef if irradiation would reduce the number of beef recalls to that of chicken but would not change the price or taste of beef, about 55% of the respondents said yes. This rate of acceptance is encouraging given the evidence provided by previous studies that Americans are rather resistant to food irradiation.

In order to obtain information on whether consumption of irradiated beef would increase total demand for beef, those who would consume irradiated beef were then asked whether they would eat beef more often if irradiation could enhance the safety level of beef without changing its taste or price. About 5% of them indicated that they would eat beef more frequently as a result, implying that consumption of irradiated beef would increase total consumption of beef, but not substantially.

The number of outbreaks and incidents of food poisoning related to beef is the highest among all kinds of meat products. In 1998, recalls of beef products accounted for about 57% of the total recalls of meat products. A major source of food poisoning related to beef is the presence of bacteria. Information was obtained on how consumers concerned are with the presence of bacteria in beef as a factor leading to outbreaks of food poisoning. More than 78% of the respondents were very concerned with bacteria in beef as a source of food poisoning.

The survey results show that consumers are very concerned about possible side effects of food irradiation. About 40% of the respondents thought that irradiated beef has a higher level of radioactivity than does non-irradiated beef. Furthermore, although there is scientific evidence that consumption of irradiated food would increase health risks, about 25% even believed that consumption of irradiated beef would increase the risk of suffering from cancers.

Consumers' unnecessary concerns about possible side effects of food irradiation is mainly due to their lack of knowledge about the technology. This implies that lack of knowledge about food irradiation may affect acceptance and consumption of irradiated beef. When asked to rate their knowledge of the process of food irradiation, about 36% of respondents had never heard of food irradiation, about 27% had heard about the irradiation process but did not know anything about it, 31% were somewhat informed about the irradiation process but did not feel comfortable enough to make an assessment of it, and only a little more than 5% claimed to be sufficiently informed about the process to make an assessment.

Consumers' health conditions may affect food consumption, especially of a cholesterol rich food like beef. Overall, respondents were confident about their health condition—40% of them claimed to be in excellent health, about 46% claimed to be in good health, more than 10% thought they were fairly healthy, and only a little more than 1% were in poor health.

It is worth mentioning that about 70% of the respondents were females. This is because primary grocery shoppers of the households were required to complete the survey. A primary grocery shopper of a household tends to be the main meal planner of the household, and in the United States the majority of the main meal planners are females. This implies that the high percentage of female respondents does not imply a sample-selection bias.

Table 1 presents definitions and sample means of the variables used in the estimation. Conceptually, participation in the consumption of irradiated beef and its impact on total beef consumption could be affected by two different sets of determinants, as denoted in the econometric model by x_1 and x_2 respectively. Empirically, we have little theory leading to the differentiation between x_1 and x_2 and we had no basis to exclude any specific variables in either equation. We therefore include the same set of explanatory variables in both the participation and consumption equations.

Estimation Results

The participation and consumption equations are estimated jointly using the maximum-likelihood method. The estimated ρ, with a t-value of 0.17, was not statistically different from zero. The insignificant ρ indicates that ε_1 and ε_2 are not correlated. This implies that the joint-estimation approach may not offer any advantage over a separate-estimation approach. We then estimated the participation equation and the consumption equation separately. The results show that the joint-estimation approach did not result in any improvement of the parameter estimates. A rule of thumb in choosing among different econometric approaches is that if a more complicated method does not lead to any gain, the simpler one should be used. We therefore report the results from the separate estimation.

The estimation results from both the participation

Table 1. Definitions and Sample Statistics of the Explanatory Variables.

Variable	Definition	Mean
Age	Actual age of respondent.	49.95
Female	= 1 if respondent is a female; 0 otherwise.	0.69
Education	1 = less than high school, 2 = high school, 3 = some college education, 4 = college degree, 5 = graduate degree or professional.	3.11
White	= 1 if respondent is a white people, 0 otherwise.	0.81
City	= 1 if respondent lives in a city, 0 otherwise.	0.49
Inc1	= 1 if annual income is less than $25,000, 0 otherwise.	0.18
Inc2	= 1 if annual income is between $25,000 and $50,000; 0 otherwise.	0.25
Inc3	= 1 if annual income is between $50,000 and $75,000; 0 otherwise.	0.20
Radity	= 1 if respondent thinks irradiated beef has a higher level of radioactivity; 0 otherwise.	0.40
Cancer	= 1 if respondent thinks that consumption of irradiated beef may increase cancer risk; 0 otherwise.	0.25
Exelhlth	= 1 if respondent is in excellent health; 0 otherwise.	0.40
Bacteria	= 1 if respondent thinks bacteria is a major source of food poisoning; 0 otherwise.	0.77
Lacknow	= 1 if respondent never heard the irradiation process before or heard about it but knows nothing about it; 0 otherwise.	0.62

equation and consumption equation are presented in Table 2. The results show that some variables are important determinants in one equation but not in the other. Age was found to have a negative effect on participation but not on consumption. Age has been considered in previous studies to be an important factor affecting the acceptance of food irradiation. Older consumers are generally more risk-averse on food safety issues than are younger consumers (Grossman 1972; Nayga 1996). Despite the overwhelming body of scientific evidence attesting to the safety of food irradiation, many consumers remain concerned about the use of radiation in food processing due to the lack of knowledge on the wholesomeness of irradiated food (Farkas 1998; Bruhn 1998; Resurreccion et al. 1995). Being more risk-averse on food-safety issues, older consumers tend to be more reluctant in accepting irradiated food.

White people are more likely to participate in the consumption of irradiated beef than are nonwhites, but the race effect on consumption is not statistically significant. The race effect on participation may be due to the difference in media exposure and the marketing environment (Putler and Frazao 1994; Guthrie et al. 1995; Nayga 1996). White people are known to have higher newspaper and magazine readership rates than are nonwhites (United States Department of Health and Human Services 1998). This implies that white people may be better informed about food irradiation because scientific evidence and authoritative attestation to the safety, wholesomeness, and effectiveness of food irradiation are often publicized in such media. Because they are better informed with correct knowledge about the processing, white people might be more confident about the benefits of food irradiation, and therefore more willing to participate in its

Table 2. Estimation Results of the Participation and Consumption Equations.

Variable	Participation	Consumption
Constant	0.6602 (2.45).................................. **	-3.0091 (-4.03)***
Age	-0.0082 (-3.14)***	-0.0003 (-0.05)
Female	-0.0606 (-0.57)	0.1528 (0.59)
Education	-0.0061 (-0.03)	-0.1706 (-1.49)
White	0.2372 (1.91)*	-0.3710 (-1.44)
City	0.0385 (0.40)	0.6771 (2.46)**
Inc1	0.2046 (1.44)	0.6788 (2.05)**
Inc2	0.2236 (1.73)*	0.3719 (1.11)
Inc3	0.2534 (1.86)*	0.2847 (0.78)
Radity	-0.3026 (-2.91)***	-0.1260 (-0.51)
Cancer	-0.4331 (-3.67)***	-0.0981 (-0.36)
Exelhlth	0.0727 (0.73)	0.4307 (1.87)*
Bacteria	0.1901 (1.67)*	0.7381 (1.75)*
Lacknow	-0.2435 (-2.38)*	-0.3751 (-1.65)*

consumption.

Consumer perceptions about beef irradiation significantly affected participation. Those who had concerns about higher radioactivity levels in beef due to irradiation and those who thought consumption of irradiated beef may increase the risk of suffering from cancers were less likely to consume irradiated beef.

Place of residence, on the other hand, significantly affects consumption of beef but not participation in the consumption of irradiated beef. As a result of participating in the consumption of irradiated beef, people living in urban areas are likely to eat beef more frequently than they currently do. Likewise, health condition is found to have a significant effect on beef consumption, but its effect on participation is insignificant. Those in excellent health tend to eat beef more frequently.

Understandably, those who are very concerned with the presence of bacteria in beef as a major source of outbreaks of food poisoning are more likely to participate in the consumption of irradiated beef. Furthermore, they tend to consume beef more frequently as a result of participation. Concerns about bacteria in beef as a source of outbreaks of food poisoning, such as the well-publicized outbreaks of E. coli illness in the past decade, could have been a major factor contributing to the decrease in beef consumption. Those who are very concerned about food poisoning by bacteria tend to consume more beef as that risk decreases.

Lack of knowledge about the process of food irradiation adversely affects both participation and consumption. As far as consumers are concerned, two aspects are of particular importance regarding consumers' lack of knowledge about the process: lack of the knowledge of its safety, and lack of knowledge of its benefits. The former is more likely to affect participation, while the latter is more likely to affect consumption. If a consumer lacks knowledge about safety, he may be concerned with potential side effects of irradiation because the word "irradiation" is usually related to the concept of "radioactivity" in people's minds; hence he may avoid consuming the irradiated beef. If he lacks knowledge of its benefits, he may participate in the consumption, but is unlikely to consume more beef as a result.

Conclusion

This study investigates consumer acceptance of beef irradiation and changes in beef-consumption frequency as a result of participating in the consumption of irradiated beef. The results support the notion that the participation and beef-consumption frequency can be viewed as two different decisions. Some factors are important determinants of the participation but do not significantly affect total consumption frequency, while some factors are important determinants of the total consumption frequency but not of the participation.

Despite scientific evidence attesting to the safety of food irradiation, the majority of consumers are very concerned with the side-effects of beef irradiation. Consumer concerns, although ungrounded, adversely affect the acceptance of irradiated beef and the related effect on the increase in beef-consumption frequency. Dispelling consumer concerns may effectively enhance consumer acceptance of irradiated beef and increase total beef consumption.

An important message from this study is that most American consumers are ignorant about food irradiation. Lack of knowledge about food irradiation negatively affects the acceptance of irradiated beef and beef-consumption frequency. This implies that information dissemination can be an effective tool to promote beef irradiation and to increase demand for beef.

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