

Relative and Absolute Risk Format in  
Eliciting Willingness-to-Pay for Beef Irradiation

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**Title:** Relative and Absolute Risk Format in Eliciting Willingness-to-Pay for Beef Irradiation

**Abstract:** The relationship between the valuation of reduced risk through irradiation and framing of risk information was determined using absolute and relative risk formats. A double-bounded CV survey was used to measure willingness-to-pay (WTP) for irradiated beef among 740 U.S. households. Results show that the WTP was sensitive to the risk formats.

**Key Words:** beef irradiation, relative risk format, absolute risk format, willingness-to-pay, double-bounded CV questions

## Relative and Absolute Risk Format in Eliciting Willingness-to-Pay for Beef Irradiation

Arbindra Rimal, Stanley M. Fletcher, and Kay H. McWatters

Food irradiation provides consumers and producers improved sanitation level, extended food shelf life, safe transport of products, replacement of chemical fumigants, and reduction of spoilage and waste (Bruhn et al., 1986; Misra et al., 1991). However, opponents of irradiation technology claim that irradiation will make food radioactive and generally increase risks to public health (Pszczola, 1990). In December 1997, the Food and Drug Administration (FDA) approved the use of irradiation to kill harmful bacteria such as *Escherichia coli*, commonly known as *E. coli*, in beef. The meat industry strongly supported this action. However, information about consumer response to this ruling and implementation of the technology is limited. In a survey of consumer reaction to the irradiation concept published in 1984, only 23 percent of consumers had heard of the process of irradiation (Wiese Research Associates, 1984). This percentage increased to 66 percent in 1986 (Brand Group, 1986) and to 72 percent in 1995 (Resurreccion et al., 1995). With heightened concerns nationwide for the safety of ground beef, consumers who may once have been skeptical of irradiation may be more accepting of irradiated products than before.

Previous studies on consumer acceptance of irradiated food have reported that consumer attitude toward irradiation may be improved through education and information (Bruhn et al., 1986; Bruhn and Noell, 1987; Bord and O'Conner, 1989). The acceptance rate also depended on demographics. Educated and wealthy respondents are more likely to accept the irradiation process. While asking whether consumers would accept irradiated food, most studies have focused on

consumers' general attitude about food safety and demographics. This study estimates consumers' willingness to pay for the safety provided by application of the irradiation technology to beef. Such information would help beef marketers and policy makers in evaluating economic benefits and costs associated with irradiation technology.

### **Willingness to Pay Estimates**

In the case of food safety, researchers must resort to nonmarket valuation techniques to measure consumers' willingness to pay (WTP) for reduced food risks when market data are not available. Contingent valuation (CV) is generally considered as the most appropriate choice for measuring food safety (Misra et al. 1991, van Ravenswaay 1990). Common applications of CV for food safety issues are to present respondents with hypothetical scenarios of risk reduction and ask them to name a price that is the most they are willing to pay above the normal purchase price to reduce the food safety risk. Individuals should be willing to pay more for a larger risk reduction than for a smaller risk reduction (Jones-Lee 1974; Harrington and Portney 1987). An individual's willingness to pay (WTP) the largest monetary amount for a specified improvement in food safety represents a measure of the value of the safer food. WTP can be measured empirically using a contingent valuation method (CVM). This method has been widely used to measure both environmental and non-environmental non-market goods. A bibliography of contingent valuation method related studies (Carson et al., 1994) lists 1672 such studies. All other methods of valuing non-market goods require some sort of linkages to actual market transaction. For example, the travel cost method uses market expenditure for transport and other items to infer a demand for recreation. The CV method does not require any such connection to market. Thus, it is the most flexible (Bishop and

Herberlein, 1979) method. The flexibility, however, is gained at certain costs. Because of the lack of connection to the market, the validity of the technique itself is questioned.

CV uses surveys to elicit individual willingness to pay (WTP) for non-market goods, e.g., reduction in foodborne illness. A hypothetical market is described to the respondents in which the good (e.g., specified improvement in food safety) can be traded with some measure of personal satisfaction such as income (risk-income tradeoff). Therefore, WTP is contingent on a hypothetical scenario, so it may vary with the type of information provided in the scenario and also, framing of information. As proposed by Lin and Milon (1995), framing of risk information may influence valuation responses. In CV questioning, the current risk level (R) and new (reduced) risk level (R') can be stated using two formats: absolute information format and relative information format. The absolute format specifies only changes in risk level for a specific food. For example, currently 1 out of 13,000 people in the U.S. get sick by consuming food Z; the risk from food Z can be reduced to 1 out of 40,000 people by using program X. Alternatively, risk information can be described by comparing the risk of eating food Z to Y. For example, the risk of getting ill from food Z is higher than from food Y; the risk can be reduced to the same level as Y by using program X.

After risk scenarios are explained, individuals are asked to provide a monetary income that they want to forgo for the good (reduced risk). A CV questioning format that is used widely in eliciting the value is the referendum question (also known as single bounded dichotomous choice, close ended or take-it-or-leave it question). Consumers are asked to respond “yes” or “no” to a question regarding an alternative bid for a particular non-market good. Although the single-bounded dichotomous choice method represents a dominant format for contingent valuation of non-market goods (Herriges and Shogren, 1996), it has many weaknesses. According to Cameron and Quiggin

(1994) it is statistically inefficient because a large number of observations is required to identify the underlying distribution of resource value with any given degree of accuracy. An alternative CV survey strategy to reduce this inefficiency was introduced by Carson et al (1986). It involves using a second threshold offer as a follow-up dichotomous choice. This approach is popularly known as a double-bounded referendum approach in the CV method. Under this method, if a respondent indicates willingness to pay the first threshold amount, the new threshold amount is offered which is about double the first threshold amount. If the respondent indicates unwillingness to pay the first threshold amount, then the second threshold amount is offered which is about half the original amount. The efficiency gained by using a follow-up bid in the CV method may be subject to the starting point bias, that is, the first bid amount may unduly influence the response to the follow-up bid. When the respondents are uncertain about the value of the non-market goods, they are likely to anchor their WTP amount on the first bid value (Herriges and Shogren, 1996). Hanneman (1985) and Carson (1985) proposed an improvement to this method by following up with a second bid that depends on the response to the first bid. The improved method is known as double-bounded referendum questions. Boland et al. (1999) were among the few who used this CV format in the area of food safety.

The objective of the study is to determine the relationship between valuation and framing of risk information. The elicited values of safety information using absolute risk information may be different from that using relative risk information.

### **Conceptual Framework**

Under both single and double-bounded referendum procedures, it was assumed that each respondent has an unobserved (latent) true value of food safety provided by the irradiation

technology. Unlike the single-bounded model, where the latent value could be any value more or less than the given single threshold, the double-bounded model provides a follow-up threshold amount which captures the latent value within a certain boundary. Let us assume that each survey respondent has some unobserved value (negative if perceived to be harmful) of irradiation of beef products. Let this unobserved value be  $y_{1i}$ . Let  $t_{1i}$  represent the first threshold value offered to the respondent. It is assumed that the respondent will indicate willingness to pay the offered amount ( $z_{1i}=1$ ) if  $y_{1i} \geq t_{1i}$ . The respondent will indicate unwillingness to pay ( $z_{1i}=0$ ) if  $y_{1i} < t_{1i}$ . The unobserved valuation of beef irradiation is assumed to be affected by systematic components,  $x'_{1i}\beta_1$  and a random unobservable component,  $\varepsilon_{1i}$ .

Once the respondent is randomly assigned the initial offered value, the follow-up offer is made which is either higher or lower than the first value depending on the response to the first bid value. The probability of receiving the predetermined higher offer in the second bid is just the probability of “yes” to the first offer, and the probability of receiving the predetermined lower offer in the second bid is just the probability of “No” response in the first offer. The indicator variable to the second offer is ( $z_{2i}=1$ ) if  $y_{2i} \geq t_{2i}$  and ( $z_{2i}=0$ ) if  $y_{2i} < t_{2i}$ . The underlying valuation is again assumed to be affected by systematic components,  $x'_{2i}\beta_2$  and a random unobservable component,  $\varepsilon_{2i}$ . The error term  $\varepsilon_{2i}$  is correlated with  $\varepsilon_{1i}$ .

The structural model using a two equation system can be specified in the following way:

$$(1) \quad y_{1i} = b'_1 x_{1i} + e_{1i}, \quad z_{1i} = 1 \text{ if } y_{1i} \geq t_{1i}, \quad z_{1i} = 0, \text{ otherwise}$$

$$(2) \quad y_{2i} = b'_2 x_{2i} + e_{2i}, \quad z_{2i} = 1 \text{ if } y_{2i} \geq t_{2i}, \quad z_{2i} = 0, \text{ otherwise}$$

where  $[e_{1i}, e_{2i}] \sim$  bivariate normal. Individual observations on  $z_{1i}$  and  $z_{2i}$  are available.  $X_{1i}$  and  $X_{2i}$  are the observable attributes of the respondents for the first and second responses, respectively. It is not necessary that they be identical.

There are four possible pairs of responses to these offers; (1,1), (1,0), (0,1) and (0,0). Hence, there are four probability regimes. As stated above,  $z_1=1$  implies  $y_{1i} > t_{1i}$ . Using  $y_1 = x_1\beta_1$ , this condition can be expressed equivalently as  $\varepsilon_1/\sigma_1 \geq (t_1 - x_1\beta_1)/\sigma_1$ , where  $\varepsilon_1/\sigma_1$  is a standard normal random variable. Setting  $\varepsilon_1/\sigma_1$  and  $\varepsilon_2/\sigma_2$  as  $\gamma_1$  and  $\gamma_2$ , we can proceed with the analysis in terms of probabilities associated with regions in the domain of standard bivariate normal distribution, BVN (0,0,1,1, $\rho$ ), where  $\rho$  indicates the correlation between the error terms in the two equations. The bivariate standard normal density function is:

$$(3) \quad g(\gamma_1, \gamma_2) = \left[ 1 / (2\pi(1 - \rho^2)) \right] \exp \left\{ -\frac{1}{2(1 - \rho^2)} \left[ \gamma_1^2 - 2\rho\gamma_1\gamma_2 + \gamma_2^2 \right] \right\}$$

where  $\gamma_1 = t_1 - x_1'\beta_1$  and  $\gamma_2 = t_2 - x_2'\beta_2$  after setting  $\sigma_1$  and  $\sigma_2$  equal to 1. The corresponding log-likelihood function is given by (see Cameron and Quiggin, 1994 for more details):



$$\begin{aligned}
(4) \quad \log L = & \sum_i \left\{ (z_1 z_2) \log \left[ \int_{t_1 - x_1' \beta_1}^{\infty} \int_{t_2 - x_2' \beta_2}^{\infty} g(\gamma_1 \gamma_2) d\gamma_1 d\gamma_2 \right] \right\} \\
& + \left\{ (1 - z_1)(z_2) \log \left[ \int_{-\infty}^{t_1 - x_1' \beta_1} \int_{t_2 - x_2' \beta_2}^{\infty} g(\gamma_1 \gamma_2) d\gamma_1 d\gamma_2 \right] \right\} \\
& + \left\{ (1 - z_1)(1 - z_2) \log \left[ \int_{-\infty}^{t_1 - x_1' \beta_1} \int_{-\infty}^{t_2 - x_2' \beta_2} g(\gamma_1 \gamma_2) d\gamma_1 d\gamma_2 \right] \right\} \\
& + \left\{ (z_1)(1 - z_2) \log \left[ \int_{t_1 - x_1' \beta_1}^{\infty} \int_{-\infty}^{t_2 - x_2' \beta_2} g(\gamma_1 \gamma_2) d\gamma_1 d\gamma_2 \right] \right\}
\end{aligned}$$

The log likelihood function contains the expressions for four probability regimes coming out of the responses to the questions: (1,1), (1,0), (0,1), and (0,0). A bivariate probit algorithm offered in LIMDEP (Greene, 1995) is used to estimate the parameters.

### Survey Design

A national telephone survey among 750 households was conducted at the end of December 1999. Primary shoppers in the households were asked questions in five broad sections. The average completion time of the interview was 15 minutes. A double bounded dichotomous choice CV technique will be used to measure willingness to pay for irradiated beef within the formats of relative and absolute risk reductions.

In order to obtain willingness-to-pay information under relative framework, respondents were read the following statements in the questionnaire:

When foods are irradiated, exposure to approved levels of radiant energy kills insects, parasites, and bacteria that cause foodborne illness and food spoilage. Food irradiation is a process approved by the Food and Drug Administration (FDA) and the World Health Organization (WHO) as safe and effective, and is designed to enhance the safety and extend the shelf life of food by preserving freshness. Recently, the United States Department of Agriculture approved the use of irradiation on beef products.

The number of outbreaks, incidents, and recall of ground beef is much higher than that of chicken. In 1998, out of a total of 44 recalls of meat products, at least 25 were related to beef while only 8 were related to chicken. If irradiation techniques would reduce such incidents for beef to the same level as chicken, would you be willing to pay 3 cents more per pound for beef relative to the current price?

Four sets of predetermined price premiums were assigned to four groups of randomly selected households. The sets of price premiums were: (3,5,2);(6,10,4);(10,15,4); and (15,20,10) cents per pound for beef. For example, a respondent is asked whether s/he is willing to pay 3 cents more per pound for irradiated beef. If s/he says “yes”, then s/he is asked whether s/he will pay 5 cents more per pound for irradiated beef. If s/he says “No” for the first offered price premium, that is 3 cents more per pound for irradiated beef, then s/he is asked whether s/he will pay 2 cents more per pound for irradiated beef.

The willingness-to-pay information under absolute questioning format was obtained using the following statement in the questionnaire:

According to the Centers for Disease Control (CDC), each year about 1 out of 13,000 people in the United States get sick from *E-coli*, which is often associated with eating ground beef. This means that each year 20,000 people get sick from *E-coli*. Suppose irradiation techniques would reduce such incidents to 1 out of 40,000 people each year so that only about 6500 would get sick from E-coli each year.

If beef irradiation reduced the likelihood of getting sick from *E-coli* from beef products and did not change the price or taste, would you be willing to pay 3 (6, 10, 15) cents more per pound relative to current price?

Table 1 reports descriptive statistics for the double-bounded referendum bid values and responses under two questioning formats. The mean value of the first bid was 8.28 and 8.24 cents per lb for absolute and relative risk formats, respectively, while the mean value for the second bid was 8.80 and 8.95 cents. More than 50 percent of the households responded “Yes” to the first bid offer while about 40 percent of the respondents said “yes” to the second bid offer when relative questioning formats were used. The percentages were 55 and 47 in the case of the relative risk format. About 31 percent of the respondents said “Yes” to the initial and the follow-up bid offers while 42 percent of the respondents said “No” to the initial and the follow-up bid offers when relative risk format was adopted. A much higher percent of respondents (41.3 percent) accepted initial and follow-up bids when risk scenario was explained using absolute risk format.

The surveys also obtained information on the respondents’ socioeconomic and demographic characteristics and perceptions of food safety. At this stage of analysis, however, only bid values are included in the independent variables.

## **Results**

Parameters for both the relative and absolute questioning format models were estimated by maximum likelihood (ML) procedures using the LIMDEP softwares (Greene, 1995). The ML parameter estimates are presented in Table 2. Indicator variables (Yes=1; No=0) were used as dependent variables. The bid prices offered to the respondents were included in the dependent variables. Models were estimated for relative questioning format, absolute questioning format, and pooled data using a dummy. One objective of estimating a WTP regression model is to obtain an estimate of the average (or median) WTP. Using the estimates of the parameters of the bivariate

probit models, the expected WTP ( $E[Y_i]$ ) for each respondent was calculated. These values were then averaged across the respondents. The mean WTP estimates are reported in Table 3.

The overall model for each data set is jointly significant at the 0.01 level as shown by the chi-square statistics. Also, the estimated rho for each data set indicating the relationship between the error terms in the two equations is statistically significant at the 0.01 level. For each of the data sets, bid values were inversely related to responses. That is, as the values increased the likelihood of accepting food safety through irradiation technology decreased.

The mean WTP for each data set was calculated. In general, the mean WTP estimated using the absolute questioning format was higher than that using the relative questioning format. The mean WTP using relative questioning format showed that consumers were willing to pay 5 to 10 cents per pound more for beef irradiation relative to the current price of beef. The estimates from the absolute questioning data show that the sample households were willing to pay between 7 to 12 cents per pound more for irradiated beef than for non-irradiated. The calculated mean WTP for the pooled data show similar differences between the relative and absolute questioning formats. Further, the differences were statistically significant at 0.05 level.

### **Implications**

The results suggest that consumers are concerned about the safety of beef and might be willing to pay more for irradiated beef relative to non-irradiated. Therefore, there may be economic incentives for meat processors and retailers to introduce irradiated beef in the market. The study, however, suggests that the WTP may vary due to the questioning format adopted to measure it. The reported valuation amount was sensitive to the risk information format. Perhaps the reference risk (chicken) helped respondents' comprehend the risk from the beef.

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Table 1: Descriptive Statistics

Description	Relative Format		Absolute Format	
	Mean values	Standard deviation	Mean values	Standard deviation
$t_1$ Exogenous threshold for first question (cents/lb)	8.28	4.44	8.24	4.46
$t_2$ Endogenous threshold for second question (cents/lb)	8.80	5.40	8.95	5.56
$I_1$ Discrete Response to first question (1=Yes, WTP amount; 0=no, not WTP)	0.53	0.49	0.55	0.49
$I_2$ Discrete Response to second question (1=Yes, WTP amount; 0=no, not WTP)	0.39	0.48	0.47	0.50
Joint frequencies of responses:				
$I_1=1, I_2=1$	0.31		0.41	
$I_1=0, I_2=0$	0.42		0.36	
$I_1=1, I_2=0$	0.20		0.15	
$I_1=0, I_2=1$	0.07		0.08	

Table 2. Maximum Likelihood Estimates of Bivariate Probit Models: Relative Format

	Relative Format	Absolute Format	Pooled
$\beta_{01}$	0.5957*** (0.1128)	0.4492*** (0.1241)	0.4753*** (0.0993)
$\beta_{11}$	-0.06311*** (0.0108)	-0.0369*** (0.0129)	-0.0399*** (0.0094)
Dummy	-	-	-0.0622 (0.0876)
$\beta_{02}$	0.1433 (0.1025)	0.2013 (0.1386)	0.1149 (0.1099)
$\beta_{12}$	-0.0298*** (0.0087)	-0.0271** (0.0131)	-0.0180* (0.0098)
Dummy	-	-	-0.2041*** (0.0864)
$\rho$	0.7395*** (0.0648)	0.7998*** (0.0548)	0.7699
Maximum Likelihood	-496.73	-525.80	-1023.38
$\chi^2$	10.28***	8.10***	22.80***

\* indicates significance at  $\alpha=0.10$ ; \*\* indicates significance at  $\alpha=0.05$ ; \*\*\* indicates significance at  $\alpha=0.01$



Table 3. WTP Estimates (cents/lb): Relative versus Absolute Format

	Relative	Absolute	Pooled	
			Relative	Absolute
First Bid	9.83	12.17	11.17 <sup>b</sup>	11.91 <sup>a</sup>
Second Bid	4.70	7.43	5.05 <sup>b</sup>	6.34 <sup>a</sup>

Means in a column with the same letter are not significantly different at 0.05 level as determined using Tukey tests.