

Department of Agricultural, Environmental, and Development Economics
The Ohio State University
Working Paper: AEDE-WP-0007-01

Absolute versus Relative Risk Perception: An Application to Seafood Safety

Ju-Chin Huang (University of New Hampshire)

Timothy C. Haab (The Ohio State University)

John C. Whitehead (East Carolina University)

Abstract

We examine the impact of perceived absolute and relative risks on consumption of goods with substitutes and complements. We provide a possible analytical explanation of the importance of relative risks on the consumption of a risky good. And, we discard the common yet unrealistic assumption of fixed baseline risk and elicit the individual subjective baseline risk from each survey respondent. Revealed and stated data are combined to trace out demand changes in response to absolute and relative risk reductions. Seafood consumption in eastern North Carolina is studied. Our results show that seafood consumption is affected by the perceived absolute risk and by the relative risk to poultry, which confirms that individuals react to the multiple risks in a nonlinear way--as predicted by our analytical model.

Key words: Absolute and Relative Risks, Risk Substitutes, Revealed and Stated Data, Food Borne Risk

* Helpful comments from the participants of the Kobe Conference on the Theory and Application of Environmental Valuation held in Kobe, Japan and V. Kerry Smith are gratefully acknowledged. The authors also thank Josh Olinick for research assistance.



AEDE Agricultural, Environmental,
and Development Economics

Ohio State University Extension
Ohio Agricultural Research and Development Center
College of Food, Agricultural, and Environmental Sciences

1. Introduction

Household surveys have often been used to value changes in economic welfare from changes in risk associated with certain behaviors. Two commonly used techniques for risk valuation are the direct elicitation of willingness to pay (WTP) for risk reductions using referendum type contingent valuation scenarios and the welfare analysis of the demand for a risky good. While it is intuitively appealing that a decrease in risk will increase welfare, empirical evidence based on either technique does not always support the intuition. Fein, Lin and Levy (1995) suggest that "consumers may underestimate the frequency of serious consequences associated with food borne illness that would motivate effective behavioral change." In a 1990 contingent valuation study, Lin and Milon (1993) conclude that there is an "absence of a systematic relationship between elicited WTP and risk information." They elicit WTP for both absolute and relative changes in the *objective* risk of eating shellfish, but their survey contains little information on how respondents perceive these changes in risk. Two issues arise when objective risks are used in risk valuation. First, an individual's risk perception can be important in describing an individual's ex ante consumption decision (Adamowicz, et al., 1997). Due to unavailability of the subjective risk measures, many risk valuation studies use objective risk measures acquired from historical events in the empirical estimation to explain changes in economic behavior, e.g. Smith, van Ravenswaay, and Thompson (1988), Brown and Schrader (1990), Lin and Milon (1993). The data analyzed under these assumptions can be quite misleading and cause inconclusive results.

Second, the use of objective or technical risk implicitly assumes the same baseline risk for all individuals. Many food safety studies assume one baseline risk and focus on changes in actual/objective risk rather than the risk as perceived by individuals that can be the key to

consumption decisions. Van Ravenswaay and Wohl (1995) caution against assuming that all respondents have similar risk perceptions and find that making such an assumption will result in incorrect measures of willingness to pay for risk reductions. There are also attempts to combine risk perception and objective risk information in valuing food safety, e.g., Eom (1994), but the welfare gains remain unclear.

One common trait of the majority of risk valuation studies is to focus on one risky good and its associated risk. In reality individuals often consume multiple risky goods. It is seldom addressed, with the exception of Lin and Milon (1995), how individuals respond to changes in multiple risks, and if they respond to absolute or relative risk changes. The omission of substitution effects can be an important factor to inclusive results in the literature.

The purpose of this research is to examine the impact of multiple risks on demands. We argue that when individuals consume multiple risky goods, both absolute and relative risks can affect demands. We derive the individual specific risk reference points by eliciting the subjective baseline risk from survey respondents and acquire multiple quantity responses to proposed price and/or risk changes from them. The information helps trace out the movement along and the shift of the individual demand curve for welfare analysis. Both revealed and stated data are used in the welfare analysis of risk reductions.

The rest of the paper is organized as follows. In section 2, we present a simple expected utility model when multiple risky goods are consumed and explain the impact of absolute and relative risks on demands. Section 3 describes the survey design and the collected data. In section 4, we show the proposed econometric model and welfare measure. In section 5, we report the estimation results and estimated consumer surplus. Concluding remarks are given in section 6.

2. Analytical Model

We begin with a simple expected utility framework. Assume that an individual consumes n goods, x_1, x_2, \dots, x_n that could possibly cause illness, and a numeraire good z with no possibility of illness. The predetermined probabilities of illness from the n goods are $\pi_1, \pi_2, \dots, \pi_n$. The consumer's budget constrained expected utility maximization problem can be written as:

$$(1) \quad \max_{x_1, \dots, x_n, z} L = EU(x_1, \dots, x_n, z; s, \pi_1, \dots, \pi_n) + \lambda \left(M - \sum_{i=1}^n p_i x_i - z \right),$$

where EU is the expected utility function; M is income; p_1, \dots, p_n are the prices of the n goods (the price of the numeraire has been normalized to 1); and s are individual characteristics. The expected utility model describes an individual's utility before the resolution of any uncertainty. Hence, the perceived probabilities of illness are more plausible than the objective/scientific risks to describe an individual's ex ante expected utility. We propose to elicit the perceived, subjective risk measures directly from individuals in the survey.

To examine the effect of multiple risky commodities on the consumers utility maximizing bundle, note that the consumers utility maximized budget identity is: $M \equiv \sum_{j=1}^n p_j x_j^* + z^*$, where x_j^* represents the uncompensated demand for good j . Differentiating the budget identity with respect to an arbitrary risk probability π_j yields:

$$(2) \quad \frac{\partial z^*}{\partial \pi_j} + \sum_{i=1}^n p_i \frac{\partial x_i^*}{\partial \pi_j} \equiv 0.$$

Assuming an increase in the risk associated with a good will decrease the quantity-demanded for that good such that: $\partial x_j^* / \partial \pi_j \leq 0$ (this will be argued subsequently), equation (2) implies that at least one other good (either another risky good, or the numeraire) must be a risk substitute for good j . For example, if the risk of eating seafood increases, then equation (2) implies that the

consumer will substitute at least one other good to compensate for the decrease in seafood consumption.

Two issues remain. One is how multiple risks affect demands in theory. The other is under what conditions should the own-risk have a negative impact on the demand for the risky good. To examine these issues a simple model of a two-good world is presented. We will show that not only does an absolute risk change affect the level of consumption, but also the risk of consuming the good relative to the risk of consuming other goods. In addition, we will show that under reasonable assumptions a change in the own-risk of consuming a good can decrease the consumption of that good, which based on the above result, implies that risk substitutes exist.

The Two-Good Case

Suppose the consumption of two goods, x_1 and x_2 are associated each with two states of the world (1 and 0). For simplicity we will call state of the world 1 the sick state and state of the world 0 the healthy state. Let π_1 and π_2 be the probabilities of getting sick from consuming x_1 and x_2 , respectively. The standard expected utility model is comprised by the weighted sum of the utilities from both sick and healthy states:

$$(3) \quad EU = g(\pi_1, \pi_2)U^1 + (1-g(\pi_1, \pi_2))U^0,$$

where $g(\cdot)$ is the probability of getting sick from consuming x_1 and x_2 , and it is a function of π_1 and π_2 . For simplicity and demonstration purposes, we assume that the marginal probabilities of illness resulting from consuming x_1 and x_2 are independent of each other, which implies that the joint probabilities can be derived by multiplying two marginal probabilities. The assumption can be relaxed to allow dependence of illness from the two goods (the general model (3)). The analytical conclusion of impact of relative risks (risk ratios) on demands will be the same.

Because a sick state and a healthy state are associated with each good, there are four possible states of the world, including three sick states and one healthy state: (1,1), (1,0), (0,1), and (0,0). Associated with each state of the world are ex-post utility functions $U^{11}(x_1, x_2)$, $U^{10}(x_1, x_2)$, $U^{01}(x_1, x_2)$, and $U^{00}(x_1, x_2)$. The first superscript represents the state of the world associated with consumption of x_1 , and the second superscript represents the state of the world associated with consumption of x_2 . Because a consumer is uncertain about the state of the world for each good ex-ante, the consumer chooses x_1 and x_2 to maximize the ex-ante expected utility function. If we assume that illness resulting from consumption of x_1 and x_2 are independent of each other, the expected utility can be written as follows.

$$(4) \quad EU = \pi_1 \pi_2 U^{11}(x_1, x_2) + \pi_1 (1 - \pi_2) U^{10}(x_1, x_2) + (1 - \pi_1) \pi_2 U^{01}(x_1, x_2) + (1 - \pi_1) (1 - \pi_2) U^{00}(x_1, x_2),$$

It can be seen from Roy's identity that the utility maximized consumption of x_1^* depends (nonlinearly) on both π_1 and π_2 .

$$(5) \quad x_1^* = - \frac{\frac{\partial E(U)}{\partial p_1}}{\frac{\partial E(U)}{\partial y}} = - \frac{\pi_1 \pi_2 U_{p_1}^{11} + (\pi_1)(1 - \pi_2) U_{p_1}^{10} + (1 - \pi_1)(\pi_2) U_{p_1}^{01} + (1 - \pi_1)(1 - \pi_2) U_{p_1}^{00}}{\pi_1 \pi_2 U_y^{11} + (\pi_1)(1 - \pi_2) U_y^{10} + (1 - \pi_1)(\pi_2) U_y^{01} + (1 - \pi_1)(1 - \pi_2) U_y^{00}},$$

where $U_{p_1}^{ij}$ is the partial derivative of utility in state ij with respect to p_1 and U_y^{ij} is the marginal utility of income in state ij . If the marginal utility of income is constant across states, then it is easy to see that the ex-ante demand for x_1 is a linear combination of the ex-post demands for x_1 in each state of the world. If the marginal utility of income varies across the states (sick and healthy), then the demand for x_1 is a nonlinear function of π_1 and π_2 . Either way the optimum demand x_1^* can be written as the ratio or product of the two probabilities. The implication is that

the demand for x_1 can depend not only on the (absolute) risk of illness from consuming x_1 but also the relative risks of illness to other goods.

Continuing with the two-good independent risk case, the marginal effect of π_1 on the consumption of x_1 is

$$(6) \quad \frac{\partial x_1^*}{\partial \pi_1} = - \frac{\frac{\partial E(U)}{\partial p_1}}{\frac{\partial E(U)}{\partial y}} = - \frac{[\frac{\partial^2 E(U)}{\partial p_1 \partial \pi_1}][\frac{\partial E(U)}{\partial y}] - [\frac{\partial E(U)}{\partial p_1}][\frac{\partial^2 E(U)}{\partial y \partial \pi_1}]}{[\frac{\partial E(U)}{\partial y}]^2},$$

which in general is also a nonlinear function of π_1 and π_2 . Substituting in the analytical expressions for the derivatives in (6), the marginal effect of a change in π_1 on x_1 is:

$$(7) \quad \frac{\partial x_1^*}{\partial \pi_1} = - \frac{(1-\pi_2)(1-\pi_2)[U_{p_1}^{10}U_y^{00} - U_{p_1}^{00}U_y^{10}] + (\pi_2)(1-\pi_2)[U_{p_1}^{11}U_y^{00} - U_{p_1}^{00}U_y^{11}] + (\pi_2)(1-\pi_2)[U_{p_1}^{10}U_y^{01} - U_{p_1}^{01}U_y^{10}] + (\pi_2)(\pi_2)[U_{p_1}^{11}U_y^{01} - U_{p_1}^{01}U_y^{11}]}{[\frac{\partial E(U)}{\partial y}]^2}.$$

To sign this marginal effect, note that the squared term in the denominator is always positive and the bracketed terms in the numerator represent a series of ex-post differences in demand, which allows us to show that the demand for x_1 is decreasing with its own risk. For example, the first

bracketed term is positive if: $\frac{U_{p_1}^{10}}{U_y^{10}} - \frac{U_{p_1}^{00}}{U_y^{00}} = x_1^{00} - x_1^{10} > 0$, where x_1^{00} is the ex-post demand for

x_1 in the healthy state, and x_1^{10} is the ex-post demand for x_1 in the sick state resulted from consuming x_1 . If the demand for x_1 is less in the sick state than in the healthy state, holding the state for x_2 constant in the healthy state, then the first bracketed term is positive.

Similar arguments can be made for the second bracketed term in the numerator to show it is also positive. For the third bracketed term to be positive, it must be the case that the demand

for x_1 in the sick state caused by consuming x_1 is less than the demand for x_1 in the sick state caused by consuming x_2 so, $x_1^{01} - x_1^{10} > 0$. Similarly, if the demand for x_1 in the sick state caused by consuming both x_1 and x_2 is less than the demand for x_1 in the sick state caused by consuming x_2 so, $x_1^{01} - x_1^{11} > 0$, then the fourth bracketed term is positive. Hence, under plausible conditions, the marginal effect of π_1 on x_1 is negative; that is, the consumption of x_1 can be inversely affected by the risk of illness from consuming x_1 . It can further be shown that a marginal increase in the risk of consuming x_2 , will unambiguously result in an increase in the consumption of x_1 in a two-good world. This follows as a direct consequence of equation (2).¹

This simple expected utility model with two risky goods shows the effects of both absolute and relative risks on the demands for these goods. This result is not specific to the two-good independent states of the world case described here. The result extends generally to n-goods and general joint probability functions for the n-states of the world. In general, we should allow for a non-linear relationship between the risks associated with each good in the empirical estimation of the partial-demand for any particular good. The exact form of this demand relationship will depend on the assumed form of the expected utility function. Alternatively, using the analytical results derived above, we can directly assume a form for the estimable Marshallian demand function and investigate the behavior of various interaction assumptions between own and cross risks on the estimated partial demand function. This is the strategy employed in the empirical exercise below. The empirical results support the analytical result that risk substitutes exist and relative risks matter.

¹ The demonstration for the two-good case is available upon request.

3. Survey and Data

To investigate the effects of multiple risk on the partial-demand for a particular good, data on seafood consumption were collected in a summer 1998 telephone survey of eastern North Carolina residents, performed by the East Carolina University Survey Research Laboratory (Wilson, et al. 1998). Individual consumption of fresh seafood (fish and shellfish), poultry (chicken and turkey), and meat (pork and beef) was surveyed under varying prices. (See the Appendix for the seafood questions. Similar questions were asked for poultry and meat consumption.) Respondents were first asked to *reveal* their typical consumption of fresh seafood, poultry, and meat meals under current prices (point a in Figure 1). The price is defined as the average cost of a fresh seafood meal whether purchased in a restaurant or a store. Next, respondents were told that fresh seafood prices vary according to catch. The hypothetical price increase (dP) was randomly drawn from one of the five amounts: \$1, \$3, \$4, \$5, and \$7. Respondents were then asked about the number of seafood meals they thought they would eat in a typical month with the higher price (point b in Figure 1). With these data we are able to trace out the seafood demand under current safety conditions which is illustrated as $X_1(\pi_1, \bullet)$ in Figure 1.

Seafood eaters' perceived risks of consuming seafood, poultry, and meat were then elicited. Perceived risk is elicited as the number of meals out of 1,000,000 meals consumed in eastern North Carolina that would result in sickness. Perceived risk is measured as the number of meals divided by 1 million (π_k , where $k=1$ (seafood), 2 (poultry), 3 (meat)). Beforehand, they were asked to identify what food they thought was the safest to consume. If a respondent thought poultry or meat to be the safest, the respondent was presented with a proposed seafood inspection program that would ensure seafood to be as safe as the food that the respondent considered

safest. The respondent was then asked to *state* how his/her consumption of seafood would be affected by the proposed seafood inspection program without an increase in seafood prices (point c in Figure 1). Finally, the respondent was asked to *state* how the proposed seafood inspection program would affect his/her consumption of seafood with an increase in seafood prices (point d in Figure 1). With these data we are able to trace out the seafood demand under improved safety conditions. This is illustrated as $X_1(\pi_2, \bullet)$ in Figure 1, where the probability of getting sick from seafood, π_1 , is reduced to the probability of getting sick from another food, π_2 . For each scenario, questions about changes in poultry and meat consumption were also asked.

These various price/risk scenarios allow for two types of risk comparisons: (1) comparing the relative risk of eating seafood to that of consuming another food, or (2) comparing the absolute risk of eating seafood to the absolute risk of consuming another food. The size of the absolute risk reduction will depend on the perceived absolute risk as defined by the respondent. By allowing the respondent to define the baseline risk, we avoid the assumption that all respondents perceive risk similarly and allow the risk reference point to vary across individuals.

The telephone survey had a 73% response rate. Of the 1010 respondents we consider only a subset. Of the full sample, 91% were seafood eaters and were presented with the seafood questions. The respondents were asked to rank the risk levels of seafood, poultry, and meat. About 20% of the respondents were unable to rank the likelihood of getting sick from seafood, poultry and meat. Of the remaining 643 cases, 67% thought either poultry or meat was the safest. These respondents were presented a risk reduction program to ensure seafood consumption as safe as either poultry or meat, whichever they thought to be the safest. The remaining 33% thought seafood was the safest to eat and those respondents were asked to value a risk prevention program that would prevent deterioration of seafood safety. In this paper, we focus on the

valuation of risk reduction based on the responses from the 67% respondents who considered seafood to be less safe than poultry or meat. Of these, 8% mistakenly had identification numbers outside of the acceptable range or duplicate identification numbers and are discarded. After dropping cases with item non-response there are 302 respondents available for analysis. Among the 302 usable cases, there are 37 respondents whose perceived risk of seafood consumption is at least 10 times larger than the risk of either poultry or meat consumption, which results in convergence problems in estimation. Those observations are excluded from the empirical estimation in this paper.² Therefore, our study includes 265 respondents with 4 observations from each respondent, which amounts to the total of 1060 observations.

Because a large number of observations are dropped to obtain the final data set for this analysis, sample selection issues appear bound to arise³. The estimated demand function for the seafood safest subsample is structurally different from the demand function for the meat and poultry safest groups. This difference is not systematic with respect to the unobservable error and therefore, dropping these observations creates no selection bias⁴. Structural similarities between the meat and poultry sub-samples can not be rejected. Recall that the quantity of interest is the demand for seafood. Since the seafood safest group was asked to evaluate a program to prevent the deterioration of the quality of seafood (as opposed to evaluating a program to improve the quality of seafood), we expect the seafood safest group to respond differently than the meat/poultry group. Kahneman and Tversky (1979) show that consumers are risk averse to gains but are risk taking to losses. According to their prospect theory, consumers evaluate gains and

² We also tried less stringent criteria for identifying outliers such as seafood risk more than 100 (25) times higher than either the poultry or meat risk, which amounts to 27 (31) observations being excluded from the analysis. The qualitative results of estimation are the same.

³ Elimination of outliers and non-responses creates no systematic bias in this case.

⁴ Joint models were estimated in which the seafood safest group is included with various dummy interaction schemes to separate the estimated parameters for the seafood safest group from the meat/poultry subsample. The

losses differently relative to the reference point. In this paper, to avoid combining the evaluation of two types of alternatives, we focus only on the valuation of gains (risk reductions).

The definition of variables is given in Table 1. There are two groups of respondents included in this study: those who thought that poultry was the safest (GROUP2=1) and those who thought that meat was the safest (GROUP2=0). In the combined sample, 38% of the respondents thought poultry to be the safest. The variable of interest is the demand for seafood that is measured by seafood meals per month (SEAMEAL). The self-reported price of seafood plus the hypothetical price increase that varies across individuals is PCFOOD. Using simple t-tests to compare the means of seafood consumption and prices, there is no statistical difference between the two groups.

In contrast, the perceived probability of sickness from eating seafood (ABSRSK) is significantly different between two groups (t-statistic=2.87). The perceived relative risks of seafood to poultry and to meat are represented by DPRCNTCP and DPRCNTCM, respectively. The relative risk variables indicate how much more likely it is to be sick from seafood than from the other foods. There are respondents who thought poultry (meat) to be the safest yet reported a higher perceived risk from poultry than from seafood. We create a dummy variable, FUNNY2 to identify the observations with noticeably large discrepancy in their quantitative and qualitative risk perceptions.⁵

As described each respondent was confronted with the proposed seafood inspection program that would lower the risk of sickness from seafood consumption to the same level as the food (poultry or meat) that the respondent thought was the safest. In total, four quantities of

meat/poultry parameter estimates were invariant to the inclusion of the seafood safest group. These results are available from the authors upon request.

⁵ In the estimation, we tried both with and without these observations and found the same qualitative results. We report the results with these observations included. Other results are available upon request from the authors.

seafood consumption were elicited: the consumption at the current price, at an increased price, at the current price with a lower risk, and at the increased price with a lower risk. The first quantity *reveals* the current seafood consumption and the next three quantities are the *stated* quantities under hypothetical scenarios. The seafood consumption corresponding to the four scenarios is summarized in Table 2. On average individuals perceive that they are 31% (the mean of DPRCNTCP in the scenario 1) more likely to get sick from eating seafood than from eating poultry and 59% (the mean of DPRCNTCM in the scenario 1) more likely to get sick from eating seafood than from eating meat. The average proposed risk reduction is 0.4% (from 4.3% to 3.9%; i.e., 4 fewer meals out of 1,000 would result in sickness). On average, seafood consumption increases by one meal (from 4.96 to 5.95 meals) per month with the proposed lower risk. The data allow us to compare the revealed and stated demand shifts due to changes in absolute and relative risks and in prices.

4. Empirical Model and Welfare Measure

In our survey, the seafood consumption was measured as meals per month and each respondent gave four quantities under different scenarios. An empirical count data model that accounts for the panel nature of the data is proposed. We employ a negative binomial model with fixed time and random group effects. The random-group effects treatment of panel data allows for individual heterogeneity and the correlation among responses from the same individual. The fixed-time effects treatment (scenario dummy variables) helps examine the potential structural changes in demand for seafood in different scenarios. A brief discussion of the construction of the model is as follows.

The Poisson regression is typically used to study count data, in our case the number of seafood meals in a month. Assume that X_{lit} , the number of seafood meals eaten by the individual i in the scenario t , is drawn from a Poisson distribution with mean μ_{it} .

$$(8) \quad \text{Pr ob}(X_{lit} = x_{lit}) = \frac{e^{-\mu_{it}} \mu_{it}^{x_{lit}}}{x_{lit}!} \quad x_{lit} = 0, 1, 2, \dots$$

The logarithm of the mean seafood consumption μ_{it} is assumed to be a function of a vector of variables W including price, risk, income, and individual characteristics. In addition, to allow for variation across observations that cannot be explained by the regressors, we assume that μ_{it} also depends on a random variable (u_{it}).

$$(9) \quad \ln \mu_{it} = \beta' W_{it} + u_{it} \quad i=1, \dots, n; \quad t=1, 2, 3, 4.$$

If $\exp(u_{it})$ follows a gamma distribution with equal (and constant) scale and shape parameters (θ, θ) , then the unconditional number of meals x_{it} follows a negative binomial distribution. If $\exp(u_{it})$ is assumed to follow a gamma distribution with parameters varying across groups (θ_i, θ_i) , and $\theta_i/(1+\theta_i)$ follows a beta distribution with parameters (a, b) , then the random group effects are "layered onto the negative binomial model" (Greene (1998)). It also indicates the possible correlation in responses to different scenarios for the same individual. Hausman, Hall, and Griliches (1984) first proposed this random-effects negative binomial model.⁶

To examine other potential differences across scenarios, the scenario dummies are included in the model; that is, we also allow for fixed time effects--the panel data terminology--in the model. An important and debated issue in the environmental valuation literature is the compatibility of revealed and stated data. In our case, the first scenario is the *revealed* seafood consumption and the other three scenarios contain information on *stated* seafood consumption. Hence, one fixed time

effect to be of particular interest is the first (revealed) scenario against the three other (stated) scenarios. We include a fixed time effect dummy variable, SP, to indicate the stated preference scenarios.⁷ The significance of SP is one test for incompatibility of the revealed and stated data.⁸

An individual's change in consumer surplus (CS) of a risk reduction is measured by the area between two demand curves corresponding to two risk levels and bounded by current and choke prices. Corresponding to our econometric model that the mean demand for seafood is a semi-log function, the total change in CS, which is the area bounded by two demand curves as shown in Figure 1, can be calculated as follows (Bockstael, Hanemann, and Strand (1984)).

$$(10) \quad \Delta CS = \frac{X_1(\pi_2)}{\beta_1} - \frac{X_1(\pi_1)}{\beta_0},$$

where $X_1(\pi_1)$ is the seafood consumption with current risk and β_0 is the price coefficient in the original demand function; $X_1(\pi_2)$ is the seafood consumption under reduced risk and β_1 is the price coefficient in the new demand function. The independent variables are evaluated at their means for these calculations. If the slope coefficient of price remains the same after the risk reduction, the benefit measure in (10) can be simplified to $\Delta CS = \frac{X_1(\pi_2) - X_1(\pi_1)}{\beta}$. We can also calculate the change in CS per meal by dividing (10) by the average number of meals consumed per month.

5. Estimation Results

⁶ Alternatively we may assume u_{it} to be normally distributed, although estimation will be much more complex.

⁷ A more general treatment of the fixed time effects is to include three dummy variables (e.g., TIME2, TIME3, and TIME4) as regressors to distinguish the mean number of seafood meals consumed, μ_{it} in four scenarios, so the baseline model is the first scenario (the revealed response). We can compare each of the stated scenarios with the stated scenario separately by examining the coefficients of the dummies. An overall test for compatibility of revealed and stated data will be to test the sum of the coefficients (TIME2, TIME3, and TIME4) equal to zero.

⁸ A random time effects model can also be estimated, although the number of periods is too short to have a meaningful hypothesis test.

The seafood demand estimation results are presented in Table 3. We begin with a count data model without treatments for the multiple responses from the same respondent. The negative binomial model estimates the mean seafood demand as a semi-log function of price, absolute and relative risks, income, individual characteristics, and a random variable (u_{it}) to allow for variation across individuals that cannot be explained by the regressors. We examine the impact of the perceived absolute and relative probabilities of sickness from seafood, poultry, and meat on seafood consumption.

Model 1 includes the perceived absolute risks (ABRSK, POPSICK, MTPSICK) as regressors and Model 2 examines the perceived absolute seafood risk and its relative risk to poultry and meat (ABRSK, DPRCNTCP, DPRCNTCM). The crucial difference between these two models is that in Model 2, by using the relative risk variables we allow the impact of seafood risk on seafood consumption to be influenced by the perceived risks of poultry and meat, which is quite plausible as discussed in section 2. The relative risk variables, DPRCNTCP and DPRCNTCM, are defined as the additional risk of seafood relative to poultry or meat. We choose this definition of relative risks for the clear interpretation of their coefficients. Alternatively, one can use the proportional risks ABRSK/POPSICK and ABRSK/MTPSICK as regressors.

All coefficients on the risk variables and the price of seafood are insignificant in Model 1. As the relative risks are included in Model 2, the perceived absolute seafood risk and the relative risk to poultry have a significant negative effect on seafood consumption--as predicted by the analytical model. The awareness of Pfiesteria has a negative impact on seafood consumption.⁹ All individual characteristics have expected signs. The white, the female, and the married tend to

⁹ Pfiesteria is a microorganism found in the water along the coast of South Carolina up to Delaware that is confirmed to cause fish deaths and possibly memory loss of the exposed humans in laboratory experiments.

consume less seafood. The older, the more educated, and those with higher incomes tend to consume more seafood.

The estimated Models 1 and 2 do not take into account the panel nature of the data; they do not consider the correlation of responses across four scenarios (from the same individual), nor do they distinguish between the different scenarios. We next estimate two negative binomial models with random group effects, Models 3 and 4, to incorporate the possible correlation of responses from the same individual. The estimation is significantly improved (with much larger values of log-likelihood and significant non-zero parameter values, a and b , for the beta distribution). The price of seafood has a significant negative impact on seafood consumption.¹⁰ The perceived absolute seafood risk also has a significant negative effect. The perceived absolute risk of poultry or meat is not significant but the perceived relative risk of seafood to poultry has a significant negative impact on seafood consumption. The results of Model 4 indicate that individual seafood consumption is affected by the perceived seafood risk and its risk relative to poultry, but not meat, which indicates that poultry is a risk substitute for seafood. By examining the correlation of food consumption in our data, seafood and poultry are substitutes and seafood and meat are complements. The effect of the relative seafood-poultry risk on seafood consumption makes sense for the substitutability between seafood and poultry. The results confirm the impact of inter-relationship of risks from different goods on good consumption--as discussed in section 2.

To examine the compatibility of data across scenarios, we also estimate the negative binomial model with fixed time effects (in addition to random group effects). The dummy variable *SP* to indicate the three sets of *stated* data is included in the model. The estimation results are

¹⁰ The effect of the price on seafood meals was also tested by decomposing PCFOOD into the current price and the hypothetical price increase (dP) and including both in the demand models. In these, the coefficient on the current price is not significantly different from zero. This result is not surprising with cross-section data and a definition of

reported as Models 5 and 6 in Table 3. Again, the difference between Models 5 and 6 is that Model 6 uses relative risk variables to allow the perceived risks of other foods to affect the relationship between seafood risk and seafood consumption. As seen, the seafood price and perceived seafood risk have negative effects on seafood consumption, and the risk of seafood relative to poultry has a significant negative effect on seafood consumption. The riskier seafood relative to poultry, the less is seafood consumption.

The stated preference dummy variable is not significantly different from zero. In this study, we do not reject the overall compatibility of the *revealed* and *stated* data.¹¹ The Models 1, 3, and 5 in Table 3 are nested to each other. So are the Models 2, 4, and 6. By simple likelihood ratio tests, the models with random group effects (Models 3, 4, 5, and 6) are preferred to the standard negative binomial models (Models 1 and 2). Comparing to Models 3 and 5, Models 4 and 6 allow for the relative risks to affect seafood consumption--as suggested by the analytical model. Since we do not reject the compatibility of data, Models 4 and 6 are statistically equivalent.¹²

We calculate CS changes for three risk reductions. From the data summary we know that on average seafood is perceived 31% riskier than poultry and is 59% riskier than meat. Based on the estimated models, we calculate the changes in CS per meal to make seafood as safe as poultry [$1-(1/1.31) \approx 23.7\%$ risk reduction] and meat [$1-(1/1.59) \approx 37.1\%$ risk reduction]. For comparison, we also calculate the change in CS for 50% risk reduction. Since the negative binomial models with random group effects are preferred, we focus our discussion of welfare measures on those models. For the Models 3 and 5, the calculation of welfare measures is

seafood meals that includes finfish and shellfish and seafood purchased from restaurants and from stores. The coefficient on the hypothetical price change is negative and significantly different from zero at the .01 level.

¹¹ Estimation with the general treatment of fixed time effects that include scenario dummy variables (TIME2, TIME3, and TIME4) is available upon request. The test of *revealed* versus *stated* data is $H_0: \text{coef_TIME2} + \text{coef_TIME3} + \text{coef_TIME4} = 0$.

straightforward since the risk reduction only affects the value of the seafood risk variable (ABRSRK). In Models 4 and 6, as the seafood risk is reduced, the values of both absolute and relative risk variables (ABRSRK, DPRCNTCP, and DPRCNTCM) are changed and should be reflected in the CS calculation. For simplicity, the change in CS per meal for a risk reduction is calculated by dividing the total change in CS by the average initial seafood consumption (=4.96 meals per month).¹³ The welfare estimates are presented in Table 4.

When seafood is made as safe as poultry (23.7% risk reduction), the CS is increased by \$.416 (\$.347) per meal based on Model 3 (5), and by \$.980 (\$.820) per meal based on Model 4 (6). When seafood is made as safe as meat (37.1% risk reduction), the CS is increased by \$.656 (\$.547) per meal based on Model 3 (5), and by \$1.552 (\$1.297) based on Model 4 (6). The increase in CS per meal with risk reduction is roughly linear. As noted, Models 4 and 6 allow for the impact of relative risks on seafood consumption. Consequently they predict approximately twice higher welfare gains than Models 3 and 5. Both the perceived absolute risk of seafood and its relative risks to other foods appear to affect the demand for seafood.

6. Concluding Remarks

This study differs from other risk and food safety studies in six ways. First, we show analytically how multiple risks enter demand equations in a nonlinear way, which implies the impact of relative risks on demands. Second, we elicit subjective baseline risk from survey respondents to help relax the unrealistic assumption of common baseline risk, which is crucial in examining relative risks. Third, we elicit multiple quantity responses under varying prices and

¹² We also examined the possible slope change by interacting PCFOOD with the scenario dummy variables and concluded that there was no slope change across scenarios. The estimation results are available upon request from authors.

¹³ According to the survey responses, on average the seafood consumption goes up to 5.95 per month for the proposed risk reduction. Using the initial seafood consumption as the denominator to calculate the per meal CS can overestimate the welfare effect. Alternatively we can use the new average seafood consumption (5.95) or estimated

risks to trace out the movement along the demand curve and the shift of the demand curve. Fourth, we incorporate panel data analysis into our empirical model to account for individual heterogeneity, response correlation, and the potential structural changes in demand across different scenarios. Fifth, we combine revealed and stated data in examining the effect of risk changes on demand. Sixth, we compute the welfare gains for consuming a good when it is made as safe as other related goods.

In the application, our results show that seafood consumption is affected by the perceived absolute risk and by its relative risk to poultry. It suggests that an individual's seafood consumption is affected by the risk relative to poultry, but not meat. The results suggest the possibility of a particular formulation of the expected utility model (1) and/or non-constant marginal utility of income in different states of utilities. The possible "risk separability" of consumption of goods in various functional forms of the utility and probability functions is left for future study.

The prices of related goods are not included in our estimation due to unavailability of data. To fully examine the impact of changes in absolute and relative risks on demands, it is necessary to construct the full demand system of equations to account for substitution effects. Also, in this study we examine the general risk perception of illness from food consumption. The severity of illness is not distinguished, nor is the short term versus long term risk. To explore the welfare effects of different levels/types of risks, more extensive risk information must be elicited in future research.

consumption predicted by the estimated models (Bockstael and Strand (1987)). Nonetheless, the qualitative conclusion is the same.

References:

- Adamowicz, Wiktor, Joffre Swait, Peter Boxall, Jordan Louviere, and Michael Williams, "Perceptions versus Objective Measures of Environmental Quality in Combined Revealed and Stated Preference Models of Environmental Valuation," Journal of Environmental Economics and Management 32, 65-84 (1997).
- Bockstael, Nancy E. and Ivar E. Strand, Jr., "The Effect of Common Sources of Regression Error on Benefit Estimates," Land Economics 63, 11-20 (1987).
- Bockstael, Nancy E., W. Michael Hanemann, and Ivar E. Strand, "Measuring the Benefits of Water Quality Improvements Using Recreation Demand Models," Benefit Analysis Using Indirect or Imputed Market Methods, Volume II, project report to Office of Policy Analysis, Office of Policy and Resource Management, U. S. Environmental Protection Agency, Washington D.C., 1984.
- Brown, Deborah J. and Lee F. Schrader, "Cholesterol Information and Shell Egg Consumption," American Journal of Agricultural Economics 72, 548-555 (1990).
- Eom, Young Sook, "Pesticide Residue Risk and Food Safety Valuation: A Random Utility Approach," American Journal of Agricultural Economics 76, 760-771 (1994).
- Fein, Sara B., C.-T. Jordan Lin, and Alan S. Levy. "Foodborne Illness: Perceptions, Experience, and Preventive Behaviors in the United States." Journal of Food Protection 58, 1405-1411 (1995).
- Greene, William H. LIMDEP Version 7.0 User's Manual, New York: Econometrics Software, Inc., 1998.
- Hausman, Jerry, Bronwyn H. Hall, and Zvi Griliches, "Econometric Models for Count Data with an Application to the Patents - R&D Relationship," Econometrica 52, 909-938 (1984).
- Kahneman, Daniel and Amos Tversky, "Prospect Theory: An Analysis of Decision Under Risk," Econometrica 47, 263-291 (1979).
- Lin, C.-T. Jordan and J. Walter Milon, "Attribute and Safety Perceptions in a Double-Hurdle Model of Shellfish Consumption," American Journal of Agricultural Economics 75, 724-729 (1993).
- Lin, C.-T. Jordan and J. Walter Milon, "Contingent Valuation of Health Risk Reductions for Shellfish Products." In Valuing Food Safety and Nutrition edited by Julie Caswell. Bolder, CO: Westview Press, 1995.
- Smith, Mark E., Eileen van Ravenswaay, and Stanley R. Thompson, "Sales Loss Determination in Food Contamination Incidents: An Application to Milk Bans in Hawaii," American Journal of Agricultural Economics 70, 513-520 (1988).

Van Ravenswaay, Eileen O. and Jennifer Wohl. "Using Contingent Valuation Methods to Value the Health Risks from Pesticide Residues When Risks are Ambiguous." In Valuing Food Safety and Nutrition edited by Julie Caswell, Bolder, CO: Westview Press, 1995.

Wilson, Kenneth, Claudia Williams, Melanie Meekins, Michael Handley, Jennifer Clarke, "Annual Survey of Eastern North Carolina: Methods Report," Survey Research Laboratory, East Carolina University, Greenville, NC 1998.

Table 1. Description of Data

Variables	Definition	Combined Sample		Poultry Safest		Meat Safest	
		Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
SEAMEAL	# of seafood meals per month	4.96	6.03	4.87	6.34	5.02	5.86
PCFOOD	Price per seafood meal (\$)	11.80	6.15	11.63	6.11	11.90	6.18
ABRSK	Prob. of sickness from a seafood meal	0.041	0.122	0.057	0.154	0.032	0.098
POPSICK	Prob. of sickness from a poultry meal	0.046	0.124	0.054	0.153	0.041	0.104
MTPSICK	Prob. of sickness from a meat meal	0.049	0.136	0.081	0.187	0.031	0.090
DPRCNTCP	(ABRSK-POPSICK)/ POPSICK	0.11	1.17	0.33	1.23	-0.01	1.11
DPRCNTCM	(ABRSK-MTPSICK)/ MTPSICK	0.27	1.47	0.07	1.26	0.39	1.56
CFLIKELY	=1 definitely get sick from seafood =2 very likely to get sick from seafood =3 somewhat likely =4 not very likely =5 will not	3.88	0.79	3.89	0.76	3.87	0.81
PFIESTER	=1 heard of Pfiesteria	0.634	0.482	.625	.485	.639	.481
EFFECT	=1 if the proposed seafood inspection program is thought to be very effective =2 somewhat effective =3 not very effective =4 completely ineffective =5 don't know	1.86	0.81	1.86	0.77	1.86	0.82
EFFECTDK	=1 if EFFECT=5	0.01	0.11	0.01	0.10	0.01	0.11
COASTAL	=1 live in a coastal country	0.72	0.45	0.67	0.47	0.76	0.43
WHITE	=1 if white	0.72	0.45	0.64	0.48	0.76	0.43
FEMALE	=1 if female	0.62	0.49	0.71	0.46	0.57	0.50
MARRIED	=1 if married	0.60	0.49	0.58	0.49	0.62	0.49
AGE	Age of the respondent	44.40	15.66	45.04	17.43	44.03	14.55
HSGRAD	=1 high school graduate	0.94	0.25	0.91	0.29	0.95	0.21
UNIVGRAD	=1 college graduate	0.16	0.37	0.16	0.36	0.17	0.37
INCOME3	Annual income in \$1,000	37.17	21.68	34.24	21.08	38.84	21.85
GROUP2	=1 if poultry is thought safest among seafood, poultry, and meat	0.36	0.48				
FUNNY	=1 if (poultry is thought safest yet DPRCNTCP<0) or (meat is thought safest yet DPRCNTCM<0)	0.21	0.41	0.18	0.38	0.22	0.42
FUNNY2	=1 if (poultry is thought safest yet ABRSK-POPSICK<-0.001) or (meat is thought safest yet ABRSK-MTPSICK<-0.001)	0.10	0.30	0.07	0.26	0.11	0.32
#Obs		1060		384		676	

Table 2. Summary Statistics

Variables	Total Sample		Scenario1: Current Price and Current Risk		Scenario2: Higher Price and Current Risk		Scenario3: Current Price and Lower Risk		Scenario4: Higher Price and Lower Risk	
	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
SEAMEAL	4.96	6.03	4.91	5.48	4.06	5.49	5.95	6.68	4.94	6.27
PCFOOD	11.80	6.15	9.78	5.66	13.82	5.98	9.78	5.66	13.82	5.98
ABSRSK	0.041	0.122	0.043	0.127	0.043	0.127	0.039	0.118	0.039	0.118
DRSKCP	-0.005	0.061	-0.002	0.076	-0.002	0.076	-0.007	0.041	-0.007	0.041
DRSKCM	-0.008	0.069	-0.006	0.076	-0.006	0.076	-0.010	0.060	-0.010	0.060
DPRCNTCP	0.11	1.17	0.31	1.52	0.31	1.52	-0.09	0.58	-0.09	0.58
DPRCNTCM	0.27	1.47	0.59	1.98	0.59	1.98	-0.04	0.46	-0.04	0.46
#Obs	1060		265		265		265		265	

Table 3. Negative Binomial Models

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	1.460*** (6.558)	1.509*** (6.909)	3.422*** (8.934)	3.540*** (9.177)	3.521*** (8.821)	3.608*** (9.122)
SP					0.092 (1.391)	0.069 (1.052)
PCFOOD	-0.003 (-0.705)	-0.003 (-0.754)	-0.035*** (-7.099)	-0.035*** (-7.190)	-0.041*** (-7.499)	-0.039*** (-7.156)
ABRSRK	0.188 (0.171)	-0.749*** (-2.582)	-1.489*** (-3.377)	-1.107*** (-3.022)	-1.448*** (-3.189)	-1.115*** (-3.002)
POPSICK	-0.714 (-0.747)		-0.357 (-0.311)		-0.412 (-0.345)	
MTPSICK	-0.325 (-0.457)		0.686 (0.784)		0.676 (0.764)	
DPRCNTCP		-0.066* (-1.822)		-0.052** (-2.336)		-0.051** (-2.327)
DPRCNTCM		0.011 (0.699)		-0.018 (-0.976)		-0.013 (-0.729)
PFIESTER	-0.123** (-1.989)	-0.129** (-2.077)	-0.097 (-0.881)	-0.122 (-1.084)	-0.104 (-0.926)	-0.124 (-1.090)
EFFECT	-0.068 (-1.485)	-0.075* (-1.645)	0.026 (0.320)	0.020 (0.231)	0.024 (0.301)	0.018 (0.214)
EFFECTDK	-0.414 (-0.763)	-0.370 (-0.682)	-0.547 (-0.599)	-0.528 (-0.573)	-0.559 (-0.608)	-0.533 (-0.575)
COASTAL	-0.076 (-1.194)	-0.074 (-1.128)	-0.096 (-0.802)	-0.097 (-0.778)	-0.101 (-0.826)	-0.100 (-0.797)
WHITE	-0.449*** (-6.842)	-0.461*** (-7.023)	-0.304** (-2.506)	-0.319*** (-2.610)	-0.302** (-2.398)	-0.319** (-2.534)
FEMALE	-0.091* (-1.704)	-0.103* (-1.907)	-0.162 (-1.527)	-0.174 (-1.603)	-0.161 (-1.489)	-0.173 (-1.577)
MARRIED	-0.233*** (-3.613)	-0.238*** (-3.697)	-0.165 (-1.396)	-0.174 (-1.465)	-0.167 (-1.393)	-0.175 (-1.452)
AGE	0.008*** (4.663)	0.008*** (4.701)	0.004 (1.224)	0.004 (1.230)	0.004 (1.014)	0.004 (1.080)
HSGRAD	0.554*** (3.648)	0.522*** (3.468)	0.288 (1.186)	0.264 (1.127)	0.294 (1.190)	0.269 (1.130)
UNIVGRAD	0.172** (2.065)	0.166** (1.972)	0.249* (1.685)	0.243* (1.651)	0.253* (1.707)	0.245* (1.657)
INCOME3	0.003** (2.070)	0.003** (2.168)	0.003 (1.044)	0.004 (1.215)	0.003 (1.072)	0.004 (1.230)
GROUP2	-0.094 (-1.471)	-0.074 (-1.154)	-0.125 (-0.993)	-0.106 (-0.851)	-0.126 (-0.971)	-0.105 (-0.827)
FUNNY2	-0.519*** (-4.010)	-0.559*** (-4.560)	-0.489* (-1.871)	-0.528** (-2.091)	-0.492* (-1.821)	-0.527** (-2.040)
u	0.663*** (14.929)	0.661*** (14.815)				
a			8.902*** (8.569)	9.286*** (8.284)	9.206*** (8.054)	9.520*** (7.927)
b			1.903*** (7.810)	1.884*** (7.829)	1.844*** (7.764)	1.842*** (7.764)
log-likelihood	-2781.51	-2780.50	-2391.83	-2385.99	-2389.27	-2384.57
Cases			265	265	265	265
Panels			4	4	4	4
#obs	1060	1060	1060	1060	1060	1060

The numbers in the parentheses are the t ratios.

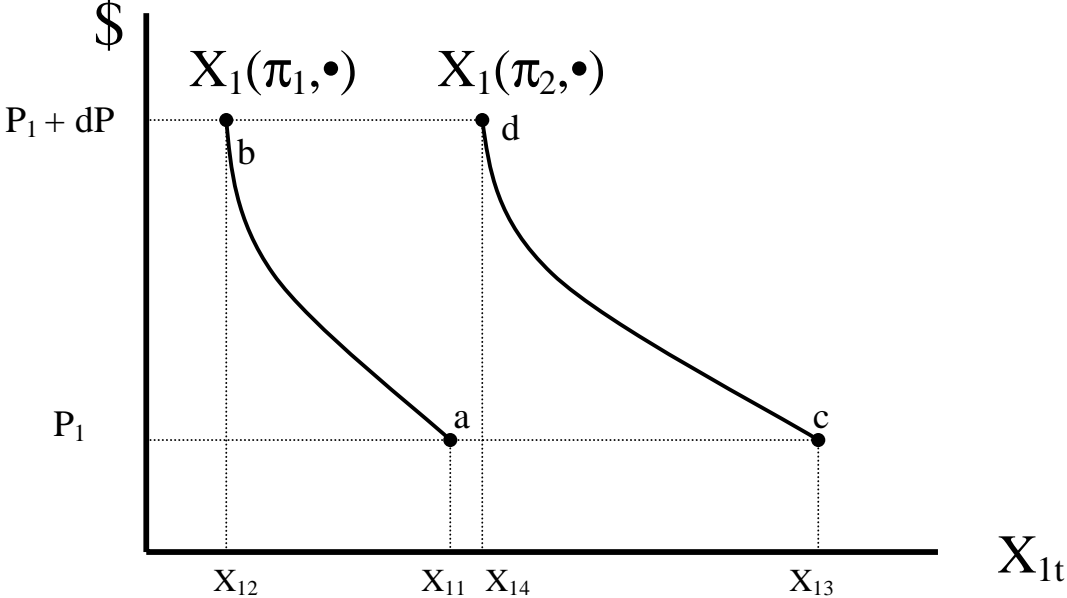
The symbols *, **, and *** indicate significance at .1, .05, and .01 levels, respectively.

Table 4. Welfare Measures of Risk Reductions

Welfare Measure (Change in Consumer Surplus Per Meal)	Model 3	Model 4	Model 5	Model 6
To make seafood as safe as poultry (23.7% risk reduction)	.416 (.136)	.980 (.229)	.347 (.120)	.820 (.205)
To make seafood as safe as meat (37.1% risk reduction)	.656 (.215)	1.552 (.364)	.547 (.190)	1.297 (.327)
To make seafood twice as safe (50% risk reduction)	.887 (.291)	1.862 (.437)	.740 (.258)	1.566 (.393)

The numbers in the parentheses are the standard errors.

Figure 1. Seafood Demand



Appendix

Q4. Do you eat seafood (fish and shellfish)?

- 1 yes
- 2 no

Q5. About how many times, including breakfast, lunch, and dinner, do you eat fresh seafood (fish and shellfish) in a typical month?

_____ meals

Q10. To the nearest dollar, how much does an average fresh seafood meal cost you? [if asked whether this is for restaurant or store bought meal, tell them whatever is typical for them]

\$_____

Q11. Seafood prices change over time. For example, if a lot of fish are caught prices go down. When fewer fish are caught prices go up. Suppose the price of your average seafood meal goes up by \$[randomly choose one of the following dP amounts: \$1, \$2, \$3, \$4, \$5] but the price of your average poultry and meat meals stay the same. How many meals of fresh seafood do you think you would eat in a typical month?

_____ meals

Q20. There is a small chance of getting sick from eating most food due to poor food handling practices or pollution. Among fresh seafood, poultry, and meat, which food do you think is MOST LIKELY to make you sick?

- 1 fresh seafood
- 2 poultry
- 3 meat

Q21. Which food do you think is LEAST LIKELY to make you sick?

- 1 fresh seafood
- 2 poultry
- 3 meat

Group 2 [For those who think poultry is the safest]

Q54. How likely do you think it is that you will get sick from eating fresh seafood in a typical month? Would you say ... ?

- 1 definitely
- 2 very likely
- 3 somewhat likely
- 4 not very likely
- 5 or you would not get sick

Q55. To get a better idea of how likely you think it is that you will get sick from eating fresh seafood, consider the following situation. Suppose 1 million fresh seafood meals are prepared and eaten in a typical month in eastern NC. How many of these 1 million meals do you think will result in someone getting sick?

Q60. Currently, there is no fresh seafood inspection program in the US. But the US Food and Drug Administration is proposing a regulation to establish one. The program will establish uniform guidelines for fresh seafood inspection and start random inspections and labeling of fresh seafood. The goal of the program is to reduce the risk of getting sick from eating seafood to be equal to the risk of getting sick from eating poultry. How effective do you think this program will be in reducing the risk associated with eating fresh seafood?

- 1 very effective
- 2 somewhat effective
- 3 not very effective
- 4 completely ineffective

Q61. Suppose the proposed seafood inspection program is successful in reducing the risk of getting sick from eating seafood to that of eating poultry. If the price of your average fresh seafood, poultry, and meat meals stay the same, how many meals of fresh seafood do you think you would eat in a typical month?

_____ meals

Q64. The proposed inspection program may result in higher prices for fresh seafood in restaurants and supermarkets. Suppose the price of your average seafood meal rises by \$[insert dP from Q11]. The price of your average poultry and meat meals stay the same. And the risk of getting sick from eating seafood would be the same as eating poultry. How many meals of fresh seafood do you think you would eat in a typical month?

_____ meals