Absolute versus Relative Risk Perception: An Application to Economic Values of Seafood Safety

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Paper Prepared for American Agricultural Economics Association Annual Meeting, Chicago, Illinois, 2001.

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April, 2001

* Helpful comments from the seminar participants at the Department of Agricultural and Resource Economics, North Carolina State University and the participants of the Kobe Conference on the Theory and Application of Environmental Valuation held in Kobe, Japan are gratefully acknowledged. The authors also thank Raymond Palmquist and V. Kerry Smith for insightful comments and Josh Olinick for research assistance.
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Abstract

We examine the impact of multiple risks of related goods on consumption of a risky good. We argue that the consumption of a risky good depends on both its absolute risk level and its relative risks to other risky goods. Seafood consumption in eastern North Carolina is studied. We elicit, in a survey, the individual perceived risks as the reference points to derive the economic value of reducing health risk in seafood consumption. Revealed and stated data are combined to trace out demand changes in response to absolute and relative risk reductions. 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 health Risk

1. Introduction

It is estimated by the Centers for Disease Control and Prevention (CDC) that foodborne diseases cause approximately 76 million illnesses, 325,000 hospitalizations, and 5,000 deaths in the United States each year. Various federal agencies such as USDA, FDA, and EPA devote significant resources to research on reducing food related health risks.[1] Most food safety studies focus on the physical and economic impacts of the health risk of one food or one pathogen. In reality individuals often consume multiple foods that can be substitutes or complements; hence, the consumption of one food can be affected by the health risks of related foods. It is seldom addressed (with the exceptions of Lin and Milon (1995)) how individuals respond to changes in risks of related foods, and if they respond to absolute or relative risk changes. The omission of effects of other risks can bias the economic value of risk reduction policies.

Different methods have been used to value risk reductions. In addition to accounting for the costs of illness and deaths, two commonly used techniques for deriving benefits of improving food safety are contingent valuation (CV) surveys and welfare analysis of the demand for a risky good. A typical CV survey asks survey respondents their willingness to pay (WTP) for a specified improvement of food safety. Comparatively, the demand analysis derives a quantitative relationship between consumption and the risk of illness from consumption. While it is intuitively appealing that a decrease in risk will increase economic welfare, empirical evidence based on either technique does not always support that 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

[1] For detailed information, see the website Gateway to Government Food Safety Information, http://www.foodsafety.gov.

valuation study, Lin and Milon conclude that there is an "absence of a systematic relationship between elicited WTP and risk information."

To value risk reduction, it is essential to establish a reference point; that is, to derive the individual baseline risk for comparison. Due to unavailability of individuals' perceived, or subjective, baseline risk measures, many risk valuation studies use the objective, or technical, risk measure acquired from historical events to explain changes in economic behavior (e.g., Smith, van Ravenswaay, and Thompson (1988), Brown and Schrader (1990), Lin and Milon (1993)). Two issues arise when the objective risk is used as the baseline risk for all individuals to value risk changes. First, the use of objective risk assumes the same technical risk as the baseline risk for all individuals. The potential discrepancy between the risk reduction stated in the research design and the risk change perceived by consumers can be the source of miscalculation of benefits. 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. Second, individual risk perceptions can differ and can be important in describing individuals' ex ante consumption decisions (Adamowicz, et al. (1997)). Using the objective risk for all individuals can be quite misleading and cause inconclusive results. There have been attempts to combine risk perception and objective risk information in valuing food safety (e.g., Eom (1994)), but the welfare gains remain unclear.[2]

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 affect demands. A possible analytical explanation of the importance of relative risks on the

[2] There are studies examining the impact of information on (non-food) risk perceptions (e.g., Smith and Johnson (1988) and McCluskey and Rausser (2001)). In this study, we focus on deriving individual perceived baseline risk and the consumption changes for a proposed risk reduction. It is assumed that there is no information update during the survey other than the proposed scenario of a fixed risk reduction.

consumption of a risky good is presented. In an application to seafood safety, 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. 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.

2. Analytical Model

We begin with a simple expected utility framework. Assume that an individual consumes n goods, x_1, x_2,…, x_n that could possibly cause illness, and a numeraire good z with no possibility of illness. The predetermined probabilities of illness from consuming one unit of the n goods are π_1, π_2,…, π_n. The consumer's budget constrained expected utility maximization problem is:

$$(1) \qquad \max_{x_1,\ldots,x_n,z} L = EU(x_1,\ldots,x_n,z;s,\pi_1,\ldots,\pi_n) + \lambda(Y - \sum_{i=1}^{n} p_i x_i - z),$$

where EU is the expected utility function; Y is income; p_1,…,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. In such a case, perceived probabilities of illness are more plausible than the objective/scientific risks to describe an individual's ex ante expected utility.

To examine the effect of multiple risky commodities on the consumers utility maximizing bundle, note that the consumers utility maximized budget identity is: $Y = \sum_{i=1}^{n} p_i x_i^* + z^*$, where x_i^*

represents the uncompensated demand for good i. Differentiating the budget identity with respect to an arbitrary risk probability π_j yields:

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

Assuming an increase in the risk associated with a good will decrease the quantity-demanded for that good such that: $\partial x_j^* / \partial \pi_j \leq 0$, 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.

One issue that remains is how multiple risks affect demands in theory. To examine the issue a simple model of a two-good world is presented. Due to non-linearity in the ex ante optimal demand function, not only does an absolute risk change affect the level of consumption, but it also affects the risk of consuming the good relative to the risk of consuming other goods.

The Two-Good Case

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

(3) $$EU = g(\pi_1,\pi_2,x_1,x_2)U^0 + (1-g(\pi_1,\pi_2,x_1,x_2))U^1,$$

where g(.) is the probability of staying healthy in a fixed time period that it is a function of π_1, π_2, and the consumption of x_1 and x_2. If we assume that the probabilities of illness are independent across units of consumption and the marginal probabilities of illness resulting from consuming x_1 and x_2 are independent of each other (which implies multiple joint probabilities), then the expected utility can be presented as follows.

$$\text{(4)} \qquad EU = (1-\pi_1)^{x_1}(1-\pi_2)^{x_2}U^0 + \left[1-(1-\pi_1)^{x_1}(1-\pi_2)^{x_2}\right]U^1 .$$

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.

$$\text{(5)} \quad x_1^* = -\frac{\dfrac{\partial EU}{\partial p_1}}{\dfrac{\partial EU}{\partial y}} = -\frac{\begin{array}{l}\left[\log(1-\pi_1)h_{p_1} + \log(1-\pi_2)k_{p_1}\right](1-\pi_1)^h(1-\pi_2)^k(U^0-U^1) \\ +(1-\pi_1)^h(1-\pi_2)^k U^0_{p_1} + \left[1-(1-\pi_1)^h(1-\pi_2)^k\right]U^1_{p_1}\end{array}}{\begin{array}{l}\left[\log(1-\pi_1)h_y + \log(1-\pi_2)k_y\right](1-\pi_1)^h(1-\pi_2)^k(U^0-U^1) \\ +(1-\pi_1)^h(1-\pi_2)^k U^0_y + \left[1-(1-\pi_1)^h(1-\pi_2)^k\right]U^1_y\end{array}}$$

$$= -\frac{(1-\pi_1)^h(1-\pi_2)^k\left[\left[\log(1-\pi_1)h_{p_1} + \log(1-\pi_2)k_{p_1}\right](U^0-U^1) + (U^0_{p_1} - U^1_{p_1})\right] + U^1_{p_1}}{(1-\pi_1)^h(1-\pi_2)^k\left[\left[\log(1-\pi_1)h_y + \log(1-\pi_2)k_y\right](U^0-U^1) + (U^0_y - U^1_y)\right] + U^1_y}$$

where h and k are the optimum consumption of x_1 and x_2 as functions of p_i, Y, and π_i; h_{p_1}, k_{p_1}, and U_{p_1} are the partial derivatives with respect to p_1; h_y and k_y are the partial derivatives with respect to Y; and U_y is the marginal utility of income. If the marginal utility of income is constant across states, then $U^0_y - U^1_y$ in the denominator in (5) becomes 0. The ex-ante optimum demand x_1^* is a highly nonlinear function of π_1 and π_2. Since these probabilities can affect the demand interactively, a demand equation linear in π_1 and π_2 may not capture the full effects. Additional terms such as the ratio or product of the two probabilities are needed. 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) $$\frac{\partial x_1^*}{\partial \pi_1} = -\frac{\partial \left[\dfrac{\dfrac{\partial E(U)}{\partial p_1}}{\dfrac{\partial E(U)}{\partial y}}\right]}{\partial \pi_1} = -\frac{[\dfrac{\partial^2 E(U)}{\partial p_1 \partial \pi_1}][\dfrac{\partial E(U)}{\partial y}] - [\dfrac{\partial E(U)}{\partial p_1}][\dfrac{\partial^2 E(U)}{\partial y \partial \pi_1}]}{[\dfrac{\partial E(U)}{\partial y}]^2},$$

which in general is also a highly nonlinear function of π_1 and π_2. 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 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.

3. Survey and Data

To investigate the effects of multiple risks on demand, data on food 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 consumption of fresh seafood, poultry, and meat meals during a typical month 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 a survey respondent thought would result in sickness.[3] The respondent's perceived risk is then measured as the number of meals divided by 1 million (π_k, where k=1 (seafood), 2 (poultry), 3 (meat)). Beforehand, the survey respondents 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.

[3] In the pretest, we tried different denominators including 1000 meals, 10,000 meals, and 1,000,000 meals. The mean perceived risk was similar. For more variation, we chose to use 1,000,000 meals.

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 us to compare the relative risk of eating seafood to that 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 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. 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 losses differently relative to the reference point. Since the seafood safest group was asked to evaluate a program to guard against losses as opposed to the poultry/meat safest groups to evaluate a program to improve (gain) quality of seafood, we expect the seafood safest group to respond differently than the poultry/meat safest groups. In this paper, to avoid combining the evaluation of two types of alternatives, we focus only on the valuation of gains (risk reductions). That is, 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 (the poultry/meat safest groups) [4]. Discarding cases with item non-response, duplicate/out of range identification numbers and unrealistic outliers, our study includes 265 respondents with 4 observations from each respondent, which amounts to the total of 1060 observations.[5]

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 average 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 (RSKCFOOD) is significantly different between two groups (t-statistic=2.87). The perceived relative risks of seafood to poultry and to meat are represented by RELRSKPL and RELRSKMT, respectively.

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[4] Despite the analytical reasoning for separating the seafood safest group from the poultry/meat safest groups in our data, econometrically sample selection issues must be discussed. To examine the sample selection issues, we estimate demand for seafood equations for all three poultry, meat, and seafood safest groups. Structural similarities between the poultry and meat safest sub-samples can not be rejected. The estimated demand function for the seafood safest sub-sample is structurally different from the demand function for the poultry and meat safest groups. This difference is not systematic with respect to the unobservable error and excluding these observations creates no significant selection bias. Joint models are also 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 poultry/meat safest sub-sample. The parameter estimates for the poultry/meat safest sub-sample are invariant to the inclusion of the seafood safest group.

[5] Among the 302 usable cases, there are 37 respondents whose perceived risk of seafood consumption is as least 10 times larger than the risk of either poultry or meat consumption, which results in convergence problems in estimation. The estimation results reported in this paper exclude those observations. 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.

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, REVERSE, to identify the observations with noticeably large discrepancy in their quantitative and qualitative risk perceptions.[6]

As described previously, 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 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 RELRSKPL in the scenario 1) more likely to get sick from eating seafood than from eating poultry and 59% (the mean of RELRSKMT 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.

[6] 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.

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_{it}, the number of seafood meals eaten by the individual i in the scenario t, is drawn from a Poisson distribution with mean μ_{it}.

(7) $$\Pr ob(X_{it} = x_{it}) = \frac{e^{-\mu_{it}} \mu_{it}^{x_{it}}}{x_{it}!} \qquad x_{it} = 0, 1, 2, ...$$

The logarithm of the mean seafood consumption μ_{it} is assumed to be a function of a vector of variables W including price, risks, 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}).

(8) $$\ell n \mu_{it} = \beta' W_{it} + u_{it} \qquad i=1,...,n; \; t=1,2,3,4.$$

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. This random-effects negative binomial model was first proposed by Hausman, Hall, and Griliches (1984).[7]

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.[8] The significance of SP is one test for incompatibility of the revealed and stated data.[9]

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 specification of a semi-log seafood demand 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)).

(9) $$\Delta CS = \frac{X_1(\pi_2)}{\beta_1} - \frac{X_1(\pi_1)}{\beta_0}.$$

$X_1(\pi_1)$ 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

[7] Alternatively we may assume u_{it} to be normally distributed, although estimation will be much more complex.
[8] A more general treatment of the fixed time effects is to include three scenario 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.

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 (9) 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 (9) by the average number of meals consumed per month.

5. Estimation Results

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 (RSKCFOOD, RSKPL, RSKMT) of seafood, poultry, and meat as regressors and Model 2 examines the perceived absolute seafood risk and its relative risk to poultry and meat (RSKCFOOD, RELRSKPL, RELRSKMT). 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, RELRSKPL and RELRSKMT, 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 RSKCFOOD/RSKPL and RSKCFOOD/RSKMT as regressors.

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

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.[10] All individual characteristics have expected signs. The white, the female, and the married tend to 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.[11] 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 negatively correlated, and seafood and meat are positively correlated.

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[10] Pfiesteria is a microorganism found in the water along the coast of South Carolina up to Delaware that is confirmed as one cause of fish kills.

[11] 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 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.

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 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.[12] 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.[13]

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

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[12] 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: coef_TIME2 + coef_TIME3 + coef_TIME4 = 0.

the estimated models, we calculate the changes in CS per meal to make seafood as safe as poultry [1-(1/1.31) ≈ 23.7% risk reduction] and meat [1-(1/1.59) ≈ 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 straightforward since the risk reduction only affects the value of the seafood risk variable (RSKCFOOD). In Models 4 and 6, as the seafood risk is reduced, the values of both absolute and relative risk variables (RSKCFOOD, RELRSKPL, and RELRSKMT) 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).[14] 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.

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[13] 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.

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

6. Concluding Remarks and Caveats

The focus of this study is the impact of multiple risks on consumption of a risky good. It differs from other risk and food safety studies in a number of ways. We show analytically how multiple risks enter demand equations in a nonlinear way, which implies an impact of relative risks on demands. 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. We elicit multiple quantity responses under varying prices and risks to trace out the movement along the demand curve and the shift of the demand curve. 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. We combine revealed and stated data in examining the effect of risk changes on demand and we compute the welfare gains for consuming a good when it is made as safe as other related goods. In this study we do not intend to address the issue of the potential gap between perceived and objective risks. Nor do we examine the information impact on perceived risk.

The empirical results support the analytical model that risk substitutes exist and relative risks matter. 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. 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.

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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
RSKCFOOD	Prob. of sickness from a seafood meal	0.041	0.122	0.057	0.154	0.032	0.098
RSKPL	Prob. of sickness from a poultry meal	0.046	0.124	0.054	0.153	0.041	0.104
RSKMT	Prob. of sickness from a meat meal	0.049	0.136	0.081	0.187	0.031	0.090
RELRSKPL	(RSKCFOOD-RSKPL)/RSKPL	0.11	1.17	0.33	1.23	-0.01	1.11
RELRSKMT	(RSKCFOOD-RSKMT)/ RSKMT	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 county	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
INCOME	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				
REVERSE	=1 if (poultry is thought safest yet ABSRSK-RSKPL<-0.001) or (meat is thought safest yet ABSRSK-RSKMT<-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		Scerario2: 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
RSKCFOOD	0.041	0.122	0.043	0.127	0.043	0.127	0.039	0.118	0.039	0.118
RELRSKPL	0.11	1.17	0.31	1.52	0.31	1.52	-0.09	0.58	-0.09	0.58
RELRSKMT	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***	1.509***	3.422***	3.540***	3.521***	3.608***
	(6.558)	(6.909)	(8.934)	(9.177)	(8.821)	(9.122)
SP					0.092	0.069
					(1.391)	(1.052)
PCFOOD	-0.003	-0.003	-0.035***	-0.035***	-0.041***	-0.039***
	(-0.705)	(-0.754)	(-7.099)	(-7.190)	(-7.499)	(-7.156)
RSKCFOOD	0.188	-0.749***	-1.489***	-1.107***	-1.448***	-1.115***
	(0.171)	(-2.582)	(-3.377)	(-3.022)	(-3.189)	(-3.002)
RSKPL	-0.714		-0.357		-0.412	
	(-0.747)		(-0.311)		(-0.345)	
RSKMT	-0.325		0.686		0.676	
	(-0.457)		(0.784)		(0.764)	
RELRSKPL		-0.066*		-0.052**		-0.051**
		(-1.822)		(-2.336)		(-2.327)
RELRSKMT		0.011		-0.018		-0.013
		(0.699)		(-0.976)		(-0.729)
PFIESTER	-0.123**	-0.129**	-0.097	-0.122	-0.104	-0.124
	(-1.989)	(-2.077)	(-0.881)	(-1.084)	(-0.926)	(-1.090)
EFFECT	-0.068	-0.075*	0.026	0.020	0.024	0.018
	(-1.485)	(-1.645)	(0.320)	(0.231)	(0.301)	(0.214)
EFFECTDK	-0.414	-0.370	-0.547	-0.528	-0.559	-0.533
	(-0.763)	(-0.682)	(-0.599)	(-0.573)	(-0.608)	(-0.575)
COASTAL	-0.076	-0.074	-0.096	-0.097	-0.101	-0.100
	(-1.194)	(-1.128)	(-0.802)	(-0.778)	(-0.826)	(-0.797)
WHITE	-0.449***	-0.461***	-0.304**	-0.319***	-0.302**	-0.319**
	(-6.842)	(-7.023)	(-2.506)	(-2.610)	(-2.398)	(-2.534)
FEMALE	-0.091*	-0.103*	-0.162	-0.174	-0.161	-0.173
	(-1.704)	(-1.907)	(-1.527)	(-1.603)	(-1.489)	(-1.577)
MARRIED	-0.233***	-0.238***	-0.165	-0.174	-0.167	-0.175
	(-3.613)	(-3.697)	(-1.396)	(-1.465)	(-1.393)	(-1.452)
AGE	0.008***	0.008***	0.004	0.004	0.004	0.004
	(4.663)	(4.701)	(1.224)	(1.230)	(1.014)	(1.080)
HSGRAD	0.554***	0.522***	0.288	0.264	0.294	0.269
	(3.648)	(3.468)	(1.186)	(1.127)	(1.190)	(1.130)
UNIVGRAD	0.172**	0.166**	0.249*	0.243*	0.253*	0.245*
	(2.065)	(1.972)	(1.685)	(1.651)	(1.707)	(1.657)
INCOME	0.003**	0.003**	0.003	0.004	0.003	0.004
	(2.070)	(2.168)	(1.044)	(1.215)	(1.072)	(1.230)
GROUP2	-0.094	-0.074	-0.125	-0.106	-0.126	-0.105
	(-1.471)	(-1.154)	(-0.993)	(-0.851)	(-0.971)	(-0.827)
REVERSE	-0.519***	-0.559***	-0.489*	-0.528**	-0.492*	-0.527**
	(-4.010)	(-4.560)	(-1.871)	(-2.091)	(-1.821)	(-2.040)
U	0.663***	0.661***				
	(14.929)	(14.815)				
a			8.902***	9.286***	9.206***	9.520***
			(8.569)	(8.284)	(8.054)	(7.927)
b			1.903***	1.884***	1.844***	1.842***
			(7.810)	(7.829)	(7.764)	(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

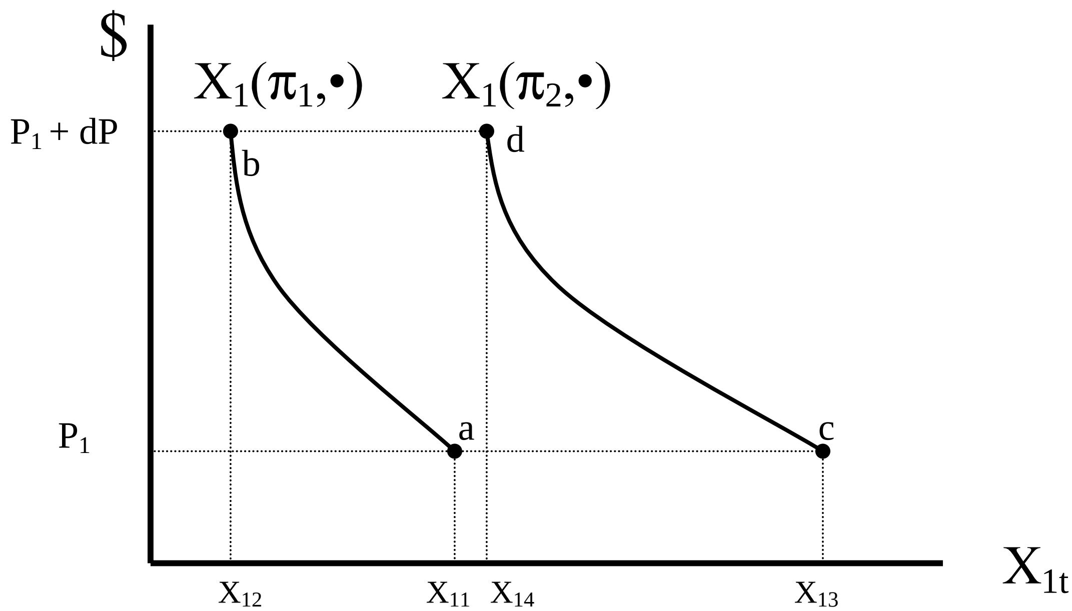
The numbers in the parentheses are the t ratios.
The symbols *, **, and *** indicate significance at .1, .05, and .01 levels, respectively.

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