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Perceived Hazard and Product Choice: An Application to Recreational Site Choice*

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Abstract

This study improves upon the standard "dummy variable" approach to modeling fish consumption advisories by jointly estimating a "perceived hazard" model and a site choice model. The perceived hazard model overcomes the shortcomings of the dummy variable model, namely that all anglers respond equally to advisories and that all anglers know of and believe the advisories. We find that anglers' perceived hazards associated with consumption advisories do affect product (recreational site) choice. Anglers' perceptions also affect welfare measures, where the benefits of contaminant removal follow a more reasonable pattern than that of the dummy variable approach. The joint perceived hazard/product choice model is applicable to a wide variety of risky choices with which consumers are faced.

1. Introduction

Consumers must often make choices in the presence of uncertainty and risk. Does one choose to purchase organic produce grown with little or no chemical inputs, or does one choose to consume conventionally grown produce that may contain cancer-causing pesticide residues? Does one avoid a genetically modified food product because of uncertainties surrounding its safety, or does one seek an unmodified food? Recreational users can face a similar choice: for example, does one choose to fish in waters that harbor contaminated fish which could cause cancer when eaten in sufficient quantity, or should one choose to fish elsewhere? This paper presents a model in which consumer choices, in this case the decision of where to fish, are influenced by a measure of perceived hazard associated with the "product" (fishing site). The econometric model estimates the recreational site choice decision jointly with a model of "hazard perception" for each fishing site.

Fish consumption advisories became widespread throughout the last decade of the twentieth century. Advisories warn anglers against consumption of fish due to toxic contamination, chiefly by mercury, PCBs, and dioxin. While advisories can be issued in many forms, all seek to warn anglers of the dangers associated with consumption of certain species of fish taken from particular lakes and streams. A number of authors have examined anglers' response to these warnings (*e.g.*, Jakus *et al.* 1997; Jakus *et al.* 1998; Triangle Economic Research 1998; Chen and Coslett 1998; Parsons and Hauber 1998; Parsons *et al.* 1999; Shaw and Shonkwiler 2000; Morey *et al.* 2000), but all have used some form of a dummy variable approach to measure the impact of advisories on anglers' behavior. In these models one of the attributes for each site is a dummy variable indicating the presence or absence of a fish consumption advisory (FCA).[1] This approach has a number of shortcomings. First, the dummy variable for fish consumption advisories may capture other site attributes that may be associated with fish contamination, but are not strictly related. For example, decreased harvest due to the advisories may increase the stock of fish available for catch-and-release anglers so that the FCA variable may be capturing stock effects. Second, the models assume that all anglers respond the same way to the advisories, an assumption that may be incorrect. Using the previous example, catch-and-release anglers may not be concerned about advisories because they will never consume the fish. Third, it is assumed that FCAs communicate information that is known, understood and followed by all anglers. Empirical evidence suggests this is not the case (Jakus *et al.* 1998; Burger *et al.* 1999; Pflugh *et al.* 1999).

The shortcomings of the current approach to modeling FCAs suggest that analysts should consider alternative ways to model advisories. This study presents one such alternative, where the FCA dummy variable is replaced with a site-specific measure of the *perceived hazard* associated with consumption of contaminated fish from that site. We draw upon prospective reference theory, the risk perception literature, and past empirical analysis of FCAs to specify an empirical model of perceived hazard associated with consuming fish from each fishing site. The measure of perceived hazard is then used as a site attribute in the site choice portion of the model.

The distinction between a model that uses expert-assessed risk (as implied by the dummy variable method) and one that uses a person's perceived risk is important. Economists often use observed behavior as the foundation for benefit and/or damage estimates, but these observed choices not based on expert-assessed risks.[2] Rather, people make choices based on their own personal risk assessment (*e.g.*, O'Connor et al. 1999). Thus, the welfare estimates used for benefit or damage assessment may differ according to whether the analysis uses expert-assessed risks or the "personal" assessment of risk on which behavioral choices are made.

The next section of the paper briefly reviews the risk perception literature. Prospective reference theory is examined, which provides a theoretical base for using personal risk assessments. We also review other empirical literature that has focused on peoples' responses to FCAs. Because our data do not perfectly correspond to the types used in other risk perception studies, the data that we have is explained in Section 3. Section 3 also develops an operational model of perceived hazard and recreational site choice, as revealed by anglers' behavior. The econometric results are presented in Section 4, followed by conclusions in Section 5.

2. What Are the Determinants of Perceived Risk?

2.1 What Influences Probabilities? The basic framework for economic analysis of risky decisions is the expected utility model developed by von Neumann and Morgenstern. The usual axioms of choice used in a model with certain outcomes (completeness, reflexivity, transitivity, continuity, monotonicity) are also maintained in the expected utility model with probabilistic outcomes.[3] A utility function based on the conventional theory has the expected utility property if for every gamble, g, $u(g) = Ó\ p_i\ u(a_i)$, where the a_i's are the outcomes, each with probability p_i. The probabilities, p, are known with certainty and are assumed to be understood, believed, and followed by the decision-maker. However, the expected utility framework is frequently inconsistent with observed behavior, so alternative models have been proposed.[4]

Prospective reference theory (PRT) was developed by Viscusi (1989) in response to the failure of the expected utility model to explain a wide variety of phenomena associated with choices with uncertain outcomes. The key aspect of PRT is that decisions are made according to a perceived risk, where perceived risk is a function of prior risk beliefs and expert risk assessments. Thus, the risk probabilities that affect decision-making represent a Bayesian updating approach, where weights are attached to both prior risk beliefs and expert risk beliefs. Viscusi and Evans (1998) recently reported a model that is conceptually very similar to that proposed here. Their model simultaneously estimated perceived risk probabilities and consumers' willingness to pay for products with varying safety attributes. Of particular interest is the formulation of the risk probability as perceived by any given subject:

$$(1) \qquad q = [\varphi\, r + \gamma\, p + \xi\, s] / [\varphi + \gamma + \xi]$$

where q is a person's perceived risk (probability of adverse outcome), r is the person's prior risk belief, p is a measure of the current (expert-assessed) risk associated with the product, and s is the risk associated with a "safer" product. The authors provided subjects with estimates of the risk associated the safety attributes of current (p) and improved (s) products. Subjects then chose among products that differed according to safety attributes and price. The empirical results indicate that the Bayesian updating model cannot be rejected, suggesting that PRT is a powerful theory in explaining choice under uncertainty. Further, the authors found that peoples' prior risk beliefs (r) were a significant component of perceived risk.[5] The implication for consumption of toxic fish is that expert assessments of hazards, as implied by consumption advisories, may have little effect relative to anglers' prior beliefs regarding the risks associated with consumption.

2.2 Personal Characteristics as Determinants of Risk Perceptions. Walker (1995) has found that people may believe that expert-assessed risks are informative for a population as a whole, but may act as if the population risk estimate does not apply to them. While not directly appealing to PRT, Walker's explanation is not inconsistent with it. Walker claims that people recognize that risk estimates can be rather imprecise, with a range of plausible risks above or below the stated figure. Further, people recognize that a population risk estimate is not necessarily applicable to them personally, for a variety of reasons. Walker argues that people assess "individuating factors" that may place them in the upper or lower tails of the risk distribution, and they make choices accordingly. Thus, someone who never eats a fish from a contaminated site may decide that the risk of contamination simply does not affect him and that consumption advisories are irrelevant to his site choice decision. As another example, someone who engages in averting behavior (consuming fish species other than those with an advisory, or engaging in "safe" cooking practices) may decide that he is at low risk relative to the population on which the risk assessment was made.

A number of empirical studies have found that demographic and other personal factors influence risk perceptions. For example, Viscusi *et al.* (1999) found that smokers tended to place less weight than non-smokers on expert risk assessments when two expert-assessments differed from one another. Flynn *et al.* (1994) discovered that perceived risk for a wide range of hazards varied by gender and race, where white males were found to have lower perceived risks for all hazards relative to non-whites or females. Burger *et al.* (1999) and Pflugh *et al.* (1999) found that anglers' belief in advisories, the perceived risk of contamination from fish consumption, and willingness to comply with advisories were all related to ethnicity.

3. Available Data and an Operational Model

3.1 Available Data. The data were collected as part of a long-term project sponsored by the Tennessee Wildlife Resources Agency. The primary goals of the data collection project are to monitor fishing, hunting, and wildlife-associated recreation in the state, as well as evaluate proposed changes in the management of fish and wildlife resources. General population random digit dial telephone surveys are conducted every six months. Respondents are asked about their outdoor activities during the previous six months. The data for this paper concern all reservoir anglers interviewed during four successive random digit dial surveys. The data cover reservoir fishing activities during one of four six-month month periods stretching from March 1997 through February 1999.[6] The data do not represent a true panel data set in that each angler appears only once in the data. Responses cover only one six-month period.

Anglers were asked about all trips to all Tennessee lakes and reservoirs during the specified six-month period. For each reservoir, anglers were asked how many fish they caught on an average trip to that reservoir, and how many fish they released on an average trip to that reservoir. Anglers were also asked if they were aware of consumption advisories on Tennessee reservoirs. Finally, anglers provided demographic information and information regarding the number of years they had been fishing.

The data are restricted to anglers from a 34 county region of east Tennessee. Statistics for the sample are presented in Table 1. The region lies east of the Cumberland Plateau, and ranges from Chattanooga, TN in the southwest corner of the study region to Bristol, TN in the northeast corner.

Anglers are faced with a choice set consisting of twelve major reservoirs, all of which are operated by the Tennessee Valley Authority. Six of the 12 reservoirs have had a fish consumption advisory issued for one or more species of fish. All advisories have been issued due to PCB contamination, which can cause cancer when they achieve sufficient concentration in an organism. Advisories are listed in the Tennessee Fishing Regulations booklet, as well as being posted at all boat launches and major bank fishing sites.

3.2 Modeling Perceived Hazard. The reader will note that the survey did not ask anglers directly about the risks associated with consuming fish from any given reservoir. Studies of risk perception will often have people rank relative risks for a variety of activities with potentially hazardous outcomes (*e.g.*, is driving a car more or less risky than riding a bicycle?). Much of the psychometric literature follows this approach. Another approach is to communicate risk probabilities and observe how people respond to them, as has been done in many empirical tests of prospective reference theory. The survey on which this paper is based did not directly elicit perceived risks or risk probabilities, but the data do provide insights into anglers' hazard perceptions.

In particular, the data reveal whether or not the angler kept fish from reservoirs that have consumption advisories (measured by the difference between the number of fish caught minus the number released). The act of keeping fish is highly correlated with (a) the number of meals prepared using reservoir-caught fish during the six-month period and, (b) whether the angler's primary goal for fishing was for consumption. Thus, it can be reasonably assumed that "keeping fish" is a measure of intent to eat the fish. This information can then be used as an indicator of anglers' perceived hazard associated with eating fish from any given reservoir.

The perceived health risk associated with consumption of fish at a given reservoir can be proxied by estimating the probability that an angler will keep fish from that reservoir. The term "perceived hazard" is used to differentiate our measure from the probability of an adverse outcome, which is often the measure used in the risk perception literature. The hazard measure to be used in this paper does not measure the probability of developing cancer as a result of fish consumption; rather, the probability of keeping fish from any given reservoir acts as a continuous indicator of perceived hazard, with higher (lower) probabilities indicating lower (higher) perceived hazard.

The probability of keeping fish at any fishing site *j* will be modeled using a two-level nested random utility model, where the angler first decides whether or not to keep fish followed by the decision at which site to keep fish. Conditional on having made the decision to keep fish, the angler can keep fish from any of the twelve sites in the choice set. Assuming an extreme value distribution for the probabilities, the conditional probability of keeping fish at site *j* is given by,

$$(2) \qquad \text{P(Keep Fish from Site } j \text{ | Keep Fish)} = [\exp(X_j\beta) / \Sigma_k^K \exp(X_k\beta)]$$

where the summation is over K sites, k = 1,…,12. The X vector contains the information believed to influence the decision to keep fish at site *j*, namely whether or not consumption advisories have been issued at the site. X may include a dummy variable that simply indicates an advisory is in effect, or it may contain a measure of "severity" of the contamination such as the number of species covered by the advisory.

At the top level is the decision to keep or not to keep fish, regardless of the characteristics of any particular reservoir. This level is required because many anglers have no desire to consume the fish they catch, instead preferring to release them. The "keep/no keep" level also allows the model to include angler-specific factors that influence the decision to keep fish at all, thus influencing the measure of perceived hazard. This probability is given by

$$(3)\qquad P(\text{Keep Fish}) = \{\exp[\phi \ln (\Sigma_k^K \exp(X_k\beta))]\} / \{ \exp[\phi \ln (\Sigma_k^K \exp(X_k\beta))] + \exp(Z\gamma) \}$$

whereas the probability of not keeping fish is given by,

$$(4)\qquad P(\text{Not Keep Fish}) = \{ \exp(Z\gamma) \} / \{ \exp[\phi \ln (\Sigma_k^K \exp(X_k\beta))] + \exp(Z\gamma) \}$$

Z represents a vector of variables believed to influence the keep/no keep decision. The numerator in equation (3) consists of the inclusive value associated with the keeping fish at any of the K sites (the logged summation term) multiplied by a parameter, ϕ.[7] The unconditional probability of keeping fish at any site j is given by the product of (3) and (4),

$$(5)\qquad P(\text{Keep at site } j) = [\exp(X_j\beta) / \Sigma_k^K \exp(X_k\beta)] \times$$

$$\{\exp[\phi \ln (\Sigma_k^K \exp(X_k\beta))]\} / \{ \exp[\phi \ln (\Sigma_k^K \exp(X_k\beta))] + \exp(Z\gamma) \}$$

More compactly, P(keep fish at site j) = $g(X, Z; \beta, \gamma, \phi)$, where the explanatory variables X and Z are specified using insights from the risk perception literature.

The risk literature has identified the importance of prior risk beliefs, individuating factors, and demographics. Severity of the risk can be measured by the number of species subject to an advisory at reservoir j and included in the vector X. A measure of advisory awareness is included in the vector Z, but Pflugh *et al.* (1999) and Burger *et al.* (1999) have noted that being aware of an advisory may or may not influence behavior because many people simply do not believe the warnings. These authors provide angler quotes such as, "I've fished here all my life and haven't gotten sick yet," and the like.

Pflugh and Burger suggest that anglers' prior experience is strongly connected to prior beliefs about risk, which is entirely consistent with the findings of Viscusi and Evans (1998). Thus a measure of fishing experience was needed: we use a dummy variable indicating whether or not the angler had begun fishing since the introduction of fish consumption advisories in Tennessee in 1986. This measure simultaneously captures an angler's experience and prior risk assessment. The key factor used in this analysis to individualize preferences for risk was the way in which anglers described their primary fishing purpose: did they fish primarily for consumption or for catch-and-release? It is anticipated that catch-and-release anglers will have very low "keep" probabilities for all sites. This is exactly what is desired, as very low probabilities for all sites implies that catch-and-release anglers find all sites are very similar in this attribute relative to those who fish for consumption. Finally, the vector *Z* includes demographic factors that others have found to influence perceived hazard (gender and race). One final factor that may influence the decision to keep fish is income, where it is hypothesized that low income anglers are more likely to keep fish than higher income anglers.

3.3 Connecting Perceived Hazard to the Site Choice Model. Site choice is assumed to be a function of site attributes *A*. The site attributes used in this model include travel cost, the average catch rate per trip, an index of reservoir ecosystem health, a measure of accessibility (the number of boat ramps interacted with whether or not the angler fishes from a boat, and the perceived hazard measure, *PH*. Again using the extreme value distribution, the site choice probabilities are given by,

(6) $$\text{Prob(visit site } j\text{)} = \exp(A_j\,\delta) \,/\, [\, \Sigma_k^K \exp(A_k\,\delta)]$$

where the summation is over K sites, k = 1,…,12. The measure of perceived hazard at site *j* is given by PH_j = 1 – Prob(Keep Fish at site *j*), or the probability that an angler would not keep and consume fish caught at site *j*. This transformation of the "keep probability" allows one to directly interpret PH_j as a hazard measure. Increasing values of PH_j indicate greater perceived hazards, whereas decreasing values indicate lower perceived hazards. Thus, the expected sign on this variable in the site choice model is negative. The site choice model and the perceived hazard model are estimated jointly.[8] The full information maximum likelihood function given by (7),

$$(7)\quad \ln L = \Sigma_i^N \left[\Sigma_j^J v_{ij} \ln P_j^V + \Sigma_j^J v_{ij}^k \ln P_j^K + v_i^{NK} \ln P^{NK}\right]$$

where the summation is over N observations and J recreational sites. The first term in the brackets is the site choice model, while the second and third terms are the hazard perception model. The v_{ij} are visits by person *i* to site *j*; P_j^V is the probability of visiting site *j*; v_{ij}^k is the number of visits by person *i* to site *j* during which fish were kept; P_j^K is the probability of keeping fish at site *j*; v_i^{NK} is the number of fishing trips during which person *i* kept no fish; and P^{NK} is the probability of not keeping fish at any site.

Other Modeling Considerations. Past research suggests that standard approach using a dummy variable as an instrument to capture consumption advisory effects is surely problematic. An advisory dummy variable as a site characteristic is not appropriate because anglers respond to advisories according to a personal assessment of the risk probabilities (*i.e.*, perceived hazard, as outlined in Viscusi *et al.* 1999 and Walker). Other determinants of perceived hazard include factors such as experience and demographic characteristics (*e.g.*, Burger *et al.*; Phlugh *et al.*). The dummy variable approach allows none of these factors to be included in the model. Thus, the dummy variable approach is subject to both measurement error *and* an omitted variables bias. Our choice is therefore between a standard model that is known to have serious deficiencies and an alternative approach that is more closely connected to both the theory of choice in the presence of risk and observed behavior in the presence of risk. We have followed the latter approach, but note that it too may be laden with some measurement error.[9]

4. Empirical Results

Parameter estimates for the joint perceived hazard/site choice model are presented in Table 2. The top portion of the table shows the results of the top level of the nested RUM for keeping fish, where the coefficients can be interpreted as if one were estimating a simple logit model for the probability of not keeping fish. The middle part of the table reports the coefficients that measure the probability of keep fish at any site *j*, conditional on the decision to keep fish. The bottom portion of the table reports parameters for the site choice model, which includes the perceived hazard measure (jointly estimated with the site choice model) .

4.1 Keep Fish /Don't Keep Fish Portion. The role of prior risk beliefs and familiarity with keeping fish was proxied by a dummy variable indicating whether the angler had begun fishing after the introduction of fish consumption advisories in Tennessee (about 1986). Those anglers who *Fished Fewer Than 12 Years* were less likely to keep any fish relative to those anglers who began fishing before the advisory program was in effect. With respect to the hazard perception index, "new" anglers perceived greater hazard than "older" anglers because they were less likely to keep fish. Also related to risk beliefs is an important "individuating factor": whether or not the angler believes he or she is at risk from FCAs is closely connected to whether or not fish are consumed. As might be expected, anglers who identified themselves as a *Catch-and-Release Angler* were less likely to keep fish than those who did not identify themselves as such. Catch-and-release anglers have greater measures of perceived hazard because the "keep" probabilities are very low for all sites.

Whether or not anglers were *Aware of Advisories* did not have an impact on the decision to keep or not to keep fish, but this should not be too surprising given the model specification. First, the keep/not keep model is for all reservoirs, not just those reservoirs with consumption advisories.

Second, the measure of awareness does not distinguish between those who fish solely for catch-and-release and those who do not, so it can be expected that some of those who know about advisories would never keep fish. Finally, the literature has demonstrated that even those who know about advisories might not necessarily heed them.

Neither *Female* nor *Nonwhite* were statistically significant predictors of the decision to keep or not keep fish, and so were not significant factors in determining the value of the perceived hazard measure for each reservoir. This was contrary to the findings of much of the risk perception literature, which has found that females and nonwhites generally perceive risks for any given hazard to be greater than the risk perceived by white males. *Income* was a statistically significant factor in explaining the decision to keep fish; those with higher incomes were less likely to keep fish. A dummy variable capturing the time period covered by the survey was statistically insignificant, suggesting that it did not matter when anglers were interviewed. Finally, the inclusive value parameter, ϕ, was positive and significant.

4.2 Keep Fish at Site j. The decision to keep fish at any given site was explained using a measure of FCA at each site and a set of site-specific intercepts. Intercepts were needed for three reservoirs (Douglas, Norris, and Watts Bar) because sample statistics indicated that anglers tended to keep fish from these reservoirs in much greater proportions than from other reservoirs. Over 4% of the full sample kept fish at each of these three reservoirs, whereas the next highest figure less than 3%. This suggests that other factors may be influencing the decision to keep at these sites relative to the remaining nine sites. Each of the site-specific intercepts was positive (as expected) and statistically significant. The FCA measure was the *# of Hazardous Species* at each site (the number of species for which some kind on an advisory had been issued). This variable was negative and significant, indicating that consumption of fish from sites with advisories was considered more hazardous than consumption from sites without advisories, and that the greater the number of hazardous species at the site, the more hazardous it was perceived.

4.3 *4.3* *Site Choice Model*. *Travel Cost* was a negative and statistically significant determinant of site choice. The average *Catch Rate* at the site was positive and significant; higher catch rates lead to greater probability of being visited relative to sites with lower catch rates, all else equal. The *Ecosystem Health Index* is a measure used by the Tennessee Valley Authority to evaluate the overall health of the reservoir environment for aquatic flora and fauna. Higher values of the index indicate better environmental conditions than lower values, so that a positive sign on the index was expected. Indeed, the parameter was positive and significant. Accessibility of reservoir sites was captured by the number of ramps at a reservoir interacted with whether the angler usually fished from a boat. The coefficient on this measure was positive, as expected, and statistically significant. The site choice model also included a site-specific intercept for Watts Bar reservoir, a very popular and highly developed reservoir located less than a hour from two major metropolitan areas (Chattanooga and Knoxville). While the expected sign on the intercept was positive, the actual sign was negative, but insignificant. Finally, the *Perceived Hazard Measure* was estimated jointly with the site choice model. For any given site j, perceived hazard is measured as [1 – P(keep fish at site j)]. Thus, the expected sign on this variable is negative. The empirical results show that the parameter was indeed negative and a statistically significant determinant of site choice.

4.4 *Estimated Welfare Measures*. A key test of the performance of the joint perceived hazard/site choice model is to observe the magnitude and distribution of welfare or benefit estimates. The welfare scenario chosen is PCB mitigation and removal of contaminated fish such that all fish consumption advisories can be lifted. Welfare changes associated with clean up and lifting of advisories are presented in Table 3.

The mean benefit estimate for clean up and lifting advisories is \$3.40 per angler per trip, with a 95% CI of \$0.96 to \$6.68. This average per trip estimate is quite comparable to the per trip measure found by other authors (*e.g.*, Jakus et al. 1997; Parsons et al. 1999). However, the hazard perception model has the added advantage of allowing one to differentiate anglers by personal risk assessment. If the model operates according to *a priori* expectations, a lower benefit measure should be observed for catch-and-release anglers than other anglers. This is the case. Catch-and-release anglers benefit to a very small degree, with a mean of \$0.15 per angler per trip (95% CI of \$0.03 to \$0.45). Anglers who consume their catch have much larger benefit measures, with a mean benefit of \$7.62 per trip (95% CI of \$2.17 to \$14.79). These results provide further support for the hazard perception model.

5. Conclusions

In this study we have modeled the impact of fish consumption advisories on recreational fishing using an econometric approach that jointly estimated a model of perceived hazard and recreational site choice. A joint hazard perceptions/site choice model is desirable because of a number of shortcomings of the traditional dummy variable method of estimating the benefits of fish consumption advisory removal. A hazard perception model can overcome the unreasonable assumptions of the dummy variable model; that advisories are applicable to all anglers, known by all anglers, and followed by all anglers. Further, the hazard perception model can be directly linked to the voluminous literature on risk perception because this literature provides the information required to specify the model.

The perceived hazard of fishing site *j* was modeled as the probability that an angler would refuse to keep and consume fish caught at site *j*. The empirical results support such an approach. The most important effect that a perceived hazard model should capture—increasing perceived hazards associated with increasing severity of the consumption warning—was a key empirical finding. Further, the empirical model also provided evidence that prior risk beliefs, as measured by angler experience, influence perceived hazard. Finally, the perceived hazard model found that an important individuating factor that affects personal perceived risk—whether the angler consumes fish at all—had the expected effect. Welfare measures for the sample as a whole were quite comparable to previous estimates found in the literature. Unlike those estimates, however, the hazard perception model permits the analyst to differentiate by angler type. In particular, it was found that catch-and-release anglers had a very low benefit from "cleaning up" the reservoirs, whereas anglers who consume their catch had a much higher benefit estimate.

The jointly estimated hazard perception/product choice model has applications beyond the realm of recreational choice. For example, the model could be applied to product choices involving other food safety decisions, such as choosing among produce items with varying degrees of chemical residues, choosing between meat (or milk) produced with growth hormones, or choosing between genetically modified foods or foods produced with traditional cross-breeding methods. Rather than rely upon an indicator variable to measure perceived risk (as we have done with the act of "keeping fish"), one could elicit risk (hazard) perceptions during the course of a consumer survey and then incorporate these responses in a joint model of hazard perception and product choice. The model is equally applicable to both revealed preference and stated preference methods.

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Table 1: Sample Statistics (n=457)

Variable	Mean
Number of fishing trips	15.3
Aware of Advisories (%)	70.2%
Fished for Less Than 12 years (%)	19.5%
Catch-and-release Angler (%)	56.5%
Gender (% female)	25.4%
Nonwhite (%)	5.0%
Income ($)	$43,459
Interviewed about Fall/Winter Activities (%)	51.2%

Table 2: Joint Hazard Perceptions/Site Choice Model

	Coefficient	**Asymptotic t-ratio**
Keep Fish/Don't Keep Fish Portion		
Fished Fewer Than 12 Years	1.793	2.985
Catch-and-release Angler	2.113	4.561
Aware of Consumption Advisories	-0.133	-0.377
Female	-0.213	-0.457
Nonwhite	-0.625	-0.837
Income ($10,000)	0.164	2.561
Interviewed About Fall/Winter Activities	0.147	0.337
Inclusive Value	0.335	1.958
Keep Fish at Site *j* Portion		
# Hazardous Species	-0.333	-1.680
Douglas Reservoir Intercept	0.875	2.204
Norris Reservoir Intercept	1.665	4.949
Watts Bar Reservoir Intercept	4.406	2.789
Site Choice Model		
Travel Cost	-0.046	-11.289
Catch Rate	0.479	4.311
Ecosystem Health Index	0.027	2.840
# Ramps ´ Boat Angler	0.017	2.491
Watts Bar Intercept	-0.310	-0.692
Perceived Hazard Measure	-10.989	-4.592

Ln L = -16,645.57 at convergence.

t-ratios based on the ratio of the coefficient to its asymptotic standard error. Standard errors calculated from White's robust variance-covariance matrix (1982).

Table 3: Benefit Estimates: "Clean Up" so as to Remove All Advisories ($/trip)

	Mean	**95% CI[a]**
All Anglers	$3.40	$0.96 - $6.68
Consumption Anglers	$7.62	$2.17 - $14.79
Catch-and-release Anglers	$0.15	$0.03 - $0.45

[a] 95% confidence intervals estimated using the method of Krinsky and Robb (1986).

ENDNOTES

[1] Morey et al. use a fairly elaborate set of dummy variables that capture both the species on which an advisory has been issued and the "severity" of the advisory (*i.e.*, do not consume any fish, consume fish in no more than one meal per month, etc.).

[2] An exception is a study by McClusky and Rausser (forthcoming) that estimates a property value model based on the perceived risk associated with a Superfund site.

[3] See Jehle and Reny, p.197.

[4] Machina (1987) outlines a number of problems associated with the expected utility model, while Starmer (2000) provides a recent survey of non-expected utility models. In addition to Viscusi's prospective reference theory, Kahneman and Tversky (1979) developed Prospect Theory, another well-known model of decision making in the presence of uncertainty. This model has been criticized because of its lack of testable behavioral hypotheses.

[5] Viscusi and Evans did not have a direct measure of r, but the econometric specification allowed them to eliminate the possibility that $r = 0$.

[6] The six month periods were March-August 1997, September 1997 through February 1998, March 1998 through August 1998, and September 1998 through February 1999.

[7] Intuitively, the inclusive value captures the "utility" associated with keeping fish. The parameter ϕ should have a positive value, indicating that as utility of keeping fish increases (*i.e.*, with contaminant remediation), the probability of keeping fish increases.

[8] The advantage of joint estimation is that one can avoid the econometric problems associated with two-stage model with a generated regressor.

[9] The joint perceived hazard/site choice model presented in the previous sections has some aspects in common with the Morey and Waldman (1998) measurement error model. The similarity is that the Morey-Waldman model estimates catch rates for each recreation site whereas our model estimates a perceived hazard for each individual, for each site. Train *et al.* (2000) have recently criticized the joint model, stating that the parameters from such a model can be biased and inconsistent. This is so because the standard random utility model cannot estimate a full set of site-specific constants, the endogenously estimated variable will act as a site-specific constant capturing all omitted effects.