Valuing Food Safety and Nutrition

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PART ONE: Setting the Stage: Research Perspectives and Theoretical Models

2. Self-Protection, Risk Information, and Ex Ante Values of Food Safety and Nutrition

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Over the past two decades, consumers have become increasingly concerned about the safety of available food and the potential linkage between diet and health. Traditionally, economists have used observed purchase behavior and tradeoffs that consumers make in the marketplace as a basis for inferences about consumers' preferences for and (implicit) values of certain food products. However, health risks and nutritional content are only part of bundles of attributes characterizing food products. That is, health risks and nutrition are nonmarket goods without directly observable price components. Therefore, the conventional consumer demand analysis may not be directly applicable in measuring the values that consumers place on changes in food safety or nutrition components.

In these circumstances, a natural tendency of economic modeling strategy is to establish some linkage between the nonmarket goods to be valued and observable market goods or private actions. Indeed, currently available empirical evidence suggests that consumers' concerns about food-related risks seem to motivate them to undertake some types of protective actions to reduce health risks (Swartz and Strand 1981, Smith et al. 1988, Foster and Just 1989, van Ravenswaay and Hoehn 1991a, Brown and Schrader 1990, Putler and Frazao 1991, Ippolito and Mathios 1990, Hammitt 1986, Rae 1987, Zellner and Degner 1989, Ott et al. 1991, van Ravenswaay and Hoehn 1991b, Conklin et al. 1992, Eom 1994).

While these studies provide evidence on consumers' revealed or stated preferences for safer and healthier food, most of the valuation research on food safety and nutrition has failed to incorporate consumers' risk perception processes into the behavioral framework. In studies investigating consumers' aggregate responses, risk information was measured using crude proxies such as number of news accounts appearing or dummy variables. On the other hand, the studies of individual responses assumed that consumers were aware of the technical estimates of risks with the exception of van Ravenswaay and Hoehn (1991b) and Eom (1994).

Unfortunately, the objective measure of food-related risk is not likely to be known exactly, even to scientific experts. Indeed, prominent psychologists such as Slovic et al. (1985) argue that there is no objective risk. In their view, all risks are subjective, whether judged by experts or lay people. In the formation of subjective risks, however, consumers often have imperfect and incorrect information about the event at risk and seem to be influenced by factors that are different from those influencing experts' risk assessments (Arrow 1982, Viscusi and Magat 1987, van Ravenswaay 1991). Recognizing this potential source of market failure, public information programs—product labeling or hazard warning—are alternative policy options for government regulations concerning food safety and nutrition. Growing empirical evidence suggests that consumers can learn about risks and update their risk perceptions after receiving new information (Viscusi and O'Connor 1984, Smith and Johnson 1988).

Therefore, a more plausible model describing consumers' behavior in the presence of food-related risks should begin with a formal analysis of the risk perception process. This chapter proposes to develop such a framework when consumption decisions must be made with incomplete information about food product attributes but self-protection actions to reduce adverse health effects are available. In terms of the three classes of household health production activities van Ravenswaay identified in the previous chapter (health maintenance, protection, and rehabilitation), the theoretical development in this chapter mainly focuses on household health protection activities to avoid harmful or hazardous exposure to contaminants, residues, or nutrients.

When we interpret consumers' protective responses to information, it is important to distinguish between two different perspectives of valuation measures—ex ante and ex post evaluation. Consumers' protective decisions focus on the probability distribution of health effects, not on the realization of health outcomes, arising from the consumption of certain food attributes. On the other hand, consumers' behavioral adjustments are undertaken after receiving (or acquiring) new information about food attributes. Hence, the valuation measures that will be derived in this chapter are ex ante measures with respect to health risks but ex post with respect to information about food attributes such as food safety or nutrients.

The next section begins by reviewing the conventional expected utility theory as a description of consumer purchase behavior with uncertain product attributes. However, our framework will modify the expected utility theory to address criticisms of the conventional framework (Arrow 1982, Slovic et al. 1985) and will extend it to a self-protection model, allowing adjustments to risks through averting behavior. Subsequently, we introduce a subjective self-protection model by treating the probability function as a subjective risk perception function based on available information. This formulation is static in the sense that learning is not taken into account. Finally, we introduce multiple time horizons into the subjective self-protection model to develop an integrated conceptual framework of risk perceptions, learning, and self-protection actions. This section also illustrates how information and self-protection can be incorporated into a Bayesian learning model. The last section provides some concluding remarks.

Expected Utility Theory and Ex Ante Value for Risk Reductions

This section outlines a model that describes a household's preferences in the presence of uncertain food quality, and uses it to derive monetary measures of willingness to pay for reductions in health risks before the quality uncertainty is resolved. A household's food purchasing decisions are made for all members of the household, so health risks from food consumption affect the entire household. However, following Becker's (1974) argument, we assume that a household decision process is the same as that of the household head, so that there exists a household preference that reflects all members' tastes.

Suppose a representative household allocates its given income over the primary food item (X) and other composite goods (Y). While the household observes some food attributes (such as color, size, shape, or freshness) prior to purchase, it does not know which particular "state of health" will actually occur from the consumption of X. For simplicity, the household is assumed to face only two states of the world—either the occurrence or nonoccurrence of adverse health outcomes. If it consumes the food item (X) suspected to contain harmful substances (residues or nutrients) over its lifetime, there is a probability π of the adverse health outcome. Because heath effects identified in the previous chapter (for example, getting cancer or having a heart attack) often involve unique and irreplaceable losses, the extreme characterization of health outcome seems reasonable. In these cases, the household is assumed to evaluate consumed food differently depending on the health outcome, implying state dependent preferences (Cook and Graham 1977). Thus, the household's state-dependent utility function can be defined as $U_b(X,Y)$ if the health event occurs, and as $U_g(X,Y)$ if it does not occur.

Given the above assumptions, household consumption behavior can be described as maximizing the following expected utility:

$$(1) \qquad \max_{X,Y} \; EU = (1 - \pi)\, U_g(X,Y) + \pi U_b(X,Y).$$

In the expected utility framework, the probability of the adverse health outcome,

π (i.e., the risk) is known or objectively given to the household (or the household acts as if it were able to attach the exact probability to various possible states of the world). Thus, the risk, π, is considered exogenous information over which the household has no control.

Following Becker (1965), we assume that the household faces a "full income" budget constraint, M. The full income constraint is defined as:

$$M = wT + A = (m_x + wt_x)X + Y = p_x X + Y \tag{2}$$

where:

m_x: money price of goods X relative to price of Y,
w: wage rate,
t_x: time spent for X relative to time spent on Y and assumed to be constant,
p_x: "full" price of X relative to "full" price of Y,
T: time endowment, and
A: non-wage asset income.

Since a household is assumed to make consumption decisions consistent with its objective—maximizing expected utility given the budget constraint—solving the constrained maximization problem, equations 1 and 2, yields the following state dependent indirect utility functions:

$$EU = \pi V_b(M,p_x) + (1 - \pi)\ V_g(M,p_x) \tag{3}$$

where $V_b(M,p_x) = U_b(X^*(M,p_x), M - X^*(M,p_x))$; $V_g(M,p_x) = U_g(X^*(M,p_x), M - X^*(M,p_x))$; and X* denotes an optimally chosen level of the commodity X. The state-dependent indirect utility functions in equation 3 are assumed to be well behaved and to satisfy the usual properties such as nondecreasingness in Y and convexity in p_x ($\partial V_i/\partial M > 0$ and $\partial V_i/\partial p_x < 0$, i = b,g).

It is important to note that risk, π, is treated as a parameter, like price (p_x) and income (M) in the expected utility function. Hence, marginal willingness to pay for changes of the exogenous risk can be derived by taking the total differential of the expected utility function, equation 3. By setting dEU equal to zero and setting dp_x equal to zero, we can solve for the income change that would need to be taken away from the household in response to an exogenous risk reduction if the two changes are to keep expected utility constant:

$$\frac{\partial M}{\partial \pi} = \frac{V_b - V_g}{\pi \partial V_b/\partial M + (1 - \pi)/\partial V_g/\partial M} = MRS_{\pi M}\ . \tag{4}$$

The left-hand side of equation 4[2] represents a gradient of the willingness to pay (WTP) risk schedule, which is equal to the marginal value of risk reduction.

The right-hand side of equation 4 is the marginal rate of substitution between π and M ($MRS_{\pi M}$), which is the difference between state-dependent utility functions divided by the expected marginal utility of income. However, it represents an *ex ante* tradeoff between income and risk because the household must reveal its value for risk changes before it experiences the adverse health outcomes. Equation 4 implies that the *ex ante* marginal willingness to pay (MWTP) for the risk reduction is equal to the *ex ante* marginal rate of substitution between income and risk. Note that equation 4 was commonly measured in job risk cases to represent the risk-dollar tradeoff selected by a worker (Viscusi 1979). For the case of the risk of premature death, this ex ante $MRS_{\pi M}$ represents the implicit value of one's statistical life. For the case of nonfatal injury, the rate of tradeoff represents the implicit value of per unit risk of injury.

Self-Protection Model and Ex Ante Value of Risk Reductions

The situations considered in our analysis—consuming chemically contaminated food or intake of fat or cholesterol—can be viewed as a case in which a household can take actions to reduce the food risks. For example, households could change their food preparation methods (i.e., spend more time in cleanup or cooking), or could decrease the consumption of the suspected food items and eventually shift to food items that are viewed to be safer and healthier.[3] In addition, households could engage in some preventative health behavior such as having a cholesterol test done or visiting doctors regularly. However, given the uncertainty of ultimate health effects, any actions undertaken by a household cannot yield a *certainty* of protection, but can only provide the reduction of the *probability* of the adverse health outcomes (i.e., the risk).

The recognition that risks can be affected by a household's action stimulated Ehrlich and Becker (1972) to develop the self-protection model. They argued that self-protection activities undertaken by a household would shift the whole probability distribution to the left to reduce the probability of adverse health outcomes and raise the probability of favorable health outcomes. Therefore, the household risk assessment was described as a function such as $\pi = \psi(v)$, where v is a vector of self-protection actions undertaken.

Our framework analyzing food purchase decisions follows Ehrlich and Becker's view and treats self-protection as a type of averting behavior. Thus, the expected utility framework discussed above is modified to describe the selection of self-protection actions undertaken (v) and how the self-protection actions would affect the probabilities ($\psi(v)$). Incorporating the opportunity of self-protection, the household aims to select the level of self-protection, v, as well as X and Y to maximize its expected utility as shown earlier:

$$EU = (1 - \psi(v))\, U_g(X,Y) + \psi(v)\, U_b(X,Y). \tag{5}$$

The health risk, π, is assumed to decrease as the household increases self-protective activities ($\partial\pi/\partial v < 0$). In addition, the household is assumed to know how its self-protection actions would affect the risk function, $\psi(v)$, as Ehrlich and Becker (1972) described. With the above assumptions, the health risk became endogenous in the household decision process but still remains "objective" information in that the functional relationship of the risk, $\psi(v)$, is known to the household.

The above description of the risk function allows the self-protection model to adopt the household production framework in the same way as averting behavior models (Gerking and Stanley 1986, Dickie et al. 1987, Berger et al. 1987). Risk, π, is equivalent to a final service flow produced using a vector of self-protection, v. Self-protection (v) may be considered to be household activities combining the householder's time and other resources (for example, a change in cooking preparation practices), and the purchase of nondurable products or services as essential inputs of the production process. Self-protection is not a direct source of utility. It only serves to reduce the health risk (i.e., nonjointness in the household production).[4]

Including the "full" price of v, p_v, the household's "full income" budget constraint can be modified from equation 2 to equation 6:

$$M = wT + A = (m_x + wt_x)X + Y + (m_v + wt_v)v \qquad (6)$$
$$= p_x X + Y + p_v v.$$

In equation 6, the opportunity cost of a household's time spent on v, X, and Y is assumed to be equal to the market wage rate.

The household production framework enables us to look at a household's choice problem in a two-stage decision process (Dickie et al. 1987, Deaton and Muellbauer 1980). In the first stage, the household is minimizing self-protection expenditures to obtain a given level of health risk such as:

$$C(p_v, \pi^o) = C = \min\ p_v v \qquad (7)$$
$$\text{s.t. } \pi^o = \psi(v).$$

This expenditure function has properties similar to a firm's cost function. It is positive, homogeneous of degree one, and concave in p_v. By Shephard's Lemma, the conditional demand function for self-protection is:

$$v = \frac{\partial C(p_v, \pi^o)}{\partial p_v} = v(p_v, \partial^o). \qquad (8)$$

In the second stage, expected utility is maximized subject to the budget constraint that induces self-protection expenditures from the first stage. Substituting equation 7 into equation 5, the Lagrangian is defined as:

$$L = [1 - \psi(C)]\ U_g(X,Y) + \psi(C)\ U_b(X,Y) + \mu[M - p_x X - Y - C]. \tag{9}$$

The optimally chosen self-protection expenditure, C, is to reduce risk but also to reduce income left over for consumption. Maximizing the expected utility for C, X, and Y subject to the budget constraint has the first order conditions:

$$\partial\pi/\partial C\ (U_b - U_g) - \mu = 0 \tag{10}$$

$$[(1 - \pi)\ \partial U_g/\partial X + \pi\partial U_b/\partial X] - \mu p_x = 0 \tag{11}$$

$$[(1 - \pi)\ \partial U_g/\partial Y + \pi\partial U_b/\partial Y] - \mu = 0 \tag{12}$$

$$M - p_x X - Y - C = 0. \tag{13}$$

Combining these equations gives:

$$\begin{aligned} \frac{\partial C}{\partial \pi} &= \frac{1}{(\partial\pi/\partial C)} = \frac{(U_b - U_g)}{\mu} \\ &= \frac{(U_b - U_g)}{[(1 - \pi)(\partial U_g/\partial Y) + \pi(\partial U_g/\partial Y)]} = MRS_{\pi Y}. \end{aligned} \tag{14}$$

The first term in equation 14 is the marginal self-protection expenditure which is observable. The last term is the *ex ante* marginal rate of substitution between π and Y ($MRS_{\pi Y}$) which is unobservable. Because of the assumption of the linear budget constraint and the normalized price of Y, the marginal utility of a composite good Y is equivalent to the marginal utility of income (i.e., $\partial U_i/\partial Y = \partial U_i/\partial M$) in each state of the world (i = g,b). This leads $MRS_{\pi Y}$ to be equal to $MRS_{\pi M}$. Hence, equation 14 can be rewritten as equation 15:

$$\frac{\partial C}{\partial \pi} = \frac{(U_b - U_g)}{[(1 - \pi)(\partial U_g/\partial M) + \pi(\partial U_g/\partial M)]}. \tag{15}$$

The right-hand side of equation 15 is exactly the same as that of equation 4. That means we can obtain equation 16 from equations 14 and 15:

(16) $$\frac{\partial M}{\partial \pi} = \frac{\partial C}{\partial \pi} = \frac{\partial C(p_v, \pi^o)}{\partial \pi} .$$

Equation 16 implies that the ex ante marginal willingness to pay for risk reduction is equal to the marginal self-protection expenditure of risk reduction. In other words, the marginal benefit of the reduction in risks is equal to the marginal cost of producing the same level of π, by increasing the use of v. For example, the willingness to pay for reduced risks from *Salmonella* contamination can be measured by the cost of additional time that consumers are willing to spend to prepare chicken more safely (Zellner and Degner 1989). In this framework, the estimation of marginal values of risk reductions requires only knowledge of household production technology and the price of protective behavior, p_v, not of unobservable households' preferences (see Smith 1990 for a more formal discussion of the household production framework).

The second order condition to assure a maximum of expected utility requires that:

(17) $$\frac{\partial^2 \pi}{\partial C^2} \left(U_b - U_g\right) - 2 \frac{\partial \pi}{\partial C} \left[\frac{\partial U_b}{\partial M} - \frac{\partial U_g}{\partial M}\right] + \left[(1 - \pi) \frac{\partial^2 U_g}{\partial M^2} + \pi \frac{\partial^2 U_b}{\partial M^2}\right] < 0.$$

In addition to the three assumptions made about the state-dependent utility functions, the only restriction required to guarantee inequality in equation 17 would be $(\partial^2\pi/\partial C^2) > 0$.

It is noteworthy that derivation of the second order condition does not necessarily require risk averse preferences. Even though the marginal utility of consumption is increasing (i.e., $\partial^2 U_i/\partial M^2 > 0$, i = b,g), there may be cases in which inequality still holds. The desire to undertake self-protection might occur for risk lovers as well as for risk averters.

Subjective Self-Protection Model and Value of Information

In the conventional expected utility framework and self-protection model, the probability or probability function of the adverse health outcome was treated as "objective" information in that any household facing the same problem will assign the same probability. However, the uncertain situation causing the adverse health outcomes is often unique and nonrepetitive. So there is little opportunity to gain the experience that is usually associated with learning.

Although the risk of short-term acute health problems due to pesticide poisoning, for example, is relatively well understood, the risk of health effects posed by long-term and low-level exposures to food contaminants (such as pesticide residues) or harmful nutrients (such as fat) are not as well known. We cannot assume that any individual, whether an informed consumer or a professional toxicologist, knows the technical risk or how it will respond to averting decisions. Nonetheless, it is reasonable to expect that a household will have subjective probabilistic beliefs. Any assignment of subjective probability is permissible, in principle, provided there is coherence in a household's judgement about the relative likelihood of various values of unknown states of the world (Winkler and Hays 1975).

Each household may perceive a different degree of subjective risks according to its demographic background, knowledge about the event at risk, and past experiences with similar situations. These factors will serve as a set of information, I, to the household in the process of forming risk perceptions at a point in time. Thus, incorporating information, a household's subjective risk perception can be defined as:

$$\pi = \psi(v,I) \tag{18}$$

where v denotes a vector of self-protection actions, and I represents information available to the household. It is assumed that information, I in equation 18, is exogenously provided and thus is not subject to the household's choices and does not explicitly enter the budget constraint. Therefore, while risk perceptions become endogenous outcomes, information is still considered an exogenous factor in the household decision process.

At the beginning of each period, a household is assumed to make self-protection decisions and consumption plans X and Y, given a set of available information about the uncertain event. A household's objective function can be written as:

$$EU = (1 - \psi(v,I))\ U_g(X,Y) + \psi(v,I)\ U_b(X,Y). \tag{19}$$

Following the analysis discussed earlier, the household's constrained expected utility maximization problem can be stated equivalently as equation 20 in terms of state-dependent indirect utility functions to yield:

$$EU = (1 - \psi(p_v,I))\ V_g(M,p_x) + \psi(p_v,I)\ V_b(M,p_x) \tag{20}$$

where $V_b(M,p_x) = U_b(X^*(M,p_x), M - X^*(M,p_x))$; $V_g(M,p_x) = U_g(X^*(M,p_x), M - X^*(M,p_x))$; $\psi(p_v,I) = \psi(C^*(p_v,I,\pi^o)) = \psi(p_v\ v^*(p_v,I,\pi^o))$; and X*, Y*, and v* represent the optimally chosen levels of X, Y, and v.

Because of the exogeneity of information at each period of consumption choice, marginal willingness to pay for additional information again can be derived by taking the total differential of the expected utility function, equation 20. The change of information that we consider is not complete but *partial* in the sense that the information affects households' risk perceptions while still leaving some uncertainty present. By setting dEU = 0 and holding $dp_x = dp_v = d\pi = 0$, we can solve for the income change that would be required in response to exogenous additional information to keep expected utility constant:

$$(21) \quad \frac{\partial M}{\partial I} = \frac{V_b - V_g}{(1 - \pi)\ \partial V_g/\partial M + \pi \partial V_b/\partial M} * \frac{\partial \pi}{\partial I} = MRS_{\pi M} \frac{\partial \pi}{\partial I} .$$

Compared with the valuation measure of *risk* reductions derived in equation 16, the expressions in equation 21 measure the marginal willingness to pay for *information* about health risk, reflecting individuals' incomplete knowledge about the risk. Consumers' risk perceptions are endogenously determined through the household health production activities in response to an exogenous change in information about the risk. In this subjective self-protection model, what consumers are evaluating is not food attributes (such as health risks) but information about the food attributes. Thus, the valuation measure of additional information in equation 21 captures both the direct effect of information on risk perceptions ($\partial\pi/\partial I$) and indirect effects through marginal values of changes in risk ($MRS_{\pi M}$).

Using the results of equations 14 and 15, which equate $MRS_{\pi M}$ to marginal self-protection expenditure, the specification of equation 21 can be reduced to equation 22:

$$(22) \quad \frac{\partial M}{\partial I} = \frac{\partial M}{\partial \pi} \frac{\partial \pi}{\partial I} = \frac{\partial C}{\partial \pi} \frac{\partial \pi}{\partial I} = \frac{\partial C}{\partial I} .$$

The first and last terms in equation 22 state that the marginal value of additional information equals the marginal cost of information in terms of the reduction in self-protection expenditures.

Since in the household production framework, whatever level of risk perception chosen in the expected utility maximization process must be produced at minimum cost, self-protection expenditure consists of $C^* = p_v\, v(p_v, I, \pi)$. Taking the total differential of the self-protection expenditure function C*, the third term of equation 22 can be re-stated as equation 23:

$$(23) \quad \frac{\partial C}{\partial \pi} \frac{\partial \pi}{\partial I} = \frac{\partial \pi/\partial I}{\partial \pi/\partial v}\ p_v = \frac{\partial C}{\partial I} .$$

Substituting equation 23 into equation 22 gives the expression for the marginal value of information as:

$$\frac{\partial M}{\partial I} = \frac{\partial \pi / \partial I}{\partial \pi / \partial v} \quad p_v = \frac{\partial C}{\partial I} \ . \tag{24}$$

Equation 24 shows that the *ex ante* marginal willingness to pay for additional information is equal to the marginal cost of achieving the same level of risk perception, π^o, by increasing the self-protection expenditure C.[5] Again, this *ex ante* MWTP expression does not require that we observe the ex ante MRS but can be derived with knowledge of the technical relationship between information and self-protection actions in the risk perception functions (see Gerking and Stanley 1986 for parallel results from averting behavior models with certainty).

Marginal WTP for new information in equation 24 deserves further explanation. First, a household's ex ante marginal willingness to pay will be higher as its "full" price of v, p_v (mainly the opportunity cost of its time) is higher and its marginal productivity of v in risk perceptions ($\partial\pi/\partial v$) is lower. Equally important, ex ante MWTP will be higher for those households in which new information has greater impact on risk perceptions ($\partial\pi/\partial I$). Based on the result of equation 24, a more educated and/or more experienced household may express lower WTP in response to new information about health risks. This possible connection between individuals' demographic profiles and the acquisition of and use of information has been recognized by economists for some time. For example, Grossman (1972) hypothesized that schooling increases the efficiency of household health production, and therefore that better educated individuals may react to risk information differently from less educated people. Kenkel (1991) empirically found that education levels reflected in the number of years of schooling helped individuals to undertake more preventive actions by improving their knowledge of the relationship between protective behavior and health outcomes.

Self-Protection Model with Learning and Value of Information

The analysis developed above incorporated self-protection and available information into the risk perception process. But the process still is "static"; it gives an account of effects of information on risk perceptions at a given point in time but does not describe how a household acquires and uses the information over time. In practice, the household takes self-protection actions while it acquires more information (through product labeling or new media reports) and learns about the risk. In this situation, the household's objective function at any time period t = i is equal to equation 25:

(25) $$EU_i = (1 - \psi(v_i,I_i))\ U_g(X_i,Y_i) + \psi(v_i,I_i)\ U_b(X_i,Y_i).$$

The difference between equations 19 and 25 is that the acquisition of information in equation 25 is a part of the household's optimizing choice at a particular point in time, whereas information available in equation 19 was exogenously given.

Since risk perceptions are endogenously determined, observed outcomes at time t = i—subjective risk perceptions and household behavioral decisions (X_i*, Y_i*, and v_i*)—reflect influences of both the acquired information and the feasibility of self-protection. If so, it will be a difficult, if not impossible, task to sort out the effects of information and self-protection on risk perceptions and behavioral decisions in a *timeless* expected utility framework. Hence, some restrictions on this integrated framework are required to separate the relative influence of acquired information and self-protection on risk perceptions from that on averting behavior decisions.

Before proposing an integrated framework, consider first a simple Bayesian learning model in which households update risk perceptions by observing additional information in the form of new labeling over *time* (Viscusi 1989). For the sake of simplicity, we formulate the risk perception process only before receiving new information about food-related risks (i.e., t = 1) and after receiving new information (i.e., t = 2). After receiving new labeling information at t = 2, the household will update its risk perception, which can be described as a reduced form:

(26) $$\pi_2 = \alpha_1\ \pi_1 + \alpha_s\ \pi_s$$

where

π_2: a household's perceived risk after receiving information,
π_1 : the perceived risk before receiving information,
π_s: sample risk inferred from risk message,
α_i (i = 1 and s): the weights for the risk perceptions.

The posterior risk perception in equation 26 is a weighted average of prior risk, π_1, and "sample" risk, π_s.[6] The weights capture the household's assessment of the relative precision of the underlying true distribution of the risk. The Bayesian updating rule implies that the α_1 would be positive and the α_s would be $0 < \alpha_s < 1$.

To develop an integrated modeling of averting behavior and learning over time, consider one way self-protective actions that can be incorporated with the Bayesian learning framework described as equation 26. Incorporating self-protection into the Bayesian learning framework, the household's prior risk assessment at t = 1 would become $\psi(v_1)$, where v_1 is a vector of self-protection undertaken at t = 1.

Assume that the functional relationship $\psi(v)$ is known and processed recursively. As Crawford (1973) has shown, the recursive notation of the information set at time t = 2, I_2, can be written as follows:

(27) $$I_2 = h(I_1(v_1),\ \pi_s)$$

where π_s again denotes the "implicit" sample risk obtained through the product label, I_1 designates a set of information available at time t = 1, and v_1 denotes the level of self-protection chosen at t = 1. The h(.) function in equation 27 can be interpreted as an updating rule.

With new labeling information similar to that hypothesized to underlie equation 27, posterior risk perception is determined to be:

(28) $$\pi_2 = \psi(v_2,I_2) = \alpha_1\pi_1(v_1) + \alpha_s\pi_s(v_2)\ .$$

As we see in equation 28, the household's new information would alter its risk perception. It does not affect its perception of the effect of self-protection on the parameters of risk assessment. In this specification, learning becomes a part of a household's decision-making with risk. However, it is still separately processed from the household's behavioral decisions (i.e., "exogenous" learning). In other words, a household's decision-making with learning becomes a sequential process; the amount and framing of information lead to revisions in a household's risk perception to π_2. Then, the household makes self-protection decisions, v_2, using I_2.

With this background, we now attempt to develop an integrated framework describing the interaction between risk perceptions, learning, and behavioral decisions. To link the information acquisition and leaning processes, the self-protection model developed earlier is extended to a two-period context in this section. With the extended *time* horizon for decision making, a more explicit consideration can be given to the way posterior risk perceptions are influenced by information as well as self-protection actions, and how learning takes place over *time*.

Households' preferences are still represented by the von Neumann-Morgenstern utility function, $U(X_1, X_2)$, where $X_t = (x_{t1},x_{t2},...x_{tn})$, t = 1,2 is a vector of disaggregated consumption goods at time t = 1,2. Thus, state-dependent utility functions, $U_g(X_1,X_2)$ and $U_b(X_1,X_2)$, in this final model combine Cook and Graham's (1977) single-period state-dependent utility function with Epstein's (1975) two-period specifications.

To implement the model, several assumptions must be made: first, risk perception, π_1, and optimal averting expenditure, C_1, at t = 1 are assumed to be known. So, when behavioral response to uncertainty takes place in the second period, $\pi_1 = \psi(C_1)$ is used as a prior risk perception in the posterior risk perception, π_2. Second, second-period price and income are known with certainty. Household savings, S, result in certain yields (1 + r)*S at t = 2, where r is an interest rate. Third, households still are assumed to be engaged in a two-stage decision process according to the household production framework.

The objective of the two-period model is to investigate how uncertainty about risk accompanied by the opportunity for learning influences the optimal consumption plans and self-protection decisions. Households in this framework select optimal levels of averting expenditure, C_2, levels of savings, S, and consumption levels for X_1 and X_2.

Following Epstein (1975) and Chavas et al. (1986), the household's expected utility maximization problem can be written as:

$$\max_{x_1,s,x_2,v_2} \quad E_1 = [EU_2] \tag{29}$$

$$EU_2 = [1 - \psi(v_2,I_2)]\ U_g(X_1,X_2) + \psi(v_2,I_2)\ U_b(X_1,X_2) \tag{30}$$

where E_1 denotes the expectation operator conditional on information available at time t = 1. The household's budget constraint at each period would be:

$$M_1 = p_{x_1}'\ X_1 + C_1 + S \qquad \text{at } t = 1 \tag{31}$$

$$M_2 + (1 + r)*S = p_{x_2}'\ X_2 + C_2 \qquad \text{at } t = 2 \tag{32}$$

where M_1 and M_2 are the household's full income at t = 1 and t = 2, respectively, and p_{x_t}', t = 1,2 is a vector of prices of goods including time costs as well as money prices.

In the first period, the household has imperfect knowledge about the risk but has subjective prior beliefs. If the household has an opportunity to undertake self-protection, C_1, and acquires new information through product labeling or public provision, the household will form the central tendency of the distribution of posterior perceived risk based on a Bayesian framework.

A backward induction method is used to solve this sequential problem (DeGroot 1970). If a household receives new information about food-related risks during the first period, then its risk perception would be updated according to equation 28. Because of the "exogenous" learning process structured in equation 28, the set of information available when the household makes choices over X_2 and C_2 at t = 2, I_2, can be treated as an exogenous factor. So, the second-period choice problem becomes:

(33) $$EU_2 = \underset{x_2,c_2}{Max}\ (1 - \pi_2)\ U_g(X_1,X_2) + \pi_2 U_b(X_1,X_2)$$

(34) $$\text{s.t.} \quad \pi_2 = \psi(C_2,I_2)$$

(35) $$M_2 + (1 + r)*S = p_{x_2}'\ X_2 + C_2\ .$$

Note that the choice of v_2 in equation 32 is converted to the choice of C_2 in equation 34, because our framework is still based on the household production framework. To take advantage of the interrelationship between periods, first order conditions are solved using the Lagrangian:

(36) $$(1 - \pi_2)\ \frac{\partial U_g}{\partial X_2} + \pi_2\ \frac{\partial U_b}{\partial X_2} - \mu_2\, p_{x_2}' = 0$$

(37) $$\frac{\partial \pi_2}{\partial C_2}\ (U_b - U_g) - \mu_2 = 0$$

(38) $$M_2 + (1 + r)*S - r_{x_2}'\ X_2 - C_2 = 0\ .$$

Manipulating first order conditions will yield marginal conditions similar to those in equation 14. However, the expected utility function at t = 2 is maximized given X_1. Thus, the expected value of the marginal utility of income, μ_2, is also a function of X_1. The solution of equations 36-38 will be:

(39) $$X_2^* = X_2(X_1,\ p_{x_2},\ M_2 + (1 + r)*S,\ \pi_2^o)$$

(40) $$C_2^* = C_2(C_1,\ p_{v_2},\ I_2,\ \pi_2^o)$$

(41) $$\mu_2^* = \mu_2(X_1,\ C_1,\ p_{x_2},\ M_2 + (1 + r)*S,\ \pi_2^o)\,.$$

Substituting X_2* and C_2* into equation 33 yields an ex ante variable indirect utility function conditional on X_1, S, and C_1:

(33') $$EU_2 = [1 - \psi(C_2^*(I_2))]\ U_g(X_1,X_2^*) + \psi(C_2^*(I_2))\ U_b(X_1,X_2^*).$$

The variable indirect utility function was defined by Epstein (1975) and was applied by Chavas et al. (1986) to derive the option price.

In the first period, the household chooses its optimal level of consumption X_1, and savings, S, given averting expenditure, C_1, provided that X_2 and C_2 are determined in the optimal manner in the second period. However, the current consumption decisions at t = 1 must be made subject to uncertainty about future risks. The first-period choice problem is to:

(42) $$EU_1 = \underset{x_1,s}{Max}\ E_1[EU_2]$$

(31) $$\text{s.t.} \quad M_1 = r_{x_1} X_1 + C_1 + S.$$

Using the envelope theorem, first order conditions are:

(43) $$E_1\left[(1 - \pi_2)\ \frac{\partial U_g}{\partial X_1} + \pi_2 \frac{\partial U_b}{\partial X_1} - \mu_1 p_{x_1}{}'\right] = 0$$

(44) $$-\mu_1 + E_1(\mu_2) * (1 + r) = 0$$

(45) $$M_1 - p_{x_1}{}' X_1 - C_1 - S = 0\ .$$

The first order conditions, equations 43-45, can be solved for the optimal level of current consumption, X_1* and savings, S*, where $X_1^* = X_1(M_1, p_{x_1}{}', r, \pi_2)$ and $S^* = S(M_1, p_{x_1}{}', r, \pi 2)$.

Substituting X_1* and S* into equation 33′ yields an ex ante unconditional indirect expected utility function such as:

(46) $$EU_2 = [1 - \psi(C_2^*(I_2))]\ V_g(X_1^*, X_2^*) + \psi(C_2^*(I_2))\ V_b(X_1^*, X_2^*)$$

where $X_1^* = X_1(M_1, p_{x_1}, r, \pi_2)$; and $X_2^* = X_2(M_1, M_2 + (1 + r) * S, p_{x_1}{}', p_{x_2}{}', r, \pi_2^o)$.

Substituting equation 46 into equation 42 will lead the first period maximization problem to equation 47 in terms of the ex ante indirect expected utility function:

(47)
$$EU_1 = E_1\{[1 - \psi(C_2^*(I_2))]\ V_g(X_1^*, X_2^*) + \psi(C_2^*(I_2))\ V_b(X_1^*, X_2^*)\}.$$

Taking total differentials with respect to I_2 while holding EU_1 constant, the marginal willingness to pay for information, I_2, which is chosen and paid at time t = 1 will be given as equation 48:

(48)
$$\frac{\partial M_1}{\partial I_2} = \frac{E_1[((\partial\pi_2/\partial C_2)(\partial C_2/\partial I_2)(V_b - V_g)] * p_{x_1}}{E_1[(1 - \pi_2)\partial V_g/\partial M_1 + \pi_2 \partial V_b/\partial M_1]}\ .$$

Using the first order conditions, equations 37 and 38, and the assumption of linear budget constraint at each period, equation 48 can be simplified as equation 49:

(49)
$$\frac{\partial M_1}{\partial I_2} = \frac{E_1[\mu_2 C_{2I}]}{\mu_1}$$

where $C_{2I} = (\partial C_2/\partial I_2)$ and μ_1 and μ_2 are expected values of marginal utility of income at t = 1,2. The detailed properties of these terms are illustrated by Chavas et al. (1986). The left-hand side of equation 49 represents a change in the first-period income that must be taken away in response to additional information to keep a household's expected utility constant. The additional information acquired during t = 1 does not resolve the uncertain nature of risk at time t = 2, π_2. Since we focus on *ex ante* MWTP which is paid at the first period, the posterior risk perception at t = 2 can be viewed as the expected value of future risk perceptions such as $\pi_2 = E_1[\psi(I_2, v_2)]$. As a result, μ_2 and C_{2I} in equation 49 become random variables when evaluated at time t = 1, which are functions of π_2 as well as M_2, p_{x_2}, and so on.

If the MWTP was paid, we obtain $\mu_1 = E_1(\mu_2)(1 + r)$ from equation 44. Substituting this expression into equation 49:

(50)
$$\frac{\partial M_1}{\partial I_2} = \frac{1}{(1 + r)} * E_1(C_{2I}) + \frac{COV(\mu_2,\ C_{2I})}{\mu_1}$$

where $COV(\mu_2, C_{2I})$ is the covariance between μ_2 and C_{2I}. Since we are dealing with two states of the world and the perceived risk, π_1, at time t = 1 is assumed to be known, equation 50 can be reduced to:

(51) $$\frac{\partial M_1}{\partial I_2} = \frac{1}{(1 + r)} * \frac{\partial C_2}{\partial I_2} + \frac{COV(\mu_2,\ C_{2I})}{\mu_1} .$$

Equation 51 suggests that the ex ante marginal willingness to pay for additional information is equal to the *discounted* marginal self-protection expenditure plus an adjustment term.

Now suppose that the amount of MWTP is chosen at time t = 1 but paid at time t = 2; the marginal willingness to pay becomes:

(52) $$\frac{\partial M_2}{\partial I_2} = \frac{\partial M_1}{\partial I_2} * (1 + r) = \frac{\partial C_2}{\partial I_2} + \frac{COV(\mu_2,\ C_{2I})}{\mu_1} * (1 + r).$$

As we see in equation 52, the MWTP for information with learning is represented by the sum of the marginal reduction of self-protection expenditure due to improved information plus an adjustment term. The second term in equation 52 was not included in the willingness to pay measure derived in a timeless framework (see equation 24). This adjustment term may reflect the influence of second-order uncertainty on consumers' decision making related to food risks. In other words, the term may reflect effects of learning over time on households' ability to make better consumption decisions, which may result in reallocations of their constrained resources.

As shown in equation 52, the sign and magnitude of the adjustment term depends on how the marginal utility of income in the second period moves with changes in the protective expenditure due to new information (i.e., COV(μ_2, C_{12})) and households' internal time preferences, which are embedded in the marginal utility of income in the first period, μ_1. Because the expected value of marginal utility of income at t = 1, μ_1, is greater than zero, the sign of the adjustment term depends on the sign of the covariance term, COV(μ_2,C_{2I}).

Following the result proved by Chavas et al. (1986),[7] the adjustment term in equation 52 can be shown to be positive. The specification of the Bayesian updating rule in the subjective self-protection model, equation 28, leads the covariance term to be:

(53) $$COV(\mu_2,\ C_{2I}) > 0 \ \text{because}$$
$$\alpha_s^3 * \left[\frac{\partial V_b}{\partial M_2} - \frac{\partial V_g}{\partial M_2}\right]^2 * (V_g - V_b) > 0 .$$

Therefore, a relationship between the MWTP without learning and with learning can be derived from equations 24 and 53:

$$(54)\quad \left|\frac{\partial M}{\partial I}\right| = \left|\frac{\partial C}{\partial I}\right| > \left|\frac{\partial C_2}{\partial I_2}\right| = \left|\frac{\partial M_2}{\partial I_2} - \frac{COV(\mu_2,\ C_{2I})}{\mu_1} * (1 + r)\right| .$$

Equation 54 concisely summarizes the difference between values of information with and without the learning opportunities. In response to new information, the marginal changes of self-protection expenditure without the learning opportunity (the second term in equation 54) is greater than those when households have opportunities to learn about the uncertain event (the third term in equation 54). As households learn more about health risks arising from food contaminants or nutrients, they may recognize that they do not need to spend as much on protective expenditures as before to achieve the same level of risk. The consequent reductions in protective expenditure would allow households to have more disposable income that can be reallocated to other consumption activities.

This interpretation of the adjustment term may provide an explanation of consumers' strong reactions to extremely low but unfamiliar food risks (e.g., the Alar scare). If a household has to take self-protection actions in a single period context, while the process underlying food-related risks is involved in multiple time periods, then the household may show alarmist reactions and overestimate its tradeoffs between risk and income. This result in equation 54 is also consistent with the empirical findings of market experiments (for example Camerer 1987), where individuals' learning opportunities, gained through experience and better information, reduced biases in market prices with regard to the predictions of a Bayesian model.

Concluding Remarks

This chapter was motivated by observations suggesting that food-related risks (either arising from food contamination or dietary habits) are not well understood by consumers. Nonetheless, consumers seemed to take self-protection actions to reduce the risks while learning more about risks in response to new information. To describe such situations, I developed a conceptual framework investigating the effects of information and learning on consumers' protective behavior. The framework incorporating the learning process did not change the basic structure of the expected utility theory: self-protection and consumption decisions that affect utility directly are separated from the processes of risk perception and learning. As long as we can identify protective behavior undertaken specifically to reduce health risks, the values of risk information could be measured from the knowledge of the technical relationship between risk and self-protection action, which is observable in principle. This three-way connection—perceptions, learning, and behavior—

clearly has important implications for governmental efforts to address market failure associated with the provision of food safety and nutrition. Greater understanding on the part of consumers, based on learning opportunities, may reduce the degree of overestimation of small risks, as reflected in smaller self-protection expenditures.

Unfortunately, the empirical implementation of the conceptual framework developed in this chapter requires intensive data collection efforts. Required are household-level primary data on patterns of food consumption and expenditures, time allocations including different cooking and shopping activities, wage rates, and the prices and quantities of protective behaviors, along with measures of levels of food attributes (such as food safety and nutrition) consumed by the same households. In addition, to understand households' learning processes, we need to accurately elicit consumer perceptions about food attributes *before* and *after* receiving new information and the effect of changes in perceptions on self-protection activities.

To date, the valuation research related to food safety and nutrition largely utilized three different data sources in various empirical applications: (1) consumers' revealed responses to food attributes or information about food attributes in actual market-based situations (hedonic price analysis, quality-augmented product demand analysis), (2) consumers' stated purchase intentions or expressed willingness to pay for safer products in hypothetical market situations (contingent valuation method, conjoint analysis), or (3) laboratory experiments involving purchase decisions on attribute-differentiated products (e.g., Vickery sealed-bid auctions).

Moreover, most of this empirical research has considered the three aspects of food safety economics— perceptions, behavior, and valuation—as separate alternatives. One line of research focuses on how best to elicit consumers' perceptions of food risks and how to examine the influences of socio-demographic characteristics on consumers' attitudes toward certain food attributes. Other researchers emphasize identifying the existence of a linkage between nonmarket food attributes and observed self-protection actions by analyzing consumer demand for attribute-differentiated food products. Others attempt to estimate values of certain food attributes or willingness to pay for safer products.

One direction that future valuation research can take to meet intensive data needs is to examine the possibility of combining different sources of behavioral responses in a utility-theoretic consumer choice model such as the one developed in this chapter. For example, consumer preferences for food attributes can be jointly estimated by using both actual market demand responses for food products and contingent behavior responses to information about food attributes. This composite research strategy will exploit individuals' behavioral "windows" more completely and thus provide more reliable measures of the value of information about food safety and nutrition.

Notes

1. This chapter was taken from research done for my dissertation at North Carolina State University. I am indebted to V. Kerry Smith for insightful and constructive suggestions on earlier versions of this paper.

2. Since M and π changed while p_x remained constant, the total differential reduced to a partial differential. Thus the partial derivative in equation 4, $(\partial M/\partial \pi)$ is equal to $(dM/d\pi)$ given r_x constant. This interpretation is applied to the discussions throughout this chapter.

3. This type of switching behavior entails discrete choices, which result in corner solutions for food consumption decisions. Eom (1994) describes a discrete choice model in a situation involving risks from pesticide residues on fresh produce.

4. Perhaps this nonjointness assumption in the household production framework may be equivalent to the separability assumption between exposure to pollutants and unobservable randomness affecting health, which permitted Quiggin (1992) to derive some positive results in applying self-protection models. As a result of the nonjointness assumption, our analysis excludes certain preventive health behaviors (such as regular physical exercise) that improve households' general health conditions as well as mitigating the adverse health outcomes associated with particular food contaminants or nutrients.

5. When changes in expenditure on marketed protective behavior are used to measure individuals' values on nonmarket goods such as risk information, we have to recognize that there are three possible measures: (1) the change in expenditure on protective behavior, v, given a constant income, M, (2) the change in expenditure on v to hold the final service flow, π, constant, and (3) the change in expenditure on v to hold expected utility, EU, constant. The third measure is a correct measure of individuals' willingness to pay for the change in an exogenous factor, I. In the case in which a protective behavior, v, is a perfect substitute for the exogenous factor, I, the second measure will be equal to the third measure. However, the first measure is not the same as the third measure because of the income reallocation associated with the change in I (see Smith 1990 for details).

6. More specifically, Viscusi and O'Connor (1984) assumed the random event (the occurrence of the adverse health outcome) follows the sequence of Bernoulli trials and prior risk perceptions follow beta distributions. The beta distribution is quite flexible and can reflect a variety of skewed and symmetric shapes by varying the parameters of the distributions (Winkler and Hays 1975). These properties are useful to explain the self-protection model.

7. Chavas et al. (1986) proved that the covariance $(COV(\mu_2(I_2), C_{2I}(I_2))$ is positive if $[(\partial\mu_2/\partial I_2) * (\partial C_{2I}/\partial I_2)]$ is positive.

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