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ESTIMATION OF STATE-DEPENDENT UTILITY FUNCTIONS USING SURVEY DATA

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Abstract—Surveys of individual's risk-dollar tradeoffs illuminate not only the local tradeoff rates but also can be used to address more fundamental questions about the structure of utility functions. This largely unexplored empirical area is investigated by developing an econometric technique to estimate utility functions based on survey data on risk-dollar tradeoffs for minor health effects. The empirical tests indicate that for all but one of the temporary health effects considered, consumers treat injuries as tantamount to a drop in income, implying that the health impact does not alter the structure of the utility function in a fundamental way.

I. Introduction

ALTHOUGH a considerable literature exists on the valuation of risks to life and health, its focus has largely been on risk-dollar tradeoffs for small changes in risk. In particular, the most frequent focus is on wage premiums for job risk based on hedonic models of wage determination.[1] Available market data do not enable one to expand the scope of such inquiries to include issues such as the underlying shape of the utility function that generated these tradeoffs. However, the increased availability of survey data that provide detailed information on multiple risky decisions can potentially extend the range of issues considered.[2] In this paper, we indicate how these data can be used to extend the conventional hedonic methodology to estimate the overall structure of utility functions for adverse health effects.

This paper utilizes survey data pertaining to four pairs of relatively minor consumer health risks. The essential feature of the data is that it provides information on multiple points on a constant expected utility locus so that one can estimate more than a local risk-dollar tradeoff. In particular, the paper develops a procedure for estimating, for each health outcome, two parameters of the state-dependent utility function that distinguish it from the utility function in good health. This estimation procedure is more general than that proposed in Viscusi and Evans (1990) since it focuses on more than just the relative marginal utility in good and ill health.

The novelty of this estimation approach is best understood by comparing it to the more standard methodology based on statistical decision theory. The traditional approach begins by presenting subjects with a succession of hypothetical choices, for which they must give a probability that makes them indifferent between a pair of lotteries with extreme outcomes. This sequence of probabilities is then used to define a utility index. The approach presented here utilizes risk-dollar tradeoffs where subjects are presented with a series of choices and respondents are asked to provide a dollar amount that makes them indifferent between the lotteries. By construction, the series of points provided by the respondent lie along a constant expected utility locus. This paper provides a procedure for estimating the parameters of an explicitly defined utility function by using these risk-dollar tradeoffs. The structure of the estimation procedure introduced here is quite general and can be applied to any data set that contains information on points from a constant expected utility locus.

Section II summarizes the alternative perspectives one could take on such health effects, treating them as monetary loss equivalents or as more fundamental changes in utility function structure. The empirical tests reported in section III indicate that for most of the temporary health impacts considered, the welfare effects are tantamount to monetary losses. Section IV explores the implications for the results of different measures of the implicit value of injury, and section V concludes the paper.

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[1] See, for example, Rosen (1986) and Viscusi (1978, 1979).

[2] Examples of such survey studies include Gerking, de Haan, and Schulze (1988); Smith and Desvousges (1987); Berger, Blomquist, Kenkel, and Tolley (1987); and Viscusi, Magat, and Huber (1987). More generally, see Cummings, Brookshire, and Schulze (1986); and Fisher, Chestnut, and Violette (1989).

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The main results are twofold. First, one can explicitly estimate utility functions that incorporate the role of health status in a formal manner. The effect of a decline in health status as both a monetary loss equivalent and as an influence on utility function structure can be recognized. Second, treatment of minor health impacts as being tantamount to some lost monetary equivalent is consistent with consumers' revealed preferences.

II. Modeling and Estimating the Utility of Ill Health

A. Utility Functions for Adverse Health Effects

Viewed in its most general form, one could treat health status as simply a component of an individual's utility function. In this specification, utility is a function of income Y and the health state. Let U and Y represent utility and income when healthy, and for each unhealthy state, let utility and income be represented by V_i and Y_i, respectively. Each unhealthy state i has an associated probability of occurrence s_i, and therefore, the probability of being healthy is $1 - \Sigma_i s_i$. The expected utility EU takes the form:[3]

$$EU = \left[1 - \sum_{i=1}^{n} s_i\right] U(Y) + \sum_{i=1}^{n} s_i V_i(Y_i). \qquad (1)$$

Given the presumed preference for good health to any state i,

$$U(Y) > V_i(Y). \qquad (2)$$

A more problematic issue pertains to the effect of ill health on the marginal utility of income. In particular, does ill health lower the marginal utility of income so that

$$\partial U/\partial Y > \partial V_i/\partial Y, \qquad (3)$$

as is plausible for catastrophic health effects such as death? Alternatively, is ill health tantamount to a drop in income, which increases the marginal utility of income such that

$$\partial U/\partial Y < \partial V_i/\partial Y,$$

or does the marginal utility of income remain unchanged? The character of health effects on utility functions has fundamental economic implications for issues such as the valuation of risk and optimal insurance compensation of health outcomes.[4]

Three different utility function formulations can be used to reflect these various concerns. First, one could treat an adverse health effect i as being tantamount to a loss L_i in income, where L_i is zero for perfect health. In this instance, the utility function in state i is simply $V_i = U(Y - L_i)$, and ill health lowers the utility level but raises the marginal utility of income. Second, one could treat ill health not as imposing a financial loss, but as altering the structure of the utility function. Since the healthy state is preferred to ill health, clearly (2) is satisfied. Although it is not clear a priori whether an injury raises or lowers the marginal utility of income, it is usually assumed that the marginal utility declines and equation (3) is satisfied. In the "mixed" case, the injury or illness imposes both a monetary loss as well as a change in utility function structure. For this model, the utility function structure is defined as $V_i(Y - L_i)$. Although the previous health state formulation is sufficiently general to include such a possibility when utility varies with each health state i, for the specific functional form that we estimate below, this distinction will prove to be important.

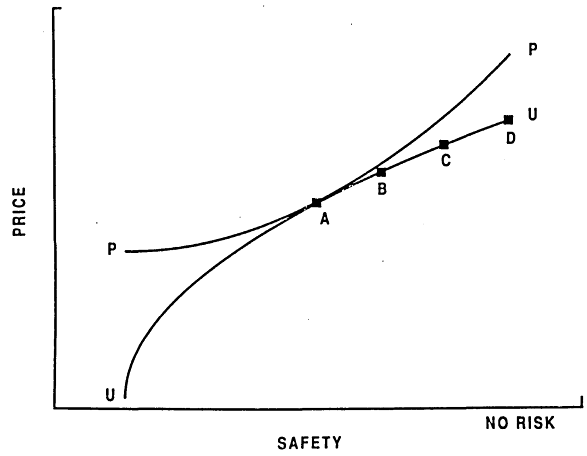
B. Toward Estimation of the Utility Functions

The nature of the empirical estimation can best be illustrated using the hedonic price model developed by Rosen (1974) as the reference point. Suppose a particular type of product varies in only two dimensions: safety and price. For simplicity, suppose that safety can be collapsed into a single variable. Although the empirical analysis will include two measures of safety, use of a single metric facilitates the graphical exposition. The price-risk schedule available for a particular type of produce is given by PP in figure 1, where this curve is upward sloping at an increasing rate

[3] The literature on state dependent utility is quite well developed, including the contributions such as Arrow (1974), Cook and Graham (1977), Karni (1985), and Keeney and Raiffa (1976).

[4] A particularly salient concern is that the optimal level of (actuarially fair) income insurance for ill health will provide for less than full income replacement if equation (3) holds, full replacement if there is no effect on the marginal utility of income, and more than full replacement if equation (4) holds.

FIGURE 1.—HEDONIC PRICE AND UTILITY SCHEDULES



since provision of product safety becomes increasingly costly at higher levels of safety. Consumers have a constant expected utility locus UU, on which they are willing to pay a higher price for greater safety. If one relies on market data to estimate the price-risk tradeoff, as in the substantial literature on hedonic wage studies, then the estimate yields the locus of observed tangencies with the market opportunities locus, such as point A.[5] All that is known about an individual tangency point is the risk-dollar tradeoff at points such as A, which provides no information as to the underlying structure of the utility function. Analysis of variations in the tradeoff with the risk level is also not instructive since the slopes at different points are for different people and are not observations along a constant expected utility locus.

In this paper, we introduce a procedure for estimating state-dependent utility functions using survey data on consumer behavior. As will be indicted below, this approach generalizes the methodology introduced in Viscusi and Evans (1990) to include an explicit test of whether the health impact can be treated as a monetary equivalent. If we denote utility at the starting value of risk by $U(A)$ and utility at the zero risk level in figure 1 by $U(D)$, then the survey includes information on three equalities:

$$EU(A) = EU(X). \tag{5}$$

where $X = B, C, D$. These multiple observations along a constant expected utility locus will enable us to estimate the specific form of the utility function in good and ill health. In contrast, Viscusi and Evans (1990) utilized information from only a single equation and estimated a single parameter of the utility function.

III. Testing for State-Dependent Utility

A. The Sample and Model Structure

The data used in this study are a subset of a survey used by Viscusi, Magat, and Huber (1987). Their work was primarily concerned with analyzing how consumers trade off product price and product risk when faced with multiple health risks. In this paper, we will use these data for a different purpose—to estimate utility function parameters.

The structure of the survey was as follows. Consumers answered a series of questions regarding one of two products: an insecticide or a toilet bowl cleaner. The products are fictitious, but their labels were professionally printed and they appeared to be commercially sold brands. Subjects were asked to read the product label and were then questioned about the proper use of the product and the frequency with which they used the general class of products.

The interviewer then informed the subject that the particular product could cause harm if misused. For each product, the interviewer identified two potential injuries that might result from the product misuse. For subjects with children under the age of five, the types of injuries were eye burns and child poisonings for the toilet bowl cleaner, and inhalations and child poisonings for the insecticide. For subjects without small children, the child poisoning risk was replaced by gassings for the toilet bowl cleaner and skin poisonings for the insecticide.

The respondents received detailed information on the characteristics of the injuries involved, which were largely temporary in nature.[6] No out-

[5] The most innovative exception is that of Biddle and Zarkin (1988), who focus on restrictions on utility functions implied by the tangency of the market offer curve and workers' bid function.

[6] For example, in the case of a fairly severe hazard—child poisonings involving insecticide—consumers received the following information:

If children drink insect spray, it can cause nausea, stomach pains, diarrhea, headaches, blurred vision, coughing, and for some children, seizures. Hospitilization may be required. Recovery time varies from a few hours in most cases to several weeks for children who drink large doses of the insect spray.

of-pocket medical expenditures were indicated, as the losses consisted solely of short-term morbidity effects. Subjects were informed that the current prices of the products were $2/bottle for the toilet bowl cleaner and $10/bottle for the insecticide, respectively. The original risk levels for all types of injuries were set at 15 injuries per 10,000 bottles sold. Consequently, an individual's risk of injury varied with the frequency of use. Subjects were then asked how much they would be willing to pay per bottle to obtain a specified reduction in the risk of injury. This set of expenditure/risk tradeoff questions provides information on a series of points on a constant expected utility locus and will be used to specify the system of equations to be estimated.

Since the subject's preferences were being elicited within a context that was purported to be a marketing study of product attributes, there would be less reason to misrepresent one's preferences than if, for example, a government agency requested their valuation of safety. Nevertheless, it should be stressed that the consumer survey was based on an experimental context, not actual market behavior. Other aspects of the survey focused on product labels, including features such as professionally drawn labels for alternative products in order to stimulate a market context as much as possible. In addition, sensitivity tests in Viscusi and Evans (1990) for a different data set indicate the robustness of the results to potential overstatement of values. Such overstatements should tend to favor the health state model, relative to the monetary equivalent model, whereas the empirical results below will support the monetary equivalent formulation.

Table 1 provides sample characteristics for all population survey groups, which include 1,371 completed survey responses in all. Survey participants consisted of adult shoppers, and the details of the survey are described in Viscusi, Magat, and Huber (1987). All four samples are fairly similar except that the subjects presented with the toilet bowl cleaner had substantially more female respondents and lower family incomes than the subjects in the insecticide sample. This difference arises primarily from only including in the study those subjects who actually used the product. On average, the respondents purchased approximately 1.5 bottles of insecticide and 6 bottles of toilet bowl cleaner per year. Given the stated prices of the products, the subjects were spending on average about $25/year on insecticide and $12/year on toilet bowl cleaner. The average annual risk in the original formulation of the product can be calculated as $USE * 15/10{,}000$, where *USE* is the number of bottles used per year.

The structure of the survey suggests the following modeling of consumer behavior. Let annual

TABLE 1.—SAMPLE CHARACTERISTICS

		Sample Means (standard deviations)			
		Insecticide Sample		Toilet Bowl Cleaner Sample	
Name	Definition	Subjects without Children	Subjects with Children	Subjects without Children	Subjects with Children
AGE	age of subject	42.7 (14.2)	34.9 (7.97)	39.6 (15.1)	29.5 (6.23)
EDUCATION	years of education	13.3 (2.59)	14.2 (2.17)	13.4 (2.70)	13.5 (2.41)
FIVE	number of children $\leq$ 5 years of age	—	1.33 (0.53)	—	1.26 (0.48)
INCOME	yearly household income ($\times$\$1000)	36.5 (19.1)	36.5 (17.6)	27.6 (18.6)	26.7 (15.7)
MALE	dummy variable (dv), = 1 if male, 0 otherwise	0.63 (0.48)	0.62 (0.49)	0.16 (0.37)	0.13 (0.33)
MARRIAGE	marriage dv, = 1 if married, 0 otherwise	0.75 (0.43)	0.95 (0.21)	0.53 (0.50)	0.78 (0.42)
USE	yearly use of product in bottles	1.86 (3.44)	1.59 (1.29)	6.15 (5.81)	6.47 (5.71)
N	number of observations	607	106	508	150

family income be denoted as Y, of which a portion is spent on a particular risky product. Let the original price of the risky product be denoted by z, and n be the average number of purchases that the consumer makes per year. Denote the consumer's annual expenditure on the product by C, where by definition $C = nz$.[7] Let P_i be the original probability of observing injury i in any given year, for $i = 1, 2$. Given the structure of the survey, $P_1 = P_2 = n * 15/10{,}000$. For simplicity, we will assume that the probability of observing both injuries occurring simultaneously is zero. Utility is a function of health status and income. Let utility in the healthy state be represented by $U[\cdot]$, and utility in the unhealthy state be represented by $V_i[\cdot]$, where i indexes the type of injury generated by the product.

The consumer can eliminate the risk of injury i through some additional expenditure on the product. Let the reduced risk of exposure be denoted by Q_i, where $Q_i \leq P_i$ for $i = 1, 2$. We assume that the perceived change in the injury risk corresponds with the risk change stated in the survey. Households that, for example, engage in self-protection may face a different risk. To control for some of these effects, the survey structure and our analysis is different for households with and without young children. Tests to examine any additional effect of demographic variables on willingness to pay for risk reductions did not indicate any significant relationships. Let income remaining after the product purchase be defined by $Y^* = Y - C$. Although the survey indicated no medical costs, if one wished to apply this approach to situations with medical expenditures, these expenditures would constitute an additional financial cost to be deducted from income. Treatment of self insurance could be handled analogously, but in the case of our model there are no financial losses to be insured against, only morbidity effects. If medical costs did enter one would have to amend the model to reflect the change in health probabilities that would result from medical care. Modeling the optimal medical care decision introduces additional complexities since one must also include the production function for health in the analysis.

Define K to be the total amount a consumer is willing to pay for this reduction in injury, where k is the amount a consumer is willing to pay per bottle, and $K = kn$. The variable K is the dollar amount that will make the consumer just indifferent between the two versions of the product, where

$$\left(1 - \sum_{i=1}^{2} P_i\right) U[Y^*] + \sum_{i=1}^{2} P_i V_i[Y^*] = \left(1 - \sum_{i=1}^{2} Q_i\right) U[Y^* - K] + \sum_{i=1}^{2} Q_i V_i[Y^* - K]. \quad (6)$$

Note that the premium K is simply the cost of a quality component of the product, and we assume that the increased cost of the safer product will not reduce demand.

To explicitly test how consumers view income in an unhealthy state, we will assume a particular form for utility. Suppose utility is logarithmic, where utility in the healthy state is $U[Y] = \alpha \ln(Y)$.[8] Without loss of generality, we can impose the restriction $\alpha = 1$ when the consumer is healthy. Given this characterization of utility in the healthy state, we can describe the two competing theories of utility in the unhealthy state as $V_i[Y] = \ln[Y - L_i]$ if the monetary loss equivalent model (MLE) is correct, and $V_i[Y] = \alpha_i \ln[Y]$, where $\alpha_i < 1$ for all health states if the health-state (HS) model is appropriate.

To capture the components of both the MLE and HS models within a more general functional form, we create the utility function for what we term the mixed form, where $V_i[Y] = \alpha_i \ln[Y - L_i]$. Both the MLE and HS models are nested within this more general form of utility in that

i) if $\alpha_i = 1$ and $L_i > 0$, the MLE model is correct, and
ii) if $\alpha_i < 1$ and $L_i = 0$, the HS model is correct.

Notice also that this formulation of utility in the

[7] The implicit assumption is that consumers do not adjust their quantity purchase in response to the premium they will pay for greater safety. Since the survey is eliciting the maximum amount the consumer is willing to pay for a safer product, respondents ideally hold constant their product usage.

[8] In an appendix in this paper, we present extremely similar results for the quadratic utility function to indicate the robustness of the results to the choice of the functional form. The appendix is available from the authors on request.

unhealthy state allows for both models to exist simultaneously. For example, suppose a consumer treats utility in the unhealthy period from a health-state perspective, but the injury is also severe enough to generate a lost workday and/or cause the consumer to seek medical attention. In this instance, the injury has caused not only some discomfort measured by $\alpha_i < 1$, but the consumer has also lost some income, indicating that $L_i > 0$.

Substituting the general form for $V_i[\cdot]$ into (6), we produce the following equality:

$$\begin{aligned}(1 - P_1 - P_2)\ln[Y^*] &+ P_1\alpha_1 \ln[Y^* - L_1]\\ &+ P_2\alpha_2 \ln[Y^* - L_2]\\ &= (1 - Q_1 - Q_2)\ln[Y^* - K]\\ &\quad + Q_1\alpha_1 \ln[Y^* - L_1 - K]\\ &\quad + Q_2\alpha_2 \ln[Y^* - L_2 - k]. \qquad (7)\end{aligned}$$

In this equation, we consider K to be the endogenous variable since its value is conditioned on all others. Because K is relatively small compared to Y and L_i, we can isolate the value of K by the use of a Taylor's Series expansion. From the definition of a first-order Taylor's Series, we produce the approximations to utility by expanding the expressions for utility at $Y^* - K$ and $Y^* - L_i - K$ about Y^* and $Y^* - L_i$, respectively, where

$$U[Y^* - K] = \ln[Y^* - K] \approx \ln[Y^*] - K/Y^* \qquad (8a)$$

and

$$\begin{aligned}V_i[Y^* - L_i - K] &= \alpha_i \ln[Y^* - L_i - K]\\ &\approx \alpha_i \ln[Y^* - L_i] - \alpha_i K/(Y^* - L_i). \qquad (8b)\end{aligned}$$

These approximations are quite accurate. If $Y =$ \$35,000 (the sample mean), and $K =$ \$100 (an extremely large value for this sample), the difference between $\ln[Y^* - K]$ and its approximation in equation (8) is less that 1/100 of 1%.

Substituting these expressions into (7) and solving for the response variable K, we find that the amount a consumer is willing to pay for a reduction in risk from P_1 and P_2 to Q_1 and Q_2, respectively, equals

$$K = \frac{\sum_{i=1}^{2} (P_i - Q_i)[\ln[Y^*] - \alpha_i \ln[Y^* - L_i]]}{[(1 - Q_1 - Q_2)/Y^*] + \sum_{i=1}^{2} Q_i\alpha_1/(Y^* - L_i)}. \qquad (9)$$

Given information on Y^*, all P_i's and all Q_i's, we are able to use (9) as the basis for an estimating equation to obtain parameter values for the α_i's and L_i's so as to test the competing models. Because of the availability of information on the three equalities in equation (5), this estimation procedure is more general than that in Viscusi and Evans (1990), which was restricted to analyzing α_1/α_2 using information from one equality.

In this analysis, we will use information from three different income-risk tradeoff questions. In the first round of questioning, the risk of injury 1 is reduced to zero while the risk of injury 2 is not altered ($Q_1 = 0, Q_2 = P_2$). For question 2, the risks are opposite that of question 1, where $Q_1 = P_1$ and $Q_2 = 0$. Finally, for question 3, risks were reduced to zero for both types of injuries.

The average amount consumers are willing to pay (per bottle) for these reductions in risk is provided in table 2. In all cases, the starting risk values were 15/1000 for both injuries and the subsequent risk values are given by the first two columns in each panel of table 2. For the insecticide sample, subjects without children were willing to pay \$0.36 more per bottle for the elimination of inhalations than for the elimination of skin poisonings (i.e., \$2.29 versus \$1.93). The most highly valued risk reduction is for the risk of child poisonings in the insecticide sample, as subjects with children were willing to pay on average \$1.31 more per bottle for the elimination of child poisonings in comparison to the elimination of inhalations.

The willingness to pay for the reductions in toilet bowl cleaner risks was generally less. For the sample without young children who were shown the toilet bowl cleaner, there is essentially no difference in the average consumer's evaluation for gassings and eye burns, while the subjects with children were willing to spend \$0.50 more per bottle for the elimination of child poisonings in comparison to gassings.

TABLE 2.—WILLINGNESS TO PAY FOR REDUCTIONS IN THE RISK OF INJURY

A: Insecticide

Subjects with No Young Children			Subjects with Young Children		
Risk of Injury Second Product (per 10,000 bottles) Inhalation	Skin Poisoning	Mean $ Bottle (Std. Dev.)	Risk of Injury Second Product (per 10,000 bottles) Inhalation	Child Poisoning	Mean $ Bottle (Std. Dev.)
0	15	2.29 (3.26)	0	15	2.84 (3.32)
15	0	1.93 (4.09)	15	0	4.15 (5.25)
0	0	3.92 (4.83)	0	0	7.84 (12.3)

B: Toilet Bowl Cleaner

Subjects with No Young Children			Subjects with Young Children		
Risk of Injury Second Product (per 10,000 bottles) Gassings	Eye Burns	Mean $ per Bottle (Std. Dev.)	Risk of Injury Second Product (per 10,000 bottles) Gassings	Child Poisoning	Mean $ per Bottle (Std. Dev.)
0	15	0.94 (1.08)	0	15	1.09 (1.55)
15	0	0.92 (1.77)	15	0	1.57 (2.15)
0	0	1.70 (2.65)	0	0	2.23 (3.09)

Let K_j represent the change in consumer expenditure given question j. Given the structure of the problem, we have $P = P_1 = P_2$. The consumer's willingness to pay for the reduced risk of injury in all three instances is defined as:

$$K_1 = \frac{P(\ln[Y^*] - \alpha_1 \ln[Y^* - L_1])}{((1-P)/Y^*) + (P\alpha_2/(Y^* - L_2))} \quad \text{(Injury 1 eliminated)}, \quad (10a)$$

$$K_2 = \frac{P(\ln[Y^*] - \alpha_2 \ln[Y^* - L_2])}{((1-P)/Y^*) + (P\alpha_1/(Y^* - L_2))} \quad \text{(Injury 2 eliminated)}, \quad (10b)$$

and

$$K_3 = PY^*\left(2\ln[Y^*] - \sum_{i=1}^{2} \alpha_i \ln[Y^* - L_i]\right) \quad \text{(Both injuries eliminated)}. \quad (10c)$$

Given that the multiple risks of injury from the use of the product are originally set equal, it is obvious from equation (9) that to identify all parameters within one equation, it is necessary to reduce one but not both risks to zero. We could estimate all parameters of the model from either equation (10a) or (10b). However, we choose to estimate a system of equations because we believe that there may be substantial correlations in errors across equations that can be modeled as a system within a more structured model.

Suppose that we have accurately specified each of the equations in (10) up to an additive error term, ϵ_{jk}, where j indexes the equations $j = 1,2,3$, and k indexes the individual survey respondent. Let ϵ_k be the (3×1) vector $(\epsilon_{1k}, \epsilon_{2k}, \epsilon_{3k})'$ for individual k. The vector ϵ_k is assumed to be multivariate normal with mean zero and covariance Σ. For convenience, we assume that for each question, there is no correlation in errors across individuals ($\text{cov}[\epsilon_{ik}, \epsilon_{il}] = 0$ for $k \neq l$), and that there is no correlation across consumers and questions ($\text{cov}[\epsilon_{ik}, \epsilon_{jl}] = 0$ for $i \neq j$ and $k \neq l$). Given this error structure, the system specified in equations (10a)–(10c) is a nonlinear multivariate regression model with cross equation restrictions, and estimates of the parameters α_i and L_i can be obtained through maximum likelihood procedures. We obtained the maximum likelihood estimates by iterative seemingly unrelated regressions (*ITNSUR*) with cross equation restrictions.[9]

The error structure that we have assumed in the above model is based on our judgement regarding the nature of the survey since the source of the error is not well defined. Possible sources of errors in our model are errors in response (i.e., systematic over- or under-responding of K_i), errors in measurement for other variables (such as P_i or Y), errors generated by the Taylor's Series approximation, or errors generated by the assumed functional form of utility. Although the sources of error in this model are numerous, the vector ϵ (for convenience we drop the individual subscript k) has the same statistical and economic interpretation as other popular systems of equations where a model is developed and an error structure added to the system, such as the estimation of flexible functional forms. The errors from our model are similar to, for example, a model where factor share equations from a translog production function are estimated. However, unlike most models derived from flexible functional forms, we can easily generate an error structure from within the model that has a well-defined interpretation.

For example, suppose the consumer's true willingness to pay for risk reduction is defined by $\tilde{K}_i$, and this value varies randomly from the response value K_i according to the equation $K_i = \tilde{K}_i + \epsilon_i$, where ϵ_i is a zero mean random error. The "true" model can then be generated by the substitution of $\tilde{K}_i$ into equation (6) and retracing the steps outlined for equations (7) through (10) above. Denote the right-hand-sides of the equations in (10) as $f_i(\cdot)$. The true model is then $\tilde{K}_i = f_i(\cdot)$. By our definition of K_i, we can write the response model as $K_i = f_i(\cdot) + \epsilon_i$. In this instance, the error terms can be thought of as errors in response generated by the consumer's unwillingness or inability to provide the correct response $\tilde{K}_i$.[10]

[9] This procedure follows the suggestion of Gallant (1986, chapter 6).

[10] The implicit assumption we are making in the above analysis is that each individual has the same α_i and L_i. This assumption can easily be relaxed by allowing each parameter to vary by a set of observed characteristics. For this model, we need only make the assumption that each individual has the same type of utility function, but a different utility function parameter. We do not consider this model here.

To estimate these models, we will make one final reparameterization. Let $\alpha_i = 1 + \nu_i$, where ν_i is a measure of the shift in utility from the good health state. The health state model is correct if $\nu_i < 0$ and $L_i = 0$ for all i, and the monetary loss equivalent model is correct if $\nu_i = 0$ and $L_i > 0$ for all i.

B. *Empirical Results*

Table 3 summarizes results for both the insecticide and toilet bowl cleaner subsamples. Each set of estimates focuses on a pair of injuries, such as insecticide skin poisonings and inhalations. Because the types of injuries are different across samples, we estimate models for each sample group. For each injury pair, these equations were estimated using the different sets of survey questions, leading to the three R^2 values in the final columns of table 3. The pooling of these results across the three equations for K_1, K_2, and K_3 using the *ITNSUR* procedure yields the coefficient estimates reported for ν_i and L_i.

For all four subsamples, the monetary loss equivalent parameters L_i are positive, and in all cases, are statistically different from zero. The relative differences in the point estimates of the L_i terms always mirror the differences in the per bottle response from table 2. For example, subjects without children find greater discomfort from insecticide inhalations than from skin poisonings caused by insecticide use.

Because α_i should be less than 1 under the HS model and equal to 1 under the MLE model, where we define $\nu_i = \alpha_i - 1$, we would expect each ν_i term to be less than or equal to zero. This occurs in six of eight cases. In the two cases where ν_i is greater than zero, the estimated standard errors are 1.5 times the value of the parameter, and in these cases, we cannot reject the hypothesis that ν_i equals zero. In only one case is ν_i significantly different from zero (inhalations caused by insecticides for subjects with young children). Moreover, in all eight instances the estimated monetary loss equivalent term L_i is statistically significant with the expected positive sign. Thus, in seven instances, the results are consistent with the monetary loss equivalent model. One case is consistent with the mixed model.

TABLE 3.—ITNSUR ESTIMATES OF LOGARITHMIC UTILITY FUNCTION
PARAMETER ESTIMATES AND ASYMPTOTIC STANDARD ERRORS

Product	Type of Injury	Utility Function Shift Parameter ν_i	Monetary Loss L_i	R^2 for Equation: K_1	K_2	K_3
Insecticide	Skin Poisoning	−3.6E-4	619.18	0.11	0.08	0.20
		(2.3E-4)	(94.49)			
	Inhalation (no young children)	−2.4E-4	848.66			
		(2.7E-4)	(107.04)			
	Inhalation (with young children)	−1.7E-3	1433.01	0.45	0.36	0.17
		(7.5E-4)	(302.32)			
	Child Poisoning	−1.6E-3	2537.51			
		(1.3E-3)	(465.48)			
Toilet Bowl Cleaner	Eye Burns	−3.3E-4	514.61	0.32	0.19	0.32
		(2.4E-4)	(78.38)			
	Gassings (no young children)	−1.3E-4	485.88			
		(9.7E-5)	(35.08)			
	Gassings (with young children)	1.8E-4	581.58	0.21	0.19	0.28
		(2.9E-4)	(88.01)			
	Child Poisoning	3.9E-4	922.95			
		(5.8E-4)	(171.80)			

Since all of the injuries considered tend to be relatively minor health effects, it is not surprising that the results indicate that the injuries do not alter one's utility function in a fundamental manner. These results contrast with the findings for job injuries for which Viscusi and Evans (1990) estimated that for injuries severe enough to generate a lost workday with an average duration of one month, the marginal utility of income falls to 0.77 in the flexible utility function model, and 0.92 in the logarithmic utility model, where good health has a marginal utility of 1.

IV. Implications for Injury Valuations

If health effects can be treated as being tantamount to a drop in income, the welfare implications of health effects become simplified. In particular, one need not focus on many of the distinctive aspects of health, such as the irreplaceability of one's health and the fundamental effect of health on the well-being one can derive from consumption expenditures.

A fundamental issue from the standpoint of health and medical policy is the value one should place on reducing such risks. From the estimated value of the monetary loss equivalents obtained above, we are able to obtain a set of these valuations. The first set consists of the average valuation of the health outcomes based on the survey response. Thus, if a respondent indicated a value K_i to eliminate a 5/10,000 risk of injury i, then the implicit value for a statistical injury is $K_i/(5/10{,}000)$. This implicit value of a statistical injury is an average value for the risk reduction interval specified. Both the actual survey response and the estimated responses appear in table 4.

The second measure is the incremental willingness to pay for a marginal change in safety or $\partial K_j/\partial Q_j$. Whereas the survey captured discrete risk increments, and the estimation yields values of certain changes in health status, this measure addresses the value of incremental changes in risk. In general, there should be a diminishing marginal willingness to pay with the extent of the risk reduction, so that the marginal valuation results should exceed the estimated incremental results.[11]

A third value of interest is the valuation for certain elimination of the risk. What income transfer is required to make one whole following an injury? In particular, what value X_j for injury j satisfies $U(Y) = U_j(Y + X_j)$? If the effect on utility of the injury is strictly a monetary loss

[11] Related derivations for the decrease in willingness to pay per unit risk reduction with the extent of the risk reduction appear in Viscusi (1979), and Viscusi, Magat, and Huber (1987).

TABLE 4.—IMPLICIT VALUE OF AN INJURY

Product	Type of Injury	Average Tradeoff Values: Actual Survey Response	Average Tradeoff Values: Estimated Survey Response	Average Tradeoff Values: Marginal Tradeoff Value	Monetary Equivalent of Certain Injury
Insecticide	Skin Poisoning	1286.6	624.5	624.4	619.1
	Inhalations (no young children)	1526.6	858.6	858.2	848.7
	Inhalations (with young children)	1893.3	2110.8	2110.7	1433.0
	Child Poisoning	2766.6	2629.7	2629.3	2357.5
Toilet Bowl Cleaner	Eye Burns	613.7	519.4	519.3	514.6
	Gassings (no young children)	626.7	491.1	490.0	485.9
	Gassings (with young children)	726.7	597.6	587.5	581.4
	Child Poisoning	1046.6	939.1	938.8	923.0

equivalent, the value is the estimated loss parameter L_i.

Although the actual survey responses differ from the estimated survey responses, the three sets of estimated values in table 4 are quite similar.[12] In particular, the marginal value of the risk reduction and the predicted value of the survey response are almost identical. This result is to be expected because both values use the original definition of expected utility as the basis for the estimates, and with such small changes in income, even for non-incremental changes in risk, the wealth effects present in the predicted survey response should be quite small. Both of these values are also quite close to the monetary loss equivalent. This similarity stems from two factors —the monetary loss equivalent aspect of the injury, and the small stakes involved.

V. Conclusion

Past studies of risk valuation using market data have focused exclusively on local risk-dollar tradeoffs. Tradeoff information does not, however, enable us to resolve fundamental issues such as the value on non-incremental risk reductions, the appropriate compensation of those who experience such outcomes, or more generally, the way in which choices involving health impacts should be modeled. For the minor injuries considered here, most outcomes are tantamount to a monetary loss equivalent. More severe injuries may have quite different implications for the structure of utility functions, as our earlier study of job injuries indicated.

The development of an econometric approach to estimating utility functions for health impacts using survey data should assist economists in extending the domain of studies or risk valuation to assess how health status affects individual welfare. The techniques presented here will enable economists to better exploit the possibilities offered by survey data on multiple risk-dollar tradeoff values. Although analysis of average tradeoff levels is instructive, these data also enable us to investigate more fully the nature of the overall structure of state-dependent utility functions and not simply the local tradeoff rates.

[12] The estimates in column (2) and (3) were generated using the parameter estimates from table 4. For the cases where the ν_i term was estimated to be statistically insignificant, we set this term equal to zero.

REFERENCES

Arrow, Kenneth J., "Optimal Insurance and Generalized Deductibles," *Scandinavian Actuarial Journal* (1974), 1–42. Reprinted in *Collected Papers of Kenneth J. Arrow, Volume* 3: *Individual Choice Under Certainty and Uncertainty* (Cambridge: Harvard University Press, 1984), 212–260.

Berger, Mark, Glenn C. Blomquist, Don Kenkel, and George S. Tolley, "Valuing Changes in Health Risks: A Comparison of Alternative Measures," *Southern Economic Journal* 53 (Apr. 1987), 967–984.

Biddle, Jeff E., and Gary A. Zarkin, "Worker Preference and Market Compensation for Job Risks," this REVIEW 70 (Nov. 1988), 660–667.

Cook, Philip, and Daniel Graham, "The Demand for Insurance and Protection: The Case of Irreplaceable Commodities," *Quarterly Journal of Economics* 91 (Feb. 1977), 143–56.

Cummings, Ronald G., David Brookshire, and William D. Schulze, *Valuing Environmental Goods: An Assessment of the Contingent Valuation Method* (Totowa, NJ: Roman and Allanheld, 1986).

Fisher, Ann, Lauraine G. Chestnut, and Daniel M. Violette, "The Value of Reducing Risks of Death: A Note on New Evidence," *Journal of Policy Analysis and Management* 8 (Winter 1989), 88–100.

Gallant, A. Ronald, *Nonlinear Statistical Models* (New York: Wiley, 1986).

Gerking, Shelby, Menno deHaan, and William D. Schulze, "The Marginal Value of Job Safety: A Contingent Valuation Study," *Journal of Risk and Uncertainty* 1 (June 1988), 185–199.

Karni, Edi, *Decision Making under Uncertainty: The Case of State Dependent Preferences* (Cambridge: Harvard University Press, 1985).

Keeney, Ralph, and Howard Raiffa, *Decisions with Multiple Objectives: Preferences and Value Tradeoffs* (New York: Wiley, 1976).

Rosen, Sherwin, "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," *Journal of Political Economy* 82 (Jan./Feb. 1974), 34–55.

———, "The Theory of Equalizing Differences," in Orley Ashenfelter and Richard Layard (eds.), *Handbook of Labor Economics, Volume 1* (Amsterdam: North-Holland, 1986).

Smith, V. Kerry, and William H. Desvousges, "The Value of Avoiding a LULU: Hazardous Waste Disposal Sites," this REVIEW 68 (May 1986), 293–299.

———, "An Empirical Analysis of the Economic Value of Risk Changes," *Journal of Political Economy* 95 (Feb. 1987), 87–114.

Viscusi, W. Kip, "Wealth Effect and Earnings Premiums for Job Hazards," this REVIEW 60 (Aug. 1978), 408–413.

———, *Employment Hazards: An Investigation of Market Performance* (Cambridge: Harvard University Press, 1979).

Viscusi, W. Kip, Wesley Magat, and Joel Huber, "An Investigation of the Rationality of Consumer Valuations of Multiple Health Risks," *Rand Journal of Economics* 18 (Winter 1987), 465–479.

Viscusi, W. Kip, and William N. Evans, "Utility Functions that Depend on Health Status: Estimates and Economic Implications," *American Economic Review* 80 (June 1990), 353–374.