Willingness to Pay for Reduced Morbidity*

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1. Introduction

Estimating human health benefits from environmental improvements is important both to policy makers and academics. In the 20 years since President Reagan signed executive order #12291 requiring regulatory impact assessments of major federal rules and regulations, benefit-cost analysis of health-oriented standards has come into widespread use in the policy arena. From an academic viewpoint, valuation of improved health and other non-market commodities is a key aspect of applied welfare and environmental economics. These two sources of interest in estimating willingness to pay for improved health have stimulated a considerable volume of research. Relatively more research has been devoted to estimating willingness to pay for reduced mortality; i.e., estimating the value of a statistical life. One reason for this emphasis is that death is a more easily measured outcome than illness or injury. Death is a one-dimensional event, whereas there are varying degrees of illness and injury. Willingness to pay for reduced morbidity, however, is still important to study in an environmental context because of the need to evaluate the reduction in nonfatal hazards and because of the potentially large size of affected populations.

This paper critically reviews methods for estimating the value of reduced morbidity and suggests directions for future research. This review looks at the three methods that have been used most widely: (1) cost-of-illness, (2) contingent valuation, and (3) averting behavior. It leaves aside the few estimates that have been obtained by hedonic methods and using risk-risk tradeoffs. Section 2 presents an overview of conceptual issues concerning the three methods surveyed. Section 3 discusses how the methods have been applied. Section 4 presents a summary of morbidity values that have been obtained in specific studies.

2. *Conceptual Framework*

The simple model used as a reference point in this survey has a long history of application in both health economics and environmental economics (Grossman 1972, Courant and Porter 1981, Bartik 1988). As shown in equation (1), individuals obtain utility (U) from consuming two types of goods: (1) their own health capital (H), and (2) goods that yield direct satisfaction but do not affect health (X).

$$U=U(X,H) \tag{1}$$

Individuals purchase X in the market place, but produce their own health using the production function shown in equation (2)

$$H=H(Z;a,W) \tag{2}$$

where Z is a market good that individuals can purchase to improve health ($H_Z>0$), i.e., reduce morbidity. Medical care can be thought of as an example of Z, but there are many other possibilities and the choice of which to adopt will depend on the particular setting in which the model is used. Also, a denotes an exogenously determined amount of an environmental good, like air or water quality, that positively affects individual health stocks and W denotes individuals' genetic endowments ($H_a>0$, $H_W>0$). An important feature of the model is that health is treated as an endogenous variable and that by consuming Z people can ameliorate effects of deterioration in environmental quality. Utility is maximized subject to the full income budget constraint shown in equation (3).

$$Xq_x+Zq_Z=WT+A \tag{3}$$

Here, q_j denotes the full time inclusive price of a good $(j=X, Z)$, $q_j=p_j+WTj$, where p_j denotes the money price of good j, T_j denotes the amount of time needed to consume a unit of j, W denotes the wage rate, and A denotes income from an exogenous source.

The model can be manipulated in order to derive two results that have been frequently applied in the health valuation literature. The first is a compensating variation type expression for marginal willingness to pay either for improved health (reduced morbidity) or for improved environmental quality. This calculation can be made algebraically (Gerking and Stanley 1986) by: (1) totally differentiating the utility function and setting $dU=0$, (2) totally differentiating the budget constraint, holding full prices, wages, and total time available constant, and (3) using the first order equations to obtain

$$(4) \qquad \partial A/\partial \alpha=-H_{\alpha}q_xU_H/U_x=-H_{\alpha}q_Z/H_Z<0$$

Equation (4) indicates that individuals' willingness to pay (by giving up income) for an improvement in environmental quality is equal to the negative of the monetized marginal rate of substitution between health and the composite good, q_xU_H/U_x (the marginal willingness to pay for improved health), times the partial effect of an improvement in environmental quality on health, holding Z and W constant (H_{α}). Using first order conditions from the model, this monetized marginal rate of substitution can be re-expressed as the marginal cost of using Z to improve health (q_z/H_Z). For example, let α denote air quality and suppose that a small deterioration in α causes headaches that can be relieved by taking two aspirin. Then, equation (4) suggests that willingness to pay for a small improvement in air quality would be the cost of the two aspirin that are not taken, where the cost includes the value of any time needed to buy the aspirin or to find some that had been purchased previously. In general, willingness to pay is greater if Z is expensive with a low marginal product for improving health and the marginal effect of environmental quality on health is comparatively large. Second, as demonstrated by Bockstael and McConnell (1983), if Z is an essential input in the production of health and there is weak complementarity between H and a, then changes in the area behind the demand curve for Z also measure marginal willingness to pay for improved environmental quality. Both approaches are attractive for applied work. As shown in equation (4), willingness to pay can be computed without knowing values of the marginal utility terms. Also, estimating the area behind the demand curve for Z is at least conceptually simple.

Five important caveats regarding the model just described, and equation (4) in particular, warrant further comment before turning to applications, however. First, the model considers an individual's optimization problem over only one period. In consequence, the perspective taken is that a person might get sick (or sicker if a pre-existing health condition is present) if environmental quality worsens, but life nevertheless goes on. Thus, the model might be thought of as more appropriate for morbidity valuation than for mortality valuation, although the distinction between the two problems is obviously not clear-cut. Illness today can, but does not necessarily, lead either directly or indirectly to death at a later time. Yet, a simple model aimed at mortality valuation might envision two (or more) periods, in which the second (last) period would specifically allow for death ($H=0$) as a possible health outcome. In this setup, first-period expenditures on safety (a good like Z) affect the probability that consumption occurs in the second. Smith (1991), Freeman (1993), and Blomquist (2001) provide careful surveys of the use of household production models to value reduced mortality risks.

Second, equation (4) of the model focuses on marginal willingness to pay for a small improvement in environmental quality. It also suggests that an individual would be willing to accept that same amount of money as compensation for a reduction in environmental quality of equal magnitude. Willig (1976) demonstrates that difference between the two measures should be quite small and due entirely to income effects. Nevertheless, field applications as well as experimental studies have repeatedly demonstrated that values of non-market goods obtained by estimating willingness to accept generally exceed those obtained by estimating willingness to pay. Reasons advanced for this outcome include the argument that people value losses more than gains, and reductions in losses more than equivalent foregone gains (Knetsch 1993). The remainder of this paper, however, leaves aside the willingness to pay vs. willingness to accept controversy and focuses on willingness to pay estimates. As discussed more fully in Section 4, most studies of morbidity values are aimed at getting willingness to pay for improvements in health rather than willingness to accept values for reductions in health.

Third, measuring willingness to pay for large changes in health or environmental quality, based on the revealed preference for *Z*, generally is more difficult than estimating marginal willingness to pay. Bartik (1988) showed that under certain assumptions, non-marginal willingness to pay for an environmental quality improvement bounded from above and below using simple calculations based on savings in averting expenditures. However, empirical efforts to estimate the exact willingness to pay for a non-marginal change in environmental quality, rather than simply to bound it, require more sophisticated theoretical and econometric methods (Dickie and Gerking 1991b; Agee and Crocker 1996).

Fourth, the model limits consideration to the case of one “target” variable (*H*) and one “instrument” (*Z*), which is not a direct source of utility. Dickie and Gerking (1991) extend the model to treat more general situations in which the individual home produces an arbitrary number of (*n*) health attributes. These could be different health symptoms like cough and headache or the health of several family members. One case envisioned involves *m* market goods that are arguments in n production functions for the health attributes, but like Z in the model just presented, the market goods provide no additional services other than in the production of health. This generalization introduces the possibility of joint production in which one of the market goods might be used in the production of two or more health attributes. This complicating factor has been treated at length by Pollack and Wachter (1975), Hori (1975), and Bockstael and McConnell (1983) and raises the question of whether willingness to pay for environmental quality ($\partial A/\partial \alpha$) still can be expressed in terms of prices and household production function parameters as in equation (4).

It turns out that if household production technologies are independent and if there are at least as many health-related goods as health attributes ($m \geq n$), then prices and production parameters alone encode enough information to identify the individual marginal health attribute values. On the other hand, if there are too few "instrument" variables or if some household production technologies for the "target" variables are not independent, then one health attribute cannot be varied independently of others. As a result, individuals do not have a choice among some combinations of health attributes, and the budget constraint on which each health attribute must lie is not differentiable. In this situation, willingness to pay for a cleaner environment cannot be written as a simple expression in terms of prices and marginal productivity of inputs to the household production function. On the other hand, if the number of "instrument" variables exceeds the number of home produced health attributes, a simple generalization of equation (4) can be obtained which expresses $\partial A/\partial \alpha$ in terms of marginal costs of using "instruments" to achieve "targets." Additionally, when $m > n$ equating of marginal conditions from the model imposes restrictions on production parameters that, at least in principle, can be tested in an empirical setting.

In another possible setup that can easily be extended to the *mxn* case, the "instrument" good is a direct source of utility, another form of joint production. To illustrate, assume that in the model presented, *Z* is an argument in both the health production and utility functions. For example, *Z* still could be thought of as medical care, but individuals now get utility directly by going to the doctor. Alternatively, *Z* could denote lifestyle factors (i.e., cigarette smoking, alcohol consumption, or exercise) that enter both the household production function and the utility function. In this situation, *Z* has an independent effect on utility apart from its effect on health and the correct expression for willingness to pay for improved environmental quality would be

$$(5) \qquad \partial A/\partial \alpha = -q_z U_H H_\alpha/(U_H H_Z + U_Z)$$

where U_Z denotes the marginal utility of *Z*. Notice that in equation (5), willingness to pay for environmental quality cannot be written as a multiple of the marginal cost of using Z to improve health, except in the trivial case where $U_Z = 0$. Thus, if $U_Z \neq 0$, it would not be possible to eliminate the marginal utility terms from the willingness to pay expression.

Fifth, the model treats the health production function as a deterministic, rather than as a probabilistic, relationship. In other words, when people use *Z* to improve health, they may not exactly know what its effect will be, so a more complete model would allow for a continuum of health outcomes. Shogren and Crocker (1991) make this point and develop a model in which self-protection influences the probability and/or the severity of an undesired (health) state. In the most general version of the model, the individual's marginal willingness to pay for better environmental quality cannot be expressed solely in the simple terms of equation (4) because unobservable utility terms cannot be eliminated from the expression for willingness to pay except in three special cases. Shogren and Crocker (1991, p.13) conclude that: (1) implications of this result for efforts to value health (and property) are unequivocally negative, (2) only the three special cases provide support regarding the efficiency of traditional valuation efforts, and (3) empirical efforts which estimate willingness to pay using marginal rates of technical substitution from the health production function are misdirected.

The Shogren and Crocker paper represents a highly pessimistic view of the ability of standard models to develop a useful guide for estimating willingness to pay for better health or for environmental goods. However, their conclusion may well be overdrawn for two reasons. First, Quiggin (1992) points out that the standard analysis relating willingness to pay to the marginal rate of substitution between environmental quality and self-protection measures (see equation (4)) still would be correct in a somewhat less general version of the Shogren and Crocker analysis. In particular, Quiggin begins with the Shogren and Crocker model and then assumes that: (1) preferences display absolute risk aversion and (2) random events (from the state of the world) affecting health outcomes are separable from self-protection efforts in the function capturing the combined impact of probability and severity of loss from environmental hazards. He goes on to argue that the separability assumption is natural one in cases where self-protection is a perfect substitute for public action to reduce a hazard and that most of the examples proposed by Shogren and Crocker can be characterized in this fashion (Quiggin 1992, p.48). Shogren and Crocker (1999, p. 44) argue that the separability assumption is an unwarranted simplification in many applications and that if adopted would subordinate the role of economists to natural scientists in environmental research and policy discussions. Yet, the Quiggin paper is important for its insight into what additional conditions are required to link the more general Shogren and Crocker framework to simpler and more widely applied methods.

Second, tractability of any valuation method does not rest entirely on whether utility terms can be eliminated from a willingness to pay expression. In some situations, it is possible to estimate these terms econometrically as coefficients in a regression equation. For example, suppose that the model initially proposed is alternatively specified so that two health "targets" are considered, H_1 and H_2, and one "instrument" Z is used in the production of both. As discussed previously, utility terms cannot be eliminated from the expressions for willingness to pay for improved health and environmental quality in this case. However, holding utility constant, a change in expenditures for Z can be written as

$$(6) \qquad d(q_z Z)=(q_x U_1/U_x)dH_1+(q_x U_2/U_x)dH_2-WdT$$

where U_1 and U_2 are marginal utilities of the health attributes and, as discussed in connection with equation (4), coefficients of dH_1 and dH_2 are the values of willingness to pay for the two health attributes. Dickie and Gerking (1996) show how equation (6) can be developed into an econometric model and apply it to field data collected from a survey designed to investigate the importance of joint production.

3. Methods of Estimating Willingness to Pay

This section discusses three commonly used methods of estimating values for reduced morbidity and shows how they relate to the model just described. The cost-of-illness method is treated first, followed by contingent valuation method and the averting behavior method.

Cost-of-Illness

The cost-of-illness method (Rice 1966, Cooper and Rice 1976, Rice, Hodgson, and Kopstein 1985, Hartunian, Smart and Thompson 1981, and Hu and Sandifier 1981) measures direct and indirect costs of morbidity. Direct costs include the value of goods and services used to treat, rehabilitate and accommodate ill or impaired individuals. Indirect costs reflect the value of foregone productivity, most often measured as foregone earnings. Key practical issues in applying the cost-of-illness approach include: (1) accounting for the full impact of chronic illness on earnings, (2) choosing an appropriate wage rate to apply to lost work time, and (3) valuing time spent in unpaid work.

The main theoretical issue concerning use of the cost-of-illness approach is that it measures *ex post* costs rather than willingness to pay. In the context of the model developed in the previous section, the cost-of-illness method ignores possible changes in defensive expenditures on *Z,* and focuses on costs of restoring health after a person becomes ill. Thus, this method treats the health production function as a dose-response relationship and then applies average treatment costs to determine values. Willingness to pay, on the other hand, looks at the marginal cost of using *Z* to defend against a reduction in health as environmental quality worsens. Theoretical comparisons of cost-of-illness to willingness to pay morbidity values are not entirely straightforward. In fact, Berger *et al.* (1987, p. 976) develop a model similar to the one presented above in which there are apparently no plausible assumptions that can be made to simplify the willingness to pay measure to cost-of-illness. Also, in a similar model to that presented in Section 2, Cropper and Freeman (1991) show that willingness to pay can be expressed as the product of the slope of a dose-response relationship times the marginal value of illness. Because the marginal value of illness, which includes pain and suffering, defensive expenditures, lost leisure time, and possible altruistic benefits, is likely to be higher than average treatment costs, an individual's cost of illness is frequently regarded as a lower bound on willingness to pay (Harrington and Portney 1987). Moreover, empirical comparisons show that willingness to pay estimates exceed corresponding cost-of-illness estimates, by a factor of 3 or more (Berger *et al.* 1987, Chestnut *et al.* 1988, 1996, Dickie and Gerking 1991a, Rowe and Chestnut, 1985, Agee and Crocker 1996, Viscusi *et al.* 1991, and Krupnick and Cropper 1992).

Contingent Valuation

Contingent valuation, first proposed by Ciriacy-Wantrup (1947) and first applied by Davis (1963), elicits individual valuations of a hypothetical commodity, such as a possible improvement in health, usually using survey research methods. Early use of this method often focused on valuing recreation benefits (Bishop and Heberlein 1979) and air quality, visibility and aesthetic environmental preferences (Brookshire et al. 1982). More recently, the method has been used extensively to obtain values for avoided morbidity; example applications include valuation of respiratory and other symptoms of air pollution exposure (Loehman *et al.* 1979, Loehman and De 1982, Dickie *et al.* 1987, Alberini *et al.* 1997, Alberini and Krupnick 1998, 2000), avoidance of asthma-related illness (Rowe and Chestnut 1985, Dickie and Ulery 2001), and avoidance of angina symptoms (Chestnut *et al.* 1988). An advantage of this method is that it is quite flexible; for example, valuation questions can ask for person's willingness to pay for any aspect of health, or any non-market good for that matter. Also, it can be used to obtain values for what a person would be willing to pay for improving the health of other family members or of persons outside the household. Standard references on contingent valuation are Mitchell and Carson (1989), Cummings, Brookshire, and Schulze (1986), and Bjornstad and Kahn (1994).

Contingent valuation can be thought of as an attempt to directly measure willingness to pay ($\P A/\P a$) in the model presented in Section 2, although investigators often set the model up a bit differently. For example, Alberini *et al.* (1997) and Alberini and Krupnick (1998) formulate a closely related version of the household production model, previously discussed in connection with the cost-of-illness method, in which willingness to pay is written as the effect of pollution on illness times the marginal value of illness. As Cropper and Freeman (1993) argue, this approach allows them to combine an epidemiological study with a contingent valuation survey in order to estimate willingness to pay to avoid air pollution-related illness episodes in Taiwan. The epidemiological portion of the study used air pollution data that were matched to health diary data collected from study participants. The contingent valuation portion was administered to participants at the end of the study and focused on describing and then valuing the most recent episode of illness experienced.

These studies illustrate three important practical issues in applying the contingent valuation method. First, a sampling plan must be developed. While some contingent valuation studies have employed small, convenience samples, a form of random sampling is obviously preferred, with a sample size large enough to support precise estimation of values and detailed analysis from subgroups of interest. Nevertheless constraints always emerge. In the Alberini *et al.* and Alberini and Krupnick studies, for example, survey respondents lived within 750 meters of an air pollution monitoring station because of the need to match their health diary data with air pollution readings for the epidemiological portion of the study. Additionally, in-person interviews (used in these studies) often are preferred over telephone and mail surveys. In-person interviews allow researchers to maintain greater control over the information presented to respondents and permit use of more complex survey designs with follow-up questions that depend on answers given previously. However, in-person surveys generally are more costly and may be susceptible to “interviewer effects” in which respondents’ answers are inadvertently influenced by the person collecting the data.

Second, the commodity to be valued must be described. Regarding questionnaire design, a particularly important issue is that respondents must understand the commodity, and believe that the amount of the commodity could be changed as described in the survey. One strategy is to present study participants with a common set of researcher-designed illnesses or risk estimates (Loehman *et al.* 1979, Berger *et al.* 1987, and Viscusi, Magat, and Huber 1987). Perhaps a better alternative, however, is to have respondents define the illness episode or risk change to be valued (Alberini *et al.* 1997, Alberini and Krupnick 1998, and Dickie and Gerking 1996). The reasoning here is that contingent valuation is more likely to be successful when participants have a clear understanding of the commodity to be valued. On the other hand, participants may be less able to express meaningful values for avoiding diseases or symptoms they may never have actually experienced.

Third, contingent values for the commodity must be elicited. Important approaches to eliciting morbidity values are the "open-ended" and "referendum" questions, while "contingent behavior" and contingent ranking," have been used less often. Early research typically used open-ended questions of the form "What is the most you would be willing to pay for….?" Respondents might circle a dollar figure from a set of values on a payment card or they might simply state a value. In principle, the open-ended approach directly elicits each respondent's maximum WTP. But respondents appear to find it difficult to answer this type of question, as evidenced by high rates of non-response, zero responses, or implausibly large values (Freeman 1993). These problems may arise because people rarely have to decide the most they would pay for something; most purchases involve a simpler decision of whether to buy an item at a posted price. In consequence, referendum approaches, in which respondents are asked whether they would be willing to pay a specific amount (Hanemann 1994) have been used more frequently in recent studies. A disadvantage of this method is that it yields less information per response: a "yes" reveals a lower bound, and a "no" reveals an upper bound to willingness to pay. This problem can be addressed by: (1) asking follow-up questions as originally proposed by Hanemann (1985) and utilized in the Taiwan study and (2) by employing econometric methods designed to use the available valuation information efficiently (Cameron and James 1987 and Hanemann 1991).

Although contingent valuation method sets out to find the theoretically correct measure of economic benefit, many economists doubt that the measures obtained actually correspond to individuals' true willingness to pay (see Diamond and Hausman 1994). The main objections to contingent valuation center on the hypothetical nature of the transaction; because a respondent does not actually have to pay the amount stated, there may be little incentive to answer carefully (see Cummings and Taylor 1999 and List 2001 for recent analyses of this issue). Strategic responses to contingent valuation questions are not thought to be a serious problem (Freeman 1993), but some economists argue that the responses do not reflect stable preferences with the generally accepted properties. For example, researchers have expressed concern that contingent valuation responses are "insensitive to scope" and are unduly sensitive to the sequencing of alternatives to be valued (Desvousges et al. 1993, Diamond et al. 1993, Samples and Hollyer 1990). Insensitivity to scope, for example, would occur if willingness to pay for a large reduction in health risk is roughly equal to the willingness to pay for a small reduction in health risk (Hammitt and Graham 1999). A related issue, embedding of values would occur if willingness to pay to avoid five health symptoms were no larger than the willingness to pay to avoid one of them.

Other criticisms of contingent valuation abound. Respondents may not understand the commodity to be valued the way researchers intend, and they almost certainly lack experience paying for a commodity not normally traded in markets (Fischoff and Furby 1988, Schkade and

Payne 1994). For example, respondents have never directly purchased relief from illness or reductions in health risk. This criticism is particularly apt for efforts to value health risks, especially for low probability illnesses, because of the apparent difficulties people have in understanding risk information. Also, respondents may express a general attitude about a commodity on a dollar scale only because that is the scale the survey offers, or they may report a high value to obtain a "warm glow" from contributing to a worthy project such as environmental improvement (Diamond and Hausman 1994, Kahneman and Knetsch 1992). They may state a willingness to pay value because they assume that by virtue of the survey, the commodity surely is worth something. Furthermore, willingness to pay may be influenced by the choice of payment vehicle (i.e., hypothetical tax, referendum bid, higher utility bills, or higher prices of other goods). On the other hand, proponents of contingent valuation argue that well-designed studies elicit contingent valuation responses that often correspond closely to value measures inferred from actual behavior (Haneman 1994, Mitchell and Carson 1989, Smith 1992). Practitioners generally have stressed careful survey design and data analysis in attempts to eliminate, minimize, or test for known sources of bias or imprecision.

Averting Behavior

The averting behavior method is based on the model presented in Section 2 in which willingness to pay is linked to actions taken to mitigate adverse health outcomes resulting from pollution. In the model, these actions are represented by consumption of the good Z, which can be defined in several ways such as (1) the purchase of a durable good, such as an air purifier or water purifier; (2) the purchase of a non-durable good such as bottled water or a service such as medical care; or (3) a change in daily activities, such as staying indoors. Thus, averting actions may be intended to avoid exposure to environmental contamination, or to mitigate the health effects of exposure. The first empirical applications of this valuation method were concerned with cleaning activities to reduce soiling damages from air pollution (Harford 1984), but the focus quickly shifted to health. Abdalla, Roach and Epp (1992) and Harrington, Krupnick and Spofford (1989) looked at actions taken to avoid contaminated water supplies and other applications have investigated individuals' efforts to avoid potential hazardous waste contamination (Smith and Desvousges 1985), to reduce radon concentrations in the home (Akerman, Johnson and Bergman, 1991; Doyle et al. 1991; Smith, Desvousges and Payne 1995), to reduce asthma or angina symptoms (Chestnut *et al*. 1988), to reduce of lead exposure (Agee and Crocker 1994, Agee and Crocker 1996) to reduce symptoms of air pollution exposure, (Cropper 1981; Gerking and Stanley 1986; Dickie and Gerking 1991b, Bresnahan, Dickie, and Gerking 1997), and precautions taken to reduce skin cancer risk (Dickie and Gerking 1996, 2001).

Most applications of the averting behavior method use surveys to collect data on averting actions taken, costs of these actions, actual and/or perceived health effects, as well as other background information. Issues regarding collection and use of survey data are similar to those discussed in connection with contingent valuation. Unlike contingent valuation, however, survey questions to implement the averting behavior approach would not directly ask participants for their willingness to pay and would instead seek to gather information needed to econometrically estimate health production parameters. For example, Agee and Crocker (1994) implemented the model presented in Section 2 using data from two related surveys to estimate parents' willingness to pay for health risk reductions posed by their child's body lead burden and for information about possible medical treatment (chelation therapy). The first survey, conducted in 1978, collected data on children's medical histories and body lead burdens (by analyzing shed teeth) as well as parents' time allocations, employment, and other characteristics. The second survey supplemented the first by obtaining information about parents' 1985 wage levels and children's chelation therapy that may have occurred during the intervening years. These data were used to econometrically estimate relevant parameters of the health (actually, health risk) production function. These estimates together with information about the price of chelation therapy were used to estimate willingness to pay values using the approach shown in equation (4). In a companion paper that adopted the approach taken by Dickie and Gerking (1991b), Agee and Crocker (1996) obtained further willingness to pay estimates for improved health by looking at the area behind the demand curve for chelation. Additonally, Agee and Crocker (2001) recently extended their earlier research to analyze the marginal rate of substitution between the health of cigarette smoking parents and their children.

As outlined in Section 2, several strict conditions must be met in order to estimate willingness to pay using the averting behavior method. When these conditions are not met, the quality of resulting estimates may be weakened. A general problem with previous averting behavior studies lies in the treatment of uncertainty. As previously discussed (Shogren and Crocker 1991), uncertainty regarding health effects induced by environmental hazards and self-protection can greatly complicate the analysis. In applied work, however, the uncertainty issue generally is ignored when developing the theory needed to estimate willingness to pay and then later on, when econometric estimates are needed, an error term is introduced into the health production function. It is quite common in economics to propose a deterministic model and then to estimate parameters using a (stochastic) econometric model; yet, in the case at hand, incorporation of uncertainty into the theoretical model changes the way in which willingness to pay should be computed. In any case, future averting behavior studies might allow for uncertainty of health outcomes both in the theory as well as in the development of estimates. Alternatively, investigators might consider using research designs that would eliminate uncertainty; i.e., in a field study, participants could be told what will happen to health when a particular averting action is taken.

In a related vein, willingness to pay calculations frequently are based on instrumental variables econometric estimates. A useful example to think of in this regard might be the estimation of a health production function (see equation (2)) in which consumption of the averting good (Z) is endogenously determined in the model. Construction of instruments, however, usually can be done in a number of plausible ways as theory often says little about how this problem should be handled and variables used for this purpose are chosen depending on what information is available together with the judgment of the investigator. Different choices of instrumental variables, of course, can produce different estimates of willingness to pay. Unfortunately, this subject has never been addressed in applied studies, so the significance of this problem is unknown. Additionally, there does not appear to be any way around this problem in studies based on secondary data such as Agee and Crocker (2001), but in future field or experimental studies, an aspect of research design worth further consideration might involve randomizing consumption of Z across study participants so that its effect on the health aspect under consideration can be obtained as a treatment effect.

Other issues in applying the averting behavior method include the difficulty of identifying a good (Z) that would be effective in improving health, but would not be a direct source of utility or disutility. Chelation therapy, used in the Agee and Crocker studies, may not be an entirely appropriate choice because parents may get disutility directly from watching a child endure this lengthy and often painful procedure. Alternative choices of Z used in other studies, however, have not been perfect either. For example, Dickie and Gerking (1991a) studied cooking with electricity rather than natural gas and use of air conditioning to alleviate symptoms of exposure to air pollution, but the main reason for running the air conditioner, presumably, is to cool the house. As discussed in connection with equation (5), disentangling the value of health from other values associated with taking averting action can then be complicated. A related difficulty is that many averting actions do not have an easily observed market price to use in computing their costs. Bresnahan *et al.* (1997) found that people spend less time outdoors when air pollution rises above national standards, but it is difficult to assign a cost to this action. There is no monetary price, and no compelling reason to use the wage rate since the time spent indoors may not be entirely lost. Even when the cost of averting action is clear, the perceived benefit of the action may be difficult to infer. A person's choice of averting behavior, and thus the value revealed by his actions, is based on his *perception* of the resulting health effects. Individuals' perceptions about health risks, however, may differ from the assessments made by experts. Also, averting behavior often involves a discrete choice of whether to take an action, rather than a decision about the level of a continuous variable. For example, a person decides whether or not to purchase an air or water purifying system. Discrete choices by themselves do not directly reveal WTP, but only bound it. It is possible to use discrete choice data to estimate the exact WTP by applying complex methods (Dickie and Gerking 1991b; Agee and Crocker 1996), but most researchers either ignore the issue or simply use averting expenditures to bound WTP.

4. Estimates of Willingness to Pay for Reduced Morbidity

This section presents estimates of WTP, averting expenditures, and costs of illness obtained in selected applications of the methods discussed above. Only studies examining environmental health effects are included, and for the most part attention is limited to cases where the same endpoint is valued in two or more studies, so that comparisons may be drawn. Thus, the discussion is intended to be illustrative rather than exhaustive.

Among environmental health effects, acute symptoms of air pollution exposure are the morbidity endpoints with the largest number of WTP studies. Taken as a group, the eight contingent valuation (or more broadly, stated preference) studies considered here have four implications for policy analysis and research. First, WTP to avoid acute illness increases less than proportionately with duration (Alberini et al. 1997, Dickie and Ulery 2001, Johnson et al. 1997, Liu et al. 2000) and with the number of symptoms avoided (Alberini et al., Dickie and Ulery, Tolley et al. 1986). These results suggest that caution should be exercised when interpreting benefit assessments that do not distinguish between one-day episodes of one symptom and episodes involving more symptoms or days. If unit values computed for one symptom-day are applied to each symptom-day of multiple-day or multiple-symptom episodes, benefits would be overstated. Second, people seem to care less about the specific symptoms experienced than about other attributes of illness, such as the extent of activity restriction (Alberini et al., Dickie and Ulery, Johnson et al. 1997, Johnson et al. 2000). Third, WTP increases with income, with estimated income elasticities ranging from 0.15 to 0.6. This result suggests that attempts to transfer benefit estimates from one sample to another population should account for income differences between the two groups. The positive relationship between income and WTP also underscores the concern that using WTP estimates to guide policy decisions would favor the rich at the expense of the poor; however, as a practical matter policy analysts typically apply an average WTP estimate to all persons affected by a policy. Fourth, parents appear to value their children’s acute health about twice as much as their own (Dickie and Ulery, Liu et al.), a finding also reported in an averting behavior study by Agee and Crocker

(2000). Thus, the practice of valuing children's acute illnesses using WTP estimates computed for adults (U.S. EPA 1997) may understate economic benefits of children's health improvements by a wide margin.

Table 1 presents estimates from eight efforts to value symptoms combinations of symptoms. Three of the studies (Dickie *et al.* 1986, 1997, Loehman *et al.* 1979, and Tolley et al.) were early, "first-generation" efforts to value symptoms. The fourth (Johnson *et al.* 1997) was a meta-analysis of the morbidity valuation literature, based partly on the three first-generation studies. The final four studies are much more recent, but three were conducted outside the U.S. (Alberini *et al.* 1997 and Liu *et al.* 2000 in Taiwan, and Johnson *et al.* 2000 in Canada).

The column of Table 1 labeled "Study WTP" gives the WTP estimates in U.S. dollars of the year 2001, using the implicit GDP deflator to adjust from the year of each study. Interpretation of the resulting estimates is hindered by the fact that most studies were conducted at times or in places with income levels much lower than those in the US today. The final column adjusts the WTP estimates for differences in real income. Mean income levels in the studies were converted to US $2001 and then adjusted to the mean income in the US today (using mean income of families with children of $65,555 for the Dickie and Ulery and Liu et al. studies and mean income of all households of $57,045, see U.S. Census Bureau 2001). The effect of the change in income on WTP then was estimated by applying an income elasticities of 0.35, a roughly representative value from the literature.

After adjusting for effects of income, the WTP estimates for adults to avoid one day episodes of one symptom range from $0 to $123, depending on symptom, severity, and study, with a median value of about $35. In comparison, WTP estimates for multiple-day episodes of single symptoms are larger but illustrate the previously noted result that WTP increases less than proportionately with duration. The table also shows valuation estimates for multiple-day, multiple symptom episodes, and the Dickie and Ulery and Liu et al. results illustrate the premium that parents appear to place on protecting their children's health.

In any case, the unit values recently used by the US EPA to estimate benefits of reduced acute morbidity are substantially lower than relevant estimates from existing valuation research. In the retrospective cost-benefit analysis of the Clean Air Act (US EPA 1997), for example, unit values inflated to US $2001 are $7/day for shortness of breath, $15/case for lower respiratory symptoms, and $57/case for acute bronchitis. All of these values are lower than most estimates in the acute health valuation literature.

Table 2 presents valuation estimates pertaining to asthma. Acute exacerbations of asthma have been linked to ambient air pollution exposures, and asthma is a major public health problem. Existing asthma benefit estimates are subject to several shortcomings. Most studies have estimated costs of illness, and thus probably understate benefits by a wide margin. Results of two cost-of-illness studies are listed in Table 2. Wiess et al. (2000) present prevalence-based estimates, while the EPA study (2001) takes an incidence-based approach. Prevalence-based costs are annual costs associated with existing cases of a condition present during the year, while incidence-based costs are lifetime costs of new cases diagnosed during the year. Practitioners point out that the prevalence approach is appropriate for valuing policies affecting treatment, alleviation or management of existing diseases, because these policies affect costs in the prevalent population while leaving incidence unchanged. The incidence approach, on the other hand, is appropriate for valuing policies that prevent or delay onset of new cases of disease, because prevention avoids the lifetime costs that would otherwise occur. To illustrate, air pollution appears to be linked to aggravation of existing cases of asthma rather than to incidence of new cases. The prevalence approach is appropriate for measuring cost savings from pollution control, because reducing pollution would cut costs in the prevalent population but would not be expected to reduce incidence of asthma. Nevertheless, application of prevalence-based cost of illness estimates would require linking variations in ambient air pollution to variations in illness costs. In any event, Weiss et al. obtain slightly higher annual cost estimates for adults than for children, and the EPA study indicates that the average asthma patient incurs substantial lifetime medical costs.

Few asthma valuation studies have estimated a theoretically correct measure of benefits like WTP. Rowe and Chestnut (1986) estimated WTP to reduce the number of "bad asthma days." Estimated WTP to avoid one bad asthma day lies within the range of estimates in Table 1 to avoid one day of one symptom, although asthma exacerbation often involves several symptoms including shortness of breath, wheezing and cough. Although the Rowe and Chestnut estimates have been useful in policy analysis, it has now been over 15 years since their report. Asthma prevalence has increased dramatically, treatment regimens have evolved, and methodology for estimating WTP has advanced. More recently, O'Conor and Blomquist (1997) estimated WTP for more effective control of chronic asthma, and Blumenschein et al. (2001) estimated WTP for an asthma management plan. It is difficult to link these values to the acute episodes of asthma exacerbation associated with air pollution. Nevertheless, the O'Conor and Blomquist annual WTP estimate for effective control of asthma symptoms is 75 to 130 percent higher than the Weiss et al. annual cost-of-illness estimates.

Examples of valuation estimates obtained from applying the averting behavior method are listed in Tables 3 and 4. All values have been converted to US $2001 using the implicit GDP deflator. The studies listed in Table 3 illustrate the most common application of averting behavior methods: estimating averting expenditures as a bound on willingness to pay. These studies use actual averting expenditures rather than the theoretically correct measure of expenditures that would hold health constant when contamination changes. Each study involves temporary incidents of water contamination. Although differences between the studies in the health risk avoided and the duration of contamination complicate comparisons of results, there does appear to be fairly wide variation in expenditure estimates across studies. Two studies value avoidance of carcinogens in drinking water contamination. The Abdalla (1990) and Abdalla, Roach and Epp (1992) expenditure estimates differ by an order of magnitude. The Harrington, Krupnick and Spofford (1986) estimates of per-person expenditures to avoid giardia contamination exceed the Laughland et al. (1996) estimates of expenditures per household. Still, it is difficult to know what to make of the variation across studies without estimates of the parameters of underlying demand, health production, or preference functions.

The studies in Table 4 estimate WTP based on parametric estimation of health production functions or of demand functions for defensive inputs. The small number of studies, and differences in conditions at the study sites and in the contaminants valued, complicate comparisons. Two pairs of studies estimate willingness to pay for reductions in the same air pollutant. Dickie and Gerking (1991b) report willingness to pay for ozone control that is three to ten times larger than the estimate in Gerking and Stanley (1986) for an ozone reduction that is smaller in percentage terms (14 to 24 percent versus 30 percent). However, average ozone concentrations at the Dickie and Gerking study site (Burbank and Glendora, California) are four to five times larger than at the Gerking and Stanley site (St. Louis), and the ozone reduction considered in the former study occurs at the upper tail of the ozone distribution where health effects are more pronounced. The divergence in valuation estimates for a ten percent reduction in sulfur dioxide concentrations between Cropper (1981) and Joyce, Grossman and Goldman (1989) also are difficult to compare because of the wide range of estimates presented in the latter study and because Cropper focuses on household heads while Joyce et al. examine infant health. However, it is worth noting that the divergence between WTP estimates in the Joyce et al. study, depending on which input is used to evaluate equation (4), would violate the equimarginal principle and thus would be inconsistent with the hypothesized maximizing behavior, if the actual input prices facing individual mothers were used in the calculation. Joyce et al. used social costs of medical care, however, rather than prices paid by mothers. As noted by Joyce et al., the apparent under-use of prenatal, relative to neonatal intensive, care therefore may not be inefficient from the individual mother's perspective, particularly if the mother bears a larger share of costs for prenatal than for neonatal intensive care. Joyce et al. argue that using social costs in equation (4) yields an estimate of social, rather than individual, WTP. But the derivation of equation (4) in this model rests on the optimality of the input mix chosen for the prices faced by the decision-maker. If mothers faced the social costs of medical care, they would choose a different input mix with different marginal products of the inputs and consequently a different WTP.

More generally, measurement of prices of defensive inputs is an important methodological issue in applying the averting behavior method. Measuring the price of medical care, a good often treated as a defensive input, is difficult in light of the (possibly endogenous) variation in insurance coverage. Medical care and many other defensive activities require time, and consequently measures of time requirements and the value of time are necessary to estimate the full price of defensive inputs. Furthermore, the cost of some defensive actions, such as staying indoors to avoid ambient air pollution, is primarily a matter of disutility rather than monetary expenditure (Freeman 1993).

Interpretation of estimates in Table 1 is further complicated by the sometimes incomplete control for joint production. For example, chelation therapy is a dangerous and painful treatment and use of pre-natal care may improve the health of mothers as well as infants, but these joint products were not treated explicitly by Agee and Crocker or by Joyce et al. Joint production may be the most serious methodological issue affecting validity of the averting behavior method, and is a major obstacle to its wider application.

Also, the demands of policy analysis rarely call for direct estimation of the marginal willingness to pay for reduced pollution as in the first four studies listed in Table 4. In policy analysis of environmental health effects in the U.S., health scientists predict the health effects resulting from a change in pollution and economists then are asked to estimate the value of the effect. Policy analysts link the economic value to the underlying change in pollution using the information provided by health scientists. Thus, apart from any methodological difficulties with the four averting behavior studies listed first in Table 4, they would have limited relevance for policy because the estimate WTP to avoid pollution rather than WTP to protect health.

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Table 1. Estimated WTP to Avoid Acute Symptoms

Symptom or Illness	Days	Severity	Age Group	Study	Study WTP ($2001)	Adj. For Income
			One Day Episodes of One Symptom			
Cough	1	-	Adults	Dickie et al.	17	16
	1	-	Adults	Tolley et al.	41	43
	1	Mild	Adults	Johnson et al. (1997)	28	28
	1	Severe	Adults	Johnson et al. (1997)	50	51
Shortness of Breath	1	-	Adults	Dickie et al.	10	9
	1	Mild	Adults	Loehman et al.	81	101
	1	Severe	Adults	Loehman et al.	100	123
	1	Mild	Adults	Johnson et al. (1997)	28	28
	1	Severe	Adults	Johnson et al. (1997)	86	88
	1	Mild	Adults	Johnson et al. (2000)	0	0
Fever/Ache	1	Mild	Adults	Johnson et al. (2000)	23	25
Symptom-Day	1	-	Adults	Dickie and Ulery	55	55
	1	-	Children	Dickie and Ulery	118	116
			Multiple Day Episodes of One Symptom			
Cough	7	-	Adults	Dickie and Ulery	111	109
	7	-	Children	Dickie and Ulery	236	232
Shortness of Breath	5	Mild	Adults	Johnson et al. (2000)	240	0
	7	Mild	Adults	Loehman et al.	244	302
	7	Severe	Adults	Loehman et al.	272	336
	7	-	Adults	Dickie and Ulery	101	100
	7	-	Children	Dickie and Ulery	215	212
Fever/Ache	5	Mild	Adults	Johnson et al. (2000)	326	354
	7	-	Adults	Dickie and Ulery	124	123
	7	-	Children	Dickie and Ulery	264	260

Table 1 (Continued). Estimated WTP to Avoid Acute Symptoms

Symptom or Illness	Days	Severity	Age Group	Study	Study WTP ($2001)	Adj. For Income
			Multiple Day, Multiple-Symptom Episodes			
Cold	5	-	Adults	Alberini et al.	41	52
	6	-	Mothers	Liu et al.	35	55
	6	-	Children	Liu et al.	72	114
Not Cold	5	-	Adults	Alberini et al.	62	78
Acute Bronchitis	7	-	Adults	Dickie and Ulery	196	193
	7	-	Children	Dickie and Ulery	416	410

Table 2. Economic Valuation of Asthma

Study	Method	Item Valued	Value ($2001)
Rowe and Chestnut	CV	One bad asthma day	$14 to $65 by severity
O'Conor and Blomquist	Efficacy-safety tradeoff (like risk-risk)	Annual control of asthma symptoms	$1,672
Blumenschein et al.	CV	Asthma management plan	$30/person
	Actual sale	Asthma management plan	$9/person
Weiss et al.	COI (prevalence)	Total annual cost	$726 (age 17 and younger) $940 (age 18 and older)
EPA	COI (incidence)	Total lifetime direct medical cost	$23,569 (average patient)

Table 3. Averting Expenditure Bounds on WTP to Avoid Contaminated Water

Study	Health Output	Averting Inputs	Contaminant	Value ($2001)
Abdalla (1990)	Cancer	Buy bottled water Haul water Boil Use other beverages	PCE	$30 / averting household / month
Abdalla et al. (1992)	Cancer	Buy bottled water Haul water Boil Home treatment	TCE	$29 / averting household / year
Harrington et al. (1986)	Giardiasis	Buy bottled water Home filtration Haul water Boil Use other beverages	Giardia	$2 to $6 / person / day of contamination
Laughland et al. (1996)	Giardiasis	Buy bottled water Haul water Boil	Giardia	$18 to $46 / household / month

Table 4. Averting Behavior Estimates of WTP

Study	Health Output	Averting or Mitigating Input	Pollution or Contaminant Change	WTP ($2001)
Cropper (1981)	Work loss days	Medical care	10% reduction SO2	$19 per person per year
Joyce et al. (1989)	Birth weight, Infant survivial	Pre-natal care	10% reduction SO2	$2 (white), $10 (black) per family per year
		Neo-natal intensive care	10% reduction SO2	$39 (white), $267 (black) per family per year
Gerking and Stanley (1986)	Chronic Illness	Medical care	30% reduction O3	$39 to $51 per person per year
Dickie and Gerking (1991)	Healthy time	Medical care	Reduce O3 to 12 pphm NAAQS	$141 to $310 per person per year
Agee and Crocker (1996)	Risks from child's body lead burden	Chelation therapy	1% reduction child's body lead burden	$31 / family