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Environmental Hazards on Children's Health**

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On Techniques to Value the Impact of Environmental Hazards on Children's Health*

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Abstract: This paper describes alternative empirical techniques of economic analysis to assess the monetary value of human health, and outlines the issues that arise when these techniques are transported to value environmental hazard interventions intended to improve the health of young children. It examines four economic valuation techniques currently used to assess changes in human health (i.e., cost of illness method, hedonic method, averting behavior method, and contingent valuation method) and critiques the applicability of these techniques for assessing the value of children's health changes.

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I. INTRODUCTION

On April 21, 1997, President Clinton issued Executive Order 13045 requiring federal agencies to make children's health a high priority in their decisions. A growing body of research suggests that children, because their bodies and minds are still developing, are especially sensitive to environmental hazards. In addition, children of lower income parents who generally live in more polluted areas may be suffering to a larger extent from these environmental hazards. Earlier, Executive Order 12866 required that agencies perform an economic analysis of the consequences of proposed or existing regulatory actions (and their alternatives) that reduce exposures to or health risks from pollution. The strengths and limitations of the various economic techniques to value improvements in human health are well known (see e.g., Tolley et al., 1994); however, the applicability and/or the robustness of these techniques in settings that involve children's health has been little discussed. Thus, if one is skeptical about the appropriateness of using economic tools to choose appropriate levels of public protection from environmental hazards for adults, the issue becomes more multifaceted when assessing the value of public protections afforded to children. To accurately assess these values, the researcher must have, at a minimum, a basic understanding of the influence that caregivers have upon the behaviors and health outcomes of their children—which may or may not include the caregivers' own responses to their children's health status and/or well-being. Undeniably, these responses could reinforce or even hinder the purposes of public protections.

This paper describes alternative empirical techniques of economic analysis to assess the monetary value of human health, and outlines the issues that arise when these techniques are transported to value environmental hazard interventions intended to improve the health of young children. Specifically:

- Section II considers the meaning of economic value, paying close attention to the meaning of children's health vis-à-vis that of adults'.
- Section III discusses the similarities and differences between adults and children to highlight the additional (or perhaps fewer) dimensions the researcher will need to consider when developing an economic assessment of child health. In order to determine how an empirical health valuation model or technique may reflect child health changes, researchers must understand the roles that caregivers, children, and the public sector may play in influencing health change.
- Section IV examines four economic valuation techniques currently used to assess changes in human health (i.e., cost of illness method, hedonic method, averting behavior method, and contingent valuation method). This section critiques the applicability of these techniques for assessing the value of children's health changes according to three criteria: how close the technique brings us to the true value (i.e., theoretical completeness); whether the technique allows us to replicate the many dimensions of family behavior (i.e.,

analytical tractability); and whether the technique is cost and time effective for making public policy decisions (i.e., empirical feasibility).

- Section V presents the results of critiquing the four valuation techniques.
- Section VI reflects on unresolved questions we think to be especially worthy of future research efforts.

Specifically, in this paper we conclude that the averting behavior and contingent valuation methods yield the most theoretically complete and analytically tractable framework for valuing child health changes due to environmental hazards. The hedonic method is the least applicable based on the three criteria. The cost of illness method runs the greatest risk of seriously understating the true values of child health changes; however, given its low cost of implementation this method suffices in situations when no other values are or would be readily available.

II. ECONOMIC VALUE

In economics, value is in the eye of the beholder, but the meaning of value is not.

Value means the benefits—in this case the benefits of a child's health improvement—of a private choice or of a public policy decision. The theoretically correct measure of "benefits" is the maximum amount of money an adult person is willing to pay to secure a change in an activity that improves a child's health (which may involve that person's own child and/or an unrelated child—as we elaborate further below), or equivalently,

the minimum amount of money a person would accept to forego the activity. The sum total of individual benefits yields "society's benefits." Given that each person's preferences allow substitution between money (from income or wealth) and the beneficial activity in question, the monetary amount should leave the person indifferent between either having the money or having the activity.

For example, suppose that your employer allows you to sacrifice one hour of work to spend one additional hour at home with your child. The economic value to you of spending that additional hour at home must be worth (at least) that one hour of work. If you could have earned \$200 from that hour of work, then the additional hour with your child must be worth at least \$200. Presume now that you subsequently learn that it was a slow day at the office, and that you would have earned only \$100 by working that hour. The difference between the earnings you were willing to sacrifice (to spend the hour with your child) and what you *actually* sacrificed represents a monetary measure of the increase in your well being, i.e., your benefits. This monetary equivalent of your benefits reflects your preferences—e.g., time with your child versus time at work, as well as your personal opportunities—such as your ability to convert work time into childcare time (the terms your employer provides you).

Three premises for the meaning of economic value reside at the core of this example.

They are:

- You know better than anyone else what is best for you; i.e., satisfaction of your preferences for being with your child advances your well being.
- Your preferences are fully formed and are immutable; i.e., you always choose that alternative which you most prefer at the time you make the choice.
- Your choice reveals your preferences; i.e., you spend that additional hour with your child.

Objectors to these three premises are legion and undiminished for at least a century or more, e.g., Anderson (1993). Objections would substitute an in loco parentis, more often known as an informed, wise, and benevolent planner, on grounds that the individual does not always know what is best, that preferences evolve and can be influenced, and that choices, especially socially isolated choices, need not be consistent with preferences. Whenever these premises about individual purposefulness are hard to swallow (either singularly or in combination), one must look outside the realms of economics to find a suitable value construction.

These three premises are in fact very hard to swallow if one is asking about the values that a young child attaches either to her current or prospective health states. Young children are at best ill-informed about the alternatives available to them and the associated tradeoffs; they know little about their likes and dislikes, and they are easily swayed by parents, peers, and the media. What's more, they too frequently behave

irrationally even when they know the alternatives.¹ Young children undoubtedly consider some alternatives and consequences of choice, but to believe that standard economic analysis can interpret a value meaning from these considerations takes a major stretch. Practicing economists accept that the required stretch for adults is much less.

Nyman (1989) provides empirical evidence that adult consumers of health care behave consistently with the above premises. The discussion to follow thus focuses almost exclusively upon the economic value implications of the choices of adult significant others (e.g., parents) upon a young child's health states and prospects.² With children, this interpersonal relationship generally dominates because the choices and behaviors of adult caregivers and children affect each other's well being (Mulligan, 1997). The parent who stays at home to be with his child affects his own and the child's well being, and in turn, the child's behavior affects her own well-being and that of her parent's.

III. SIMILARITIES AND DIFFERENCES

As discussed in Section II, economists embrace a distinct definition of value based on the idea of consumer preference and choice bound by limited resources. When valuing children's health, the most reasonable approximation likely derives from the child's parents or caregivers. However, inferring values from adult caregivers introduces either new theoretical issues or new twists to existing issues recognized in the adult

valuation literature. This section considers some of the main theoretical issues associated with adult health valuation and their similarities and differences to issues encountered when applying the same techniques to children.

The theory and practice of human health valuation has made significant advances over the past three decades, both in intensity and scope as economists attempt to value an increasing number of health outcomes and risks. Increasing sophistication, both in analytical structures and estimation procedures, has increased the optimism of economists about using these innovative techniques as a tool to assist decision making. But as the techniques move forward in sophistication, so do the issues that accompany them. Below we discuss three important issues that play an important role in the economic valuation of health, and particularly child health—motivations, opportunity sets, and other important parameters.

(1) Motivations. If the economic value of children's health is to be constructed from the choices of adults, one must worry about what motivates these choices. Motivations affect the tradeoffs among alternatives adults are willing to make. The motivations the researcher accounts (or fails to account) for can influence the value measure he is able to infer for a change in a child's health. Thus a complete measure of value must include all relevant motivations. The literature in economics recognizes three plausible types of factors that motivate adults to care about children's health.

(i) Altruism. Simple affection and empathy is the first motivating factor. The literature calls this altruism, and captures it by writing down an adult taste for the well-being of children (Becker and Tomes, 1979), a taste by children for the well-being of prior generations (Bernheim and Stark, 1988), or both (Kimball, 1987). Affection and empathy is generally considered the greatest between parents and children and among blood relatives. A side street in the altruism literature raises the possibility that parents may get simple pleasure from making transfers to a child without considering the impact on the child's well-being (Blinder, 1974).³

(ii) Self-regard. Adults may also advance children's well being for purely selfish reasons. In a multiple period setting—a so-called overlapping generations setting—parents may help children so that the children, when adults, will have the empathy and the resources to help the parents in their dotage (Hurd, 1989). That is, parents purchase an insurance policy when they help their children: they sacrifice some current consumption to enhance the likelihood of a more comfortable old age. Children are thus valued for what they can contribute to parents' future wealth and utility.⁴

(iii) Children as Public Goods. The taste and the insurance aspirations that parents have for their child's well being may apply as well to entire communities and societies. Perhaps communities help children for empathetic reasons; e.g., miserable-looking children in public venues may detract from the adult community's enjoyment

of these venues. That is, the children are a public good—in many ways—which may or may not complement other public goods. For example, child health subsequently becomes adult productivity that benefits entire communities (Becker and Murphy, 1992). In addition, improved health for children enhances their educational efficiency and thus increases their demands, when adults, for public goods such as a cleaner environment that benefits the community (Haveman and Wolfe, 1984, 1995).

(2) Opportunity Sets. Motivations are not the sole source of the economic values that adults attach to the health of children. The opportunity set—that which defines the choices available to each adult or household, limits the range of decisions adults can make regarding their children's health. Each opportunity set differs according to a number of personal attributes and situations, such as his or her position in society, income, education, race, gender, residence location, or access to various markets, to name a few. A researcher who constructs a model of households with unrealistically restricted opportunity sets limits each caregiver's alternatives for maximizing gains or minimizing losses from an environmental change. As a result, the opportunity set upon which the model relies limits the alternatives caregivers are presumed to consider, thus limiting the values that are inferred from caregivers' choices. A complete measure of value must include all relevant opportunities in the opportunity set. The idea here is not unique to the children's health valuation issue, but the presumption that adults act as agents for children introduces a few special problems less prominent in the health valuation literature directed toward adults. A few examples are listed below.

(i) Parents' Control over Children. One easily overlooked feature of the child health valuation problem is that adults deliberately constrain the life experiences of children. Generally, the experiences allowed children are considerably narrower than those of adults. Children usually cannot sample the fullness of life. Either for reasons of taste or insurance, adults make decisions about what activities a child can participate in (the extensive margin) as well as decisions about the extent of her participation (the intensive margin). Any analysis that constructs values exclusively from tradeoffs parents make among already selected activities will miss the value implications of any activities newly engaged under a policy action that is being evaluated. For example, a child who was never allowed to play at a polluted site might now be allowed to play ball there once the site is restored. Evaluation of the value implications of the decision to engage the child (i.e., let her play at the site) requires attention to the total rather than the marginal benefits and costs of the activity. Neglect of this feature will underestimate the sacrifices parents or other caregivers are willing to make for the child if the likelihood of engagement increases with the magnitude of the policy action (Conley, 1976).

(ii) The Form of Household Preferences. The form of household preferences introduces yet another opportunity feature that distinguishes the child health valuation problem from its adult counterpart. We are unaware of any empirical health valuation study that nests the adult in a household, though numerous labor

supply studies do so. The few empirical child health valuation studies which exist do nest the child but the preferences of the household are treated as being unified, e.g., Agee and Crocker (1996a). However, household adults can be in conflict with each other and with their children (Bourguignon and Chiappori, 1991). Although no current evidence exists to support a valuation bias, ongoing attempts at household reconciliation and dissolution can affect both the wealth the household devotes to child health as well as the tradeoffs the household is willing to make between adult consumption and child health, and among assorted child-centered activities.

(iii) Ex Ante versus Ex Post Perspectives: Acknowledging Endogenous Risks.

The strongly intertemporal flavor of most environmentally induced health effects introduces a set of issues common to adults as well as children. With children, however, the seriousness of these issues to valuation questions is exacerbated if only because children have longer expected lives than do their adult caregivers (Moore and Viscusi, 1988). Moreover, whether wealth-constrained caregivers sacrifice own-consumption and own-investment for reasons of taste or insurance, investments in a child are riskier than most because the child as a child has as yet made few, if any, of his own human capital investment decisions (Carlin and Sandy, 1991). Caregivers or parents are wealth constrained because they are unable to borrow against the child's adult earnings for investments in the child and then make the debt the child's future obligation. That is, contingent claims

markets in child health are incomplete.

Complete markets enable parents to redistribute income toward undesirable prospective states. Erlich and Becker (1972) show that, if insurance prices are actuarially fair and if the marginal utility of income is decreasing, insurance (or future claims) would be acquired in just the right amounts so that adults would be indifferent between any realized future state of nature (e.g., health outcome).

Regardless of the state of nature, the ex ante (i.e., before any health outcome is realized) insurance premium paid and the ex post (i.e., after the health outcome is realized) compensation (that the insurance provides) will maintain the ex ante utility level. Questions of how people behave (either ex ante versus ex post) in relation to their valuation of future outcomes therefore becomes irrelevant, because the expected consequences of ex ante choice are always realized.

However, given incomplete markets (i.e., prospective outcomes are inherently uncertain), a parent's planned rather than realized outcomes best explains their behavior and therefore his (complete) valuation (Buchanan, 1969).

In contrast, an ex post representation establishes a number of contingent states, and proceeds to treat each of them as if it were certain. Thus it is incapable of accounting for the parent's attitude toward risk; that is, it disregards the expenditures the parent makes in preparing for future health outcomes that go unrealized (Graham, 1981). The alternative ex ante representation addresses the

consequences for the parent when the effects of a child health investment (or caregiving activity) are not yet known. It accounts for the value the parent attaches to the absence of risk—his risk premium.

Incomplete futures markets for the adult consequences of child health are an important opportunity dimension. A complete measure of the value of children's health effects must account for incomplete futures markets. With a few exceptions, the adult health valuation literature treats risk as immutable (exogenous) to the decision agent, e.g., Cropper and Freeman (1991). Marshall (1976), however, showed that exogenous risk requires complete futures markets. However, markets are incomplete; parents must expend their scarce resources either to define states of nature contractually (self-insurance) or to alter them (self-protection) (Shogren and Crocker, 1991). Children's health risk is surely endogenous to caregivers since those very few parents who leave their children to fend for themselves attract loud media attention. Parents often thus choose to protect their child from environmental hazards with their private resources rather than depending on collectively supplied protection. Collective protection may not be a perfect substitute for private protection (especially if pollution is found in or around the home, such as lead). In the extreme, the collectively supplied protection will be redundant. Thus a complete measure of the value of child health will be an ex ante value, and include both private caregiver and collectively supplied protection efforts. Otherwise, the child health valuation exercise will

systematically underestimate the value of reducing the risk that an environmental hazard poses to children (Shogren and Crocker, 1990).

Incorporating the endogenous risk and ex ante perspectives into the valuation methodology raises a few issues that are worthy of mention. To obtain unique solutions (i.e., individual measures of willingness-to-pay) that are readily estimable using observed data, researchers usually maintain a hypothesis that self-protection becomes more effective as the risk of unfavorable health impacts increases (Berger et al., 1987). Unfortunately this is not always so; e.g., the effectiveness of a garden hose in putting out house fires does not become greater as the risk of serious house fires increases. If, as risk increases, the usefulness of self-protection diminishes faster than the perceived benefit of risk reductions, the value of risk reduction will decline—even if the baseline level of risk is rising (Shogren and Crocker, 1999). This phenomenon seems most likely to occur in poor families for whom self-protection is relatively costly (Crocker and Shogren, 1998). Indeed, the poor may have fewer opportunities to protect their children from environmental hazards and their productivity in those opportunities they do have may be less than for the wealthy. Decreasing (incremental) valuations of child health improvements can therefore occur—even if the family resides in a more polluted area. Those who are at greater risk and who have greater wealth need not value a given collectively supplied risk reduction more highly. These results stress the importance of not focusing exclusively on any single protection

mode (public or private) for risk reduction. The researcher must account for all modes of risk reduction available to parents, and not assume a standard usefulness of all modes across all parents. Restricting the opportunities that parents have to protect their children's health can lead to an undervaluation of reduced risk, and the misidentification of those who value risk reductions most highly.⁵

Child health protections that a caregiver offers and the adaptations that he makes need not be independent of collectively supplied protections. Collective protections may "crowd out" private protections (Barro, 1974), just as private protections may render collective protections redundant. Complete measures of the economic value of collectively supplied reductions in environmental health risks to children nevertheless account for the impact the publicly supplied change has upon the private protections caregivers offer, as well as the other adaptations they might make that reinforce or compensate the collective provision that influenced their behaviors.

(iv) Joint Linkages. Another complication which endogenous risk poses for a child health valuation exercise is the joint determination of child health states and the environmental hazards the child suffers (Agee and Crocker, 1998). The necessary linkages have environmental hazards reducing child health (e.g., lead exposure causing child behavior problems), and reduced health draws down the child's prospects as an adult. However children also affect the behavior of their

parents. For example, child behavior problems could stress the provision of empathy and security by parents, diminishing further protection supplied the child (perhaps causing more lead exposure), which in turn further diminishes the child's future prospects—a kind of behavioral multiplier effect, given that children's nature and nurture are not autonomous. The existence or potential influence of this effect on child health valuation has not been examined.

(3) Important Parameters. Certain parameters are arguably more influential in the health protection decisions that caregivers make for their children than they are in the decisions caregivers make for themselves as adults. These parameters represent sources of differences in how caregivers view their world and thus represent possible sources of behavior differences. Valuation efforts must account for these differences since they affect the shape and the position of caregivers' demands for child health commodities, and hence the value measures inferred from these demands. For example, a substantial economic literature, theoretical (e.g., Becker and Tomes, 1979) and empirical (e.g., Mulligan, 1997, Chapter 7) exists on the intergenerational determinants of investments in children (such as time, effort, and market goods) that influence children's abilities, their accumulation of education, and thus their future incomes. However, none of this literature specifically considers investments in the protection of children from environmental hazards, such as, for example, the detrimental effect lead exposure poses upon the cognitive development of children.

Even though the weight of various parameters has not been explicitly studied in an environmental hazard problem, several parameters consistently appear in the child human capital investment literature. The influence of household specific endowments, such as parents' resources, sources of housing, time, money,⁶ parents' and children's health states, children's genders and birth order and spacing, have been studied at length in a variety of cultural settings, e.g., Behrman et al. (1995) and Pitt and Rosenzweig (1990). The impact of community structure has been little studied, although a few papers exist (e.g., Corman and Grossman, 1985, on neonatal mortality rates) which ask how children's health outcomes vary with the provision of local health and hospital services. All of these papers on community responses suffer from implicit assumptions that private provision of children's health/protection is invariant across communities and across households within communities. Also, they make the questionable assumptions that the provision of community services has no income effects upon caregivers nor any other effects that would induce caregiver behavioral adjustments, e.g., Joyce et al. (1989). In short, in accordance with an exogenous risk perspective, they presume that caregivers' behaviors do not respond to public policy actions.

There is one important legal parameter related to community structure that is likely to have a significant effect on the estimated magnitude of child health values. Because it is more relevant to constructing value than to explaining behaviors, no attention has been devoted to it in the child investment literature. The feature in question is to whom the legal authorities are assumed to have granted the right to "call the shots" on whether to

accept or to deny an improvement or a deterioration in a child health outcome. For a prospective child health improvement, does the caregiver have to pay for it or is he to be compensated if it is not provided? Conversely, for a deterioration, does the caregiver have to pay to prevent it or is he to be compensated if it occurs? Cook and Graham (1977) and Hanemann (1991) demonstrate that differences in maximum willingness-to-pay and minimum compensation demanded will be large when the state in question constitutes a substantial portion of wealth and has limited substitution possibilities—which is exactly the case for health states, especially for poorer people. The environmental economics literature provides many empirical examples of the compensation demanded for environmental resources being much larger than the willingness-to-pay (e.g., Brookshire and Coursey, 1987). We are not aware of any empirical studies of this issue in the health valuation literature. In terms relevant to child health valuation, the nature and importance of the issue in an altruistic or interpersonal utility setting appears not to have been theoretically or empirically explored.

(4) Conclusions: Importance of Behavioral Dimensions. Caregivers can directly respond to a change in environmental hazards confronting children by altering protections they provide their children. For a given hazard, many plausible modes of private protection exist, and the set of such modes and their relative efficacies may differ across hazard types (Agee and Crocker, 1996b). Caregivers may have preferences about how they reduce a hazard; e.g., some parents may choose to reduce their child's exposure to air pollution by keeping her indoors on high pollution days, whereas others may choose to

migrate from the polluted area. The protection response caregivers prefer is that which they believe best serves their personal empathy, insurance, and/or consumption interests. The choice is determined by the tradeoffs the family confronts. Relative prices and the physical and biological realities of the hazard and the alternative protection technologies define these tradeoffs.

Other behavioral adjustments permit the caregiver to increase the extent to which a particular mode and level of protection serves his interest. He substitutes away from activities which cost him more than they benefit him; he substitutes toward activities which benefit him more than they cost him. He thereby maximizes the gains he acquires or minimizes the losses he bears from a given mode and level of child health protection, whether personally or collectively supplied. Valuations of child health improvements will be biased downward if the researcher does not recognize these gain accentuating or loss attenuating adaptations. The list of possible adaptations in the opportunity set may be extensive (e.g., information acquisition about hazard risks and protection technology effectiveness, migration, fertility spacing and timing, child schooling quality and quantity, compensatory education, household chore time allocations, adult health investments, labor supply, job choice, planned bequests, marital formation and dissolution).

Lack of available data may restrict the researcher's ability to acknowledge important elements of the opportunity set or other relevant behavioral parameters. The current lack

of child health valuation research limits an objective cost assessment of the relative biases to child health values caused by the omission of important elements. However, other useful information is available. For example, with the sole exception of caregiver investment in information about hazards, empirical linkages between child health states and various caregiver adaptations have been extensively studied.⁷

IV. ALTERNATIVE VALUATION TECHNIQUES

In light of the discussion in the preceding sections, this section considers the applicability of four types of nonmarket valuation techniques to the problem of valuing child health risks. The four are averting behavior (household production), hedonics, cost of illness, and contingent valuation. All have a general character relative to any particular empirical observation they are asked to explain. More robust and precise explanation of empirical particulars thus requires that more specific restrictions be imposed. The restrictions shape the theory to the particulars. We adopt three criteria -- theoretical completeness, analytical tractability, and empirical feasibility -- to evaluate the applicability of the four techniques. The criteria are not necessarily exhaustive or mutually exclusive:

- *Completeness* refers to how much of the fullness of a problem the framework used to construct it captures. Fullness is defined in terms of plausible motivations, opportunity set, behavioral dimensions, and important parameters.

- *Tractability* involves a believable representation of cause and effect and the ability to derive analytically sharp results.
- *Feasibility* simply asks whether the measurement issue is relatively straightforward and inexpensive or whether it necessitates the convoluted application of complex estimators whose discriminatory power may exceed the finiteness of any available data.

(1) Cost of Illness. Human exposure to pollution can result in at least five types of losses of welfare. Three of the obvious losses are the medical expenses associated with treating pollution-induced illness (including the opportunity cost of time spent in obtaining treatment), lost wages resulting from the inability to work, and defensive or averting expenditures necessary to prevent or recover from illness. The remaining two less tangible monetary measures include the pain and suffering associated with symptoms of the illness and/or lost opportunities for normal activities, and the change in life expectancy or risk of premature death.

The cost of illness (COI) method attempts to estimate the money equivalent of health benefits associated with an environmental improvement as the sum of savings in medical expenditures (direct costs) and lost wages (indirect costs) from either morbidity or premature mortality due to illness. Savings are typically evaluated on either a prevalence (total number of cases avoided in a given time period) or an incidence (total number of new cases avoided in a given time period) basis. Prevalence and incidence are

determined with epidemiological dose-response functions or by extrapolations from controlled biomedical experiments. These functions assume that the environmental risk in question is exogenous, beyond the control of ordinary caregivers. In effect, the behavioral choices that caregivers make which influence prevalence and incidence are treated as unchanging and beyond the reach of relative prices, incomes, and other economic and social factors.

By design, the COI estimates also exclude both the savings in defensive expenditures and the value of pain and suffering avoided due to ill health. The design does provide simplicity of implementation: quantities are clear, well defined, and observable. Moreover, there are a number of sources of relatively good quality national databases. Nevertheless, since the COI method does not attempt to measure the less tangible aspects of ill-health, the COI estimates represent an incomplete measure of the full benefits of a health improvement—where the full measure is the willingness to pay (WTP) or compensation demanded (willingness to accept—WTA).

For the case of ex post child health effects, measurable indirect costs include the parent's or care-giver's cost of time of obtaining medical treatments for their child—valued either as lost work time (using the care-giver's wage rate) or as lost household production time.⁸ If the pollution-induced health effects reduce a child's human capital or life expectancy, indirect costs include the (discounted) future losses in labor market earnings. As WTP or WTA measures for reductions in child mortality risks become more available (e.g.,

Joyce, et al., 1989; Blomquist, et al., 1995; Carlin and Sandy, 1991), COI estimates of the value of life threatening illnesses become less useful.⁹

While the COI quantities represent some ex post aspects of the benefits of an improvement in a child's health, the COI approach suffers from a number of additional conceptual and methodological flaws which set it apart from ex ante WTP and WTA. The inattention to risk premia is a prime failing. Additionally, in the past, COI measures in general were referred to as lower bounds to WTP. Indeed, conceptually, COI measures do not include values of pain and suffering and defensive expenditures and, if positive, represent understatements of WTP; however, a number of researchers (e.g., Shogren and Crocker, 1991; Berger, et al., 1987; Harrington and Portney, 1987) show that COI measures may or may not represent a lower bound to WTP. For example, the empathetic disutility a parent bears from the pain and suffering a child endures from additional chelation for a body burden of lead may outweigh the parents' benefits from the reduced body lead burden. Thus for any arbitrarily selected change in the incidence or prevalence of a lead-induced child health state, a COI will overestimate the cost of self-protection the parent is willing to bear. Kenkel (1994) suggests that, as a first approximation, contemporary COI benefit estimates may represent society's viewpoint for reductions in total medical expenditures. However, these effects cannot successfully be evaluated without developing a more rigorous model of the supply and demand for medical care. Thus not only would individuals' preferences, but also distortions in the U.S. supply for medical care have to be accounted for.

Despite its real shortcomings, the COI approach remains widely accepted by medical professionals as an easy method for valuing changes in health status. However, significant weaknesses exist even for estimates based on foregone earnings alone. To determine future earnings requires that the child's educational choices and its career path over the life cycle be predicted—a task that not even a doting parent would likely attempt with any assurance.

Estimation of parents' forgone earnings due to their child's ill health appears somewhat more straightforward than that of a child's forgone future earnings. However, since COI estimates focus on output or production lost, whether market or non-market related, the measure does not capture all the costs a parent or caregiver incurs with the child's medical and remedial treatments. Utility maximizing behavior implies that parents will allocate time toward work, childcare, and other household related activities including leisure. At the margin, the value of leisure time is just as valuable as working time. Thus additional time allocated to care of a sick child, whether it comes from leisure time or from work time, is valued by the wage rate of the individual, a source of possible error, in particular, for full time homemakers.¹⁰

(2) Hedonic Method. The use of differences in property values or wages to construct the money equivalent of the health benefits from reductions in environmental hazards is based upon the following observations. An individual free to choose his residence or job site or type will try to balance the cost of access against the utility of different sites or jobs. The utility of different sites or jobs is determined by his expectations about future combinations of attributes (amenities, safety, transport costs, etc.) which are not costlessly unbundled (Tinbergen, 1956). Thus the individual will seek to balance, among

other attributes, his expectations about future environmental risk consequences and site rents or wages (Rosen, 1974). At the chosen site or job, property prices or job wages must, at the margin, reflect equilibrium between the person's demand for risk avoidance and the supply of risk at the site or job.¹¹ Property price or wage difference compensates for the difference in expected levels of the environmental hazard. Embodied in this theoretical parable are several strong assumptions:

(i) Observed levels of the environmental hazard correspond to market expectations of future environmental hazards.

(ii) Households have a positive marginal willingness to pay for environmental hazard avoidance only at those sites or in those jobs in which they actually live or work.

(iii) Land markets are highly competitive and complete. People are willing and able to change sites or jobs at a moment's notice in order to reequilibrate.

(iv) Only by moving are people able to influence the level of environmental hazards they confront.

(v) Prices of commodities or activities other than residences or jobs do not change when people move.

Additional issues arise with empirical implementation of the story. They arise because the hedonic method is more a language for explaining modeling strategies than a source of explicit restrictions with which to mold data in order to construct economic value measures.

- Hedonic theory provides no guidance about which attributes in a bundle are more or less or not at all valued. Thus attempts to measure the contribution of attributes to price or wages provide a fertile ground for data mining to obtain desired signs for the price-attribute relation as well as for the selective reporting of unrepresentative results (Atkinson and Crocker, 1987).
- Measurement of willingness to pay when a change in the level of an environmental hazard has caused the relationship between property prices or wages and the hazard to change requires that information on this relationship from several markets be obtained (Epple, 1987). Exactly what constitutes a market for a particular attribute can be ambiguous and market constitutions can differ among attributes (Atkinson and Crocker, 1992).
- Estimates of marginal prices are extremely sensitive to the functional form assumed for the relation between property prices or wages and attributes of interest (Cropper et al., 1988).

Most wounding, however, for the application of hedonic methods to economic valuation of child health impacts of environmental hazards is the presumption that the value of the contribution that an environmental hazard makes to child health at a site can be distinguished from the value of its contribution to the health, amenities, and productivity of the child's caregivers. To make this separation would require empirical implementation of a model of internal household decisionmaking. Since this effort could also provide detached information about child health valuations, subsequent application of the hedonic method would be redundant.

(3) Contingent Valuation Method. The contingent valuation method (CVM), which has been used to estimate benefits of a broad range of environmental improvements (see Cummings et al., 1986; Hanemann, 1994), requires the collection of primary data usually by means of a written survey or a person-to-person interview. Survey respondents are presented with a hypothetical situation describing the increase in the supply of a non-market good (such as an environmental improvement), or the government provision of a public good (such as a child safety initiative) and how the payment can be made—either as a tax, or a price as for the purchase of a product. Respondents are then asked for their maximum willingness to pay for the good described. A few applications of this method to valuing child health risks exist in the literature (e.g., Viscusi, et al., 1988); such an application to assessing economic values of government or other programs that improve children's health seems feasible.

An advantage of the CVM lies in its flexibility. Questions can be framed so as to capture

aspects of individuals' preferences, including uncertainty about the state of the world, which are impossible to measure using the COI approach. Furthermore, the good can be alternatively described so as to elicit the importance of different motives for desiring such a good or service both at the present time and in the future. For example, one approach might request that respondents reveal whether or not they would vote yes on a specified tax that would reduce pollution and an associated number of child illnesses. Viscusi, et al. (1988) for example, surveyed North Carolina residents asking them how much more they would be willing to pay for an improved insecticide spray product that would reduce the number of poisonings of North Carolina children from 15 to 10 for every 10,000 bottles sold.¹² This amount of money, assuming that it can be obtained in an unbiased fashion (i.e., from an ideally structured survey), is interpreted as an option price comprised of two components: (1) the value of retaining an option to consume the future good or service, or to realize the future state, and (2) the expected consumer surplus that would be derived from actually purchasing and enjoying or realizing the good or service.¹³ The concept of option price is important to assessing benefits that involve a future time that is characterized by uncertainty. Because long-term epidemiological and toxicological consequences of some pollutants may ex ante only be known imprecisely, the focus on uncertainty is clearly warranted. However, the sword cuts in two directions, particularly when applying the CVM. What are respondents' attitudes toward risk? Have they ever thought about what alternative outcomes are possible? Are they familiar with currently available scientific evidence? Do respondents believe that taking defensive actions can reduce risks of adverse consequences of

exposure or are hazards posed seen as inevitable? At a minimum, CVM surveys should lead respondents through a carefully structured thought process prior to eliciting values. Yet, no matter how carefully the instrument is designed, there still will be room for debate concerning interpretation of the dollar amounts obtained.

There exist some environmental hazards (e.g., ambient lead prior to the 1980's) to children with which caregivers have had little experience. They may even be ignorant of the existence of the hazard and, if not, are uncertain as to how they feel about the severity and the time pattern of its consequences. They may not know their beliefs and preferences. When this scenario is plausible, difficulties arise in interpreting the meaning of value statements that CVM applications elicit because respondent preferences for the commodity or activity of interest are then incomplete and incoherent (Crocker et al., 1998). Completeness implies that a person's buying price for a gamble equals his selling price and coherence requires that when confronted with the gamble he not accept a sure loss. Economic rationality demands completeness and coherence in belief and the constructs which give economic value meaning presume economic rationality. Empirical evidence is abundant and strong that exchange institutions such as the market force individual and collective rationality (e.g., Gode and Sunder, 1993; Plott, 1996). The exchange institution provides the gravity or arbitrage pressure to hold together a person's economic rationality. Empirical evidence is also abundant and strong that, when this gravity is absent, completeness and coherence in preference expressions is problematic (e.g., Thaler, 1992). Because respondents in a CVM exercise are requested only to

imagine their participation in an exchange institution rather than actually to participate in such an institution, little or no arbitrage is applied to induce rational economic behavior. Consequently, unarbitrated CVM value expressions may say something meaningful about values but their strict interpretation as economic values can be questioned. Experimental evidence does exist that CVM value expressions will converge on arbitrated values when a CVM exercise and an auction operate in parallel (e.g., Fox et al., 1998). In settings where such parallel operations cannot be implemented, checks on the completeness and the coherence of CVM respondent beliefs would seem appropriate. The results of these checks would allow policymakers to decide the extent to which economically irrational value statements provide information useful to them (Machina, 1990).

CVM also provides a way to capture the values people attach for public good reasons to environmental hazard reductions that could lead to improvements in the health of children not one's own. If local community programs exist uniquely identified with children's health, differences in taxpayers' willingness to pay for these programs across communities would provide insight about the collective values rather than just the private caregiver values of child health. An exclusive focus on taxpayers who are not currently and who do not expect to be caregivers would remove any possibility of confounding private and public values as well as confounding affects of protection activities directed toward private gain. A CVM study of this sort would be usefully complemented by application of the median voter model (Barr and Davis, 1966) to assess the relationship

between local collective expenditures on child health care activities and local incomes and tax rates.

Cummings, et al. (1986) and Hanemann (1994) summarize several practical problems that can arise in applying the CVM. These problems include possibilities for strategic misrepresentation of preferences and various types of bias of respondents' answers due to unfamiliarity with the situation posed, the choice of payment mode, or the type of bidding procedure used. Also, even in situations where these potential biases either can be avoided or minimized, CVM bids can display an uncomfortably large variance.

Dickie, et al. (1987) cite several examples of this phenomenon from applications of CVM in a health symptoms context.¹⁴ These problems do not rule out use of contingent valuation, yet they have prompted the development of alternative methods, such as the averting behavior method described below.

(4) Observed Averting Behavior Approach -- Household Production. Averting behavior models are yet another approach to estimating option prices of environmental commodities. Based upon the paradigm of constrained utility maximization, such models can be configured to capture a number of different aspects of environmental problems. In the context of valuation of human health, most models portray some form of household production of commodities for final consumption by immediate family members. The economics of consumer choice asserts that individuals' chosen tradeoffs between income and aspects of personal well-being, such as one's own health or the health of family

members, can reveal a unique (compensated) demand curve for a range of health outcomes associated with differing levels of environmental quality. A monetary equivalent of the value an individual attaches to an environmental improvement represents the area under this demand curve.

In the household production framework, parents are seen as producers of the commodity 'child health' by combining their own time, effort, and market goods purchases such as medical care, diet, shelter, and so forth. Currently there are very few empirical studies that use a household production technique to assess monetary equivalents of parental benefits of reduced pollution-related health effects in children.¹⁵ Data limitations likely have hampered their development; until detailed household level data are made available on parental expenditures, time allocations, commodity prices and wage rates, along with environmental quality measures experienced by these same households, few empirical advances can be made in applying the approach more generally.

Nevertheless, the household production framework has proved especially helpful in describing the basic structure of the household, and thus in developing familiar restrictions between commodities that are especially helpful in specifying empirical models for measuring the demand for environmental improvements. Based on the work of Becker (1965) and Grossman (1972), the household production model assumes that parents have the ability, in addition to general childcare, to protect their children from known hazards in or around their home environment. The linkage is typically described

using a production function wherein parents combine private commodities to reduce either their child's risk of harm (which may include fatality), or to enhance their child's general health or safety. As Bockstael and Kling (1988) demonstrated, these linkages (usually expressed in the form of the demand for a child-protection commodity) between groups of private commodities and a nonmarketed good (or bad) provide a comparable means of inferring the value of the good. Thus the framework simply affords a means of identifying the groups. Other authors, for example, Pollak and Wachter (1975), Bockstael and McConnell (1983; 1993), Maler (1985), Gerking and Stanley (1986), Agee and Crocker (1999) and others, have developed and in some cases applied the necessary restrictions to arrive at empirically tractable expressions for the demand for environmental quality consistent with the utility maximization paradigm.

Typically, values derived from the household production technique involve expressions for the demand for an input that can either be classified as a substitute or a complement to the environmental service or state in question. These inputs, which either are directly observable (like medical care to alleviate sickness) or inferred from other observable (like the demand for child health), encode enough information to infer value, but must be subject to certain restrictions to justify the value on theoretical grounds. Thus far two methods have been applied to market data in the literature, both of which are similar in the initial modeling stage. The first method involves the case of perfect substitutes, i.e., a production technology involving two items that can replace each other; for example, a child health ailment--such as a cough--can be alleviated by the purchase of a medication.

Smith (1991) shows that for the case of perfect substitutes (a.k.a. a pure averting good), parental valuation of increased child health (i.e., reducing child coughing) can be accomplished by estimating an expression for the demand for the cough suppressant (including the opportunity cost of parental time to administer it, valued at the parent's wage or opportunity cost of time).¹⁶

Unfortunately, most health technologies are not so simple; parents usually face a variety of choices to improve their child's health status, some of which may be weak substitutes for the environmental commodity, complementary with other inputs which, together, substitute for the commodity, or there may be a combination of inputs (with differing relationships to one another) which may either serve as substitutes or complements to the commodity. Bockstael and McConnell (1983) show that if a particular input can be regarded as essential to the production of child health, with or without other inputs, the area under the demand for that essential input will provide an accurate and theoretically sound value for the environmental commodity. However, if an essential input cannot be identified, but clearly important health production inputs *are* observable, then the area under the demand curve for the observable input represents a lower bound to the parent's true willingness to pay for the child health state.¹⁷

While economists have found the previous restrictions to be potentially useful, the restrictions do not guarantee that value of the environmental state can be estimated accurately from market data. Because demands derived using the household production

approach refer to Hicksian (compensated) demands and because there is no clear cut distinction between Hicksian demands and Marshallian demands (demands that are estimated with market data), there may be significant errors encountered in the final value estimates.¹⁸ The work of Willig (1978) and Neil (1988), demonstrates, however, that it is possible to bound the observed Marshallian demand functions and corresponding value measurements if either expenditures for the private good inputs represent a small fraction of the household's total budget, or if it is possible to show that the environmental state affects different groups of private household inputs in a special way (see Neil, 1988 for further details). Research on this area remains incomplete; however at present, the available evidence suggests that characterization of the size of the errors arising from estimation of Marshallian demands must rely on simulation analysis (Smith, 1991).

V. CONCLUSIONS

Our evaluation of alternative nonmarket techniques to value child health has employed three criteria-- theoretical completeness, analytical tractability, and empirical feasibility. For most levels of research effort, we believe that the household production (HPM) and the contingent valuation (CVM) methods will yield the most theoretically complete and analytically tractable framework for valuing the child health risks cast by environmental hazards. The cost-of-illness (COI) method has the greatest empirical feasibility but, in our view, its failings with respect to completeness and tractability pose a substantial risk of producing seriously misleading results. Calculations of the cost savings that could

accrue from a posited reduction in risks to child health do not mean that people would actually pay these amounts. The risk reduction may cause them to move their resources to other uses they now value more highly. That is, the COI method only acquires empirical feasibility at the substantial cost of disconnecting prices and human behaviors. Because of the difficulty in determining the extent to which differences in site or job prices are due to caregivers' concerns about themselves or about their children, hedonic methods (HM) are dominated on all criteria by the other three methods.

We view the HPM and CVM approaches as complements to rather than substitutes for each other when used to estimate child health values. They are properly viewed as complements because each provides different advantages and has different failings with respect to the three aforementioned criteria. Given that the connections between environmental hazards and valuations of child health risks have been little studied, identification of these three purported advantages and failings must necessarily be somewhat conjectural rather than based on a careful study of research experiences on the problem of interest.

Applications of the HPM must always be sensitive to the tradeoff between theoretical completeness and analytical tractability that is inherent in the approach. It yields sharp results which are empirically testable only by imposing auxiliary restrictions on the inclusion and properties of motivations, opportunity sets, behavioral adaptations, and parameters. The parable within the general HPM framework that the researcher

constructs steers the interpretation on the inferences from this data. Acquisition of tractability in the HPM is an exercise in the art of selecting separability and exogeneity assumptions that do minimal violence to the real-world problem or policy intervention question at issue. The selection problem will differ from intervention to intervention and from data set to data set. More complete data than are now available about "who gets what" in households under varying environmental risks, and adult and child health states would do much to relax the completeness-tractability tradeoff for the HPM approach. Matching this new information with traditional demand information (e.g., Blundell and Walker, 1984) on identical households would allow the calibration of these separability and exogeneity assumptions when only this traditional demand information is available.

Use of no more than the HPM limits valuation exercises to the private features of protecting children from environmental hazards. The benefits measured are only those which accrue to the caregiver and to the caregiver's aspirations for his charge's future. Whether privately or collectively supplied, the public good features of child health protection are neglected. CVM is the most tractable and empirically feasible way to get at measuring these benefits. However, its theoretical completeness -- even its plausibility in the sense of what its results mean in terms of economic value -- is unsettled. Thus simply to design a stand-alone CVM exercise to get at these public good values seems imprudent. Prudence requires, at minimum, that these CVM exercises proceed in parallel with carefully controlled laboratory experiments designed to get at the same public good valuations. The laboratory experiments involve real rather than hypothetical payments,

thus imposing the gravity of arbitrage upon exercise of the participant's economic (or lack of) rationality.

When one thinks within the HPM framework and the CVM approach, some potentially high payoff, analytically tractable, and empirically feasible modest research efforts become visible. The efforts have a potentially high payoff because they are likely to do much for theoretical completeness.

VI. RECOMMENDATIONS

Our charge for this paper was to summarize the analytical background and to evaluate the applicability to child health valuation of the four nonmarket valuation techniques discussed in Section III. We have two major recommendations for further research regarding child health valuation, these include further consideration of the discount rate, and the adult-oriented perspective of the current models to value child health.

Discount Rate

The criteria used to evaluate the techniques for valuing child health in part account for the varying types and levels of caregivers decisions. Therefore, it is important to understand the potential effect of these decisions on value estimates. No single feature of

caregiver decisions is likely to exceed the leverage that the discount rate caregiver apply to child health investments has upon child health outcomes. Though the theoretical literature on family economics and human capital formation always includes a term for this discount rate and then works out its implications, empirical knowledge of its magnitude appears to be limited to a single paper, i.e., Agee and Crocker (1996b).¹⁹ This paper employed the HPM framework. It showed that the discount rate caregivers use varies inversely with their education and income, but it did not consider what the rate implies for child health. Given the leverage the discount rate exerts upon caregiver investment decisions, and given that it condenses in a single scalar measure a wide variety of caregiver behaviors which have intertemporal effects on a child's development, improved empirical knowledge about its magnitude and how this magnitude varies seems imperative if reliable estimates of the value of child health are to be obtained. Because of the strongly intertemporal (decades-long) nature of child health investments, all other research dimensions of this valuation question are likely secondary.

For the private caregiver, investment and consumption decisions which determine caregiver valuations of own-child health, the relevant discount rate is unequivocally that which this caregiver applies. But the use of this rate to value the intertemporal public good features of child's health is problematic. Three classes of arguments appear in the literature. First, Marglin (1963) argues that private markets fail to account for the interdependence of potential savers' generalized concerns for the society's future well-being. This is shown to imply that the market discount rate is inefficiently high for any

investment decision, whether public or private. Second, Arrow and Lind (1970) and others take the position that the discount rate is applied to collective provision of public goods -- the social rate of discount -- is probably less than the private rate because governments have a lower risk premium than do private individuals. Governments are better able to diversify and arbitrage their investments across space and time. Third, and counter to the Arrow and Lind (1970) argument, collective provision of public goods has an opportunity cost when it displaces private investments having a higher rate of return (Bradford, 1975). The displacement justifies a social rate of discount higher than the private rate. In sum, the question of the economically efficient discount rate to apply to public good investments is unsettled. Lind (1990) suggests that the federal government's borrowing rate constitutes the best compromise among the contending arguments. Also for the public good features of child health, the reliability of CVM exercises would be improved substantially if checks on the economic rationality (completeness and coherence) of respondents were developed for CVM surveys.

In a longer-term research perspective, application of the HPM and the CVM to child health valuation questions would be considerably improved by an enhanced understanding of children's reactions to changes that they perceive in their safety and security. Caregiver investment decisions are plausibly not independent of these reactions nor are caregiver beliefs identical to those of their children. Existing literature (e.g., Johansson, 1994; Jones-Lee, 1991; Rangazas, 1991) assumes they are identical. Variants of existing models of family altruism (e.g., Becker and Tomes, 1986) in which the well-

being of both parents and progeny depend on the behaviors of the child, on the safety and security the parents provide the child, and on family wealth have the potential to capture the impact of the child's reactions and beliefs upon parents' child health valuations. The core condition in such variants would be that parents can use the costly provision of safety and security to purchase those child behaviors the parents desire, while the child can increase its safety and security by behaving as its parents desire.

Adult-Oriented Perspective

Because each of the above discussed techniques refers only to individuals who currently possess economic standing in the society, our treatment of the valuation issue has been limited to existing caregiver and general adult public valuations of alternative child health states. We have not considered the valuation implications of having children grow up to have a life vision and their own economic standing. But when children achieve this standing, they may regret the relative values that their former adult caregivers attached to child health states. Though outside the scope of the current effort, it is by no means clear to the authors that it is either economically or even ethically correct to base child health valuations solely on the preferences of those who currently claim economic standing. Current children, when adults, and current caregivers may have quite different preference orderings about current health states.

Given that the preference orderings of current caregivers are not properly viewed as immutable, the unassailable fact remains that we cannot know now what the adult preference orderings of current children will be. The valuation techniques reviewed in Section III cannot be applied without such knowledge, whatever the economic and ethical justifications of accounting for children's preferences when adults. An alternative approach to valuation is called for that would complement current caregiver valuations.

Without having fully explored its strengths and problems, we suggest that an approach which ranks future opportunity sets for current children by the freedom of choice the sets will offer the children when they achieve economic standing has intuitive appeal. The ranking would be subject to current private and public resource constraints. We want a valuation criterion independent of the specific child health states which current caregivers favor. Sen (1991), for example, sets forth criteria for ranking of future opportunity sets in terms of freedom of choice, where such freedom refers to the range of available options. Hence if one opportunity set has more elements from which to choose than does another, it conveys more freedom. Thus current investments in child health which widen and deepen a child's capabilities enhance that child's future freedom of choice and life chances. Alternatively, if the freedom of choice across sets is similar and one set offers greater value to current caregivers, then that set is preferred. When the maximization of current caregiver valuations and the child's future freedom of choice conflict, a choice must be made. Neither the properties nor the appropriate weighing of this choice is self-evident. Granted that only those who have current economic standing

can make the choice but at least the opportunities that children will have to realize their own unique preferences are then being recognized.

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ENDNOTES

¹ By irrationality, we mean a violation of one or more of the axioms (reflexivity, completeness, continuity, and transitivity) which underlie all economic theory, whether positive or normative. See Thaler (1992) for a discussion of violations and De Palma et al. (1994) and Crocker et al. (1998) for ways of making some of them consistent with economic theory.

² Note this need not imply that children are simply passive receptacles. A child's behaviors clearly do influence caregivers' choices about how to treat the child. If children respond to incentives, economic analysis can contribute to explanations of these behaviors (Pollak, 1988) but, for the reasons stated, it cannot say much about their value to the child qua child.

³ Such transfers could be negative, as with child abuse.

⁴ Children as well as parents can behave selfishly. Becker's (1974) "rotten kid" theorem specifies conditions under which transfers can be used as a carrot or a stick to make selfish children behave as their parents wish, thus justifying analytical frameworks which treat the child as a passive receptacle of the parents' bounty. These conditions are fairly broad, though Bergstrom (1989) and Bruce and Waldman (1990) show that they are by no means all-inclusive.

⁵ These potential mischaracterizations could also extend to the public good motivation for child health protection. For example, a policy decision (such as a child safety initiative) could be made based on the value of statistical lives saved. "Value" is computed by multiplying the incidence of child mortalities across communities times the value of a statistical life—the estimated loss from an unidentified single death weighted by a probability of death that is uniform among individuals within a community (Cropper and Freeman, 1991). However, this approach to a collective risk reduction fails to address the differences in the risks of individual children induced by the protections that individual caregivers may provide (Crocker et al., 1991). It can therefore undervalue child health improvements that contribute to the provision of public goods. One possible remedy in this area would be the construction of a median voter model to infer values from differences in the provision of collectively supplied inputs to child health across different communities (see Barr and Davis, 1966, for an example of this approach).

⁶ Women often act as uncompensated childcare and home care providers. This lack of compensation can affect their health and thus their caregiving productivity. See Wolfe and Haveman (1983).

⁷ See Browning (1992) and Wolpin (1997) for thorough reviews. Rosenzweig and Wolpin (1988) construct a dynamic model of child health that accounts for unobserved heterogeneity in child endowments prior to birth and parental learning after birth. The learning they consider is passive rather than active, however. The only study of which we are aware that considers information acquisition for children is Agee and Crocker (1994), which estimates parents' willingness-to-pay for information about the health risks posed by their children's body burdens of lead, an environmental hazard. In a related study, Agee and Crocker (1996b) develop an alternative technique to infer the near limitless list of plausible adaptations caregivers can make to the risks environmental hazards pose their children as a single scalar measure—the change in the discount rate caregivers apply to investments in their children. They find that caregivers who value their child's future more highly will apply a low rate to investments in their children; caregivers who value their child's future less highly will apply a higher rate. Thus the caregiver discount rates serve as a theoretically well defined index for a broad array of nurturing investments in children that have an intertemporal dimension, including, for example, time and money resources devoted to improving separately and jointly the child's physical and mental health, social skills, learning, motivation, appearance, reputation, credentials, attitudes, and many other qualitative dimensions.

⁸Non-health sector expenditures, such as transportation to and from providers, special diets, etc., are typically omitted in COI studies although these expenditures are not prevented (reduce the probability of illness) and should be included.

⁹ The COI method was used to value children's health effects from elevated blood lead levels (EPA, 1985) from use of lead in U.S. gasoline. The monetary value of child health benefits associated with a reduction in child blood lead levels comprised of two measures: the savings in expenditures for medical testing and treatment of children found to have 'excessive' blood lead levels, and the savings in compensatory education—for the (estimated) percentage of children detected who suffer from IQ deficits and learning problems. Health risk was established using a dose-response function to establish the relationship between blood lead levels in children (of a given age) and the estimated number of U.S. children to be above a given threshold known to cause diminished IQ or learning or behavior problems. COI measures summed the number of children requiring either medical treatment and/or compensatory education times the cost of these treatments, which included parental time costs for child treatments and follow-up visits. The measures did not include values of the child's pain and suffering, parental defensive measures (such as home improvements to reduce exposure—a potentially significant expenditure; see, e.g., HUD, 1991), nor did they include the altruistic losses of parents—i.e., parents fear of irreversible reductions in their child's adult prospects. In addition, measure did not include the value of children's lost earnings from lead-related IQ deficits. Schwartz (1994) and Salkever (1995) who used a variety of labor market earnings research to estimate children's adult earnings losses due to lead-related IQ deficits investigated this latter component. These studies

found the money equivalent of this component to be sizable. Agee and Crocker (1996a) estimate parents' WTP for reductions in perceived risks to their children from lead exposure. These estimates were found to be more than twice the EPA's 1985 COI estimates.

¹⁰ The estimation of the forgone earnings of full time homemakers is also less precise than the estimation for the currently employed. For example, Paringer and Berk (1977) use data on the cost of housekeeping services to estimate the value of household production time lost. Again, problems are encountered, because what is relevant to the individual keeping house is the wage rate she is giving up by staying out of the market. The study by Gronau (1973) is a case in point; he found that full time homemakers valued their time by 13 to 22 percent more than their offer wages.

¹¹ The conditions under which the simple relation between observed property prices (or wages) and the level of the environmental hazard represent willingness to pay are specified in Palmquist (1988, 1989). These conditions basically require that the prices of the other sites not be influenced by the changes in the hazards at the subset of sites. When the prices of other sites are so affected because of substantial changes in the stock of sites with a particular level of the hazard, construction of a willingness to pay measure becomes considerably more complicated.

¹² Each consumer considered a single product, which had an initial price per bottle of \$10 and a current poisoning rate of 15 poisonings per 10,000 bottles sold. The interviewer then told the consumer that the product could be reformulated to make the product safer.

¹³ Option price net of consumer surplus is referred to as option value (see Fisher, 1981). Option value for environmental assets generally will be positive because there is value in refraining from present actions that can cause irreversible damages (such as chronic illnesses or fatalities), and because information about the extent of possible damages will improve with the passage of time.

¹⁴ Mean bids often were so highly skewed that mean bids were five to ten times higher than median bids.

¹⁵ Agee and Crocker (1996a) use expenditures on medical treatment (chelation therapy) to reveal the values parents place on reductions in perceived risks to their children's health from exposure to lead sources. Inferences are based on a household production model in which parents' invest in medical treatments and other exposure reducing activities to reduce their perceived risk of their child developing lead-induced neurological deficits.

¹⁶ Inferring consumer surplus from medical treatment demands has some advantages. First, medical treatments are unlikely to provide direct sources of utility to parents

either in the form of consumption or time spent with children (Pollak and Wachter, 1975). Thus the problem of overestimating consumers surplus from expenditures motivated by considerations other than reducing parents' perceived risks to child health—such as home restorations, purchasing air conditioners, purifiers, etc.—is avoided.

¹⁷ A second and more general sufficient condition (Maler, 1974) for willingness to pay to be measurable from a health production input requires weak complementarity between the final health commodity and the environmental good or state. This means that parents will derive zero benefits from use of the child health input if no health ailment exists, which holds trivially for the problem at hand.

¹⁸ Demand functions are usually estimated using conventional methods for continuous quantities; however, function estimates for commodities consumed in discrete quantities are more common in the health valuation literature (see e.g., Dickie and Gerking, 1989; 1991; Desvousges, et al., 1989; Agee and Crocker, 1996 for applications). If the input is consumed in discrete quantities (e.g., medical care or no medical care obtained), the approach developed by Small and Rosen (1981) and updated by Hau (1986) can be used. The Small and Rosen (1981) procedure relies on the criterion that parents' marginal utility of money income is constant—that parents compensated and Marshallian demands for medical treatment are analogous. Hau (1985) develops a newer specification of utility functions for discrete choice models that satisfies both the homogeneity properties of demand and Roy's Identity. Hau's method allows the marginal utility of parental money income, albeit restricted to equal the marginal disutility of price, to vary across households, thus ensuring better consistency of benefit estimates.

¹⁹ Cropper and Sussman (1990), and Moore and Viscusi (1990), are among several efforts to measure the discount rates that adults apply to investments in their own health.