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Economic Uncertainties in Valuing Reductions in Children's Environmental Health Risks

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RESOURCES FOR THE FUTURE

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Abstract

The recognition that environmental hazards can affect children differently and more severely than adults has provoked growing concern in industrialized nations about the impact of environmental pollution on children's health. In this paper, commissioned by the OECD, we are charged with examining "economic uncertainties" associated with valuing the benefits of environmental policies that reduce risk to children's health.

We examine two sources of uncertainty in benefits estimation: forecasting uncertainty and modeling uncertainty. We explore how these sources of uncertainty affect the use of standard economic and non-economic approaches to the valuation of health benefits. These include willingness-to-pay measures, cost-of-illness and human-capital measures, and quality-adjusted life years (QALYs) and related non-economic measures.

Key Words: willingness to pay, QALY, children, social welfare function, health valuation, environmental health, household behavior

JEL Classification Numbers: Q51, I18, I1, J17, D13, D6, D63, D64

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The recognition that environmental hazards can affect children differently and more severely than adults has provoked growing concern in industrialized nations about the impact of environmental pollution on children's health. That concern has reinforced the commitment of governments to ensure that environmental policies take into account the special vulnerability of children. Among the indications of that commitment are the creation in 1997 of a special office for children's health in the U.S. Environmental Protection Agency (EPA)[1] and work on a children's environment and health action plan for Europe at the WHO Fourth Ministerial Conference on Environment and Health in Budapest in June 2004.[2]

Governments in many countries are also expanding their use of regulatory impact assessment, including valuation of the benefits of environmental policy (OECD 1997; Pearce 1998; *c.f.* Grasso and Pareglio 2002). The greater reliance on regulatory impact assessment means that benefits to children's health from environmental policies need to be valued. Yet it is far from clear how best to do this, given uncertainties associated with the methods used to value children's health improvements and the economic uncertainties inherent in valuing children's health.

What Is "Economic Uncertainty"?

This paper focuses on the effect of economic uncertainty on valuation of children's benefits from environmental health programs. By *economic uncertainty*, we mean uncertainties in any of the factors that influence individuals' behavior and preferences, as well as uncertainty about the physical and financial effects of environmental hazards on children. Failing to account

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[1] http://yosemite.epa.gov/ochp/ochpweb.nsf/homepage (accessed June 2005).

[2] http://www.who.dk/childhealthenv/Policy/20030625_1 (accessed June 2005).

for important economic uncertainties can result in poor measures of the effectiveness of environmental policy, inappropriate policy priorities, or poorly targeted policy instruments.

To economists, the benefit of a public program is the change in social welfare resulting from that program. *Social welfare* is defined as an aggregation of the utility of all individuals in society. Individual utility associated with environmental health policies is determined by the change in health risks resulting from the policy and by the consumption of other goods and services as constrained by income. Exogenous changes in the underlying structure of the economy and social institutions will affect the level of program benefits actually experienced. Any one of these factors can be a source of uncertainty in measuring program benefits.

The formal denotation of the change in social welfare with and without the program,

$$W\,(\mathbf{U}(\mathbf{x}^{w})) - W(\mathbf{U}(\mathbf{x}^{w/o})) \qquad (1)$$

highlights two types of economic uncertainty: uncertainty about physical factors that affect the level of benefits from the program, **x**, and uncertainty about how to represent and measure preferences, U(•). The first is associated with measurement error and forecasting uncertainty; the second with modeling uncertainty.

In the next section we identify sources of both types of uncertainty in estimates of the value of reducing risk to children's health. We then go on to examine how economic uncertainty affects the use of standard economic and noneconomic approaches to the valuation of health benefits and the implications of economic uncertainty for operationalizing those measures. The approaches include willingness-to-pay measures, cost-of-illness and human-capital measures, and quality-adjusted life years (QALYs) and related noneconomic measures. We end the paper by suggesting some ways to improve valuation of the benefits of reducing children's health risks from environmental hazards by accounting for critical sources of economic uncertainty.

Identifying Sources of Economic Uncertainty

In this section we explore how economic uncertainty can influence measurement of the benefits of environmental health policy (measurement error and forecasting uncertainty) and how it affects modeling of preferences or economic choice.

Measurement Error and Forecasting Uncertainty

Error in measurement—of both baseline conditions and expected change in those conditions—is always a fundamental concern in benefits analysis. That we expect children to live longer, on average, than adults suggests that the passage of time may influence outcomes more for children than for adults. Economists concerned with economic forecasting have given considerable thought to the ways in which the passage of time may influence economic projections or forecasts, but we are aware of very little work relating the more general research on economic forecasting to the problem of measuring baselines for environmental health valuation. Some of this research on forecasting, such as projections of change in the labor markets, may be of very direct interest to health valuation. Other parts of the literature may be a source of ideas for issues that may be important in environmental health valuation but that have not yet been addressed. Because of children's long lifespan and concerns about the impact of environmental hazards on child development, these issues may be of critical importance in valuing benefits to children's health.

We find as a helpful guide a framework developed by econometricians for examining how time-series analysis can be used to conduct economic forecasts. In this framework, forecasting uncertainty is reflected in the dispersion of actual outcomes relative to those forecasted (Hendry and Ericsson 2001). Clements and Hendry (1998, 168, modified) identify six broad sources of economic uncertainty in time-series analysis:

- changes in the underlying structure of the economy,
- uncertainty and therefore misspecification of the relationships modeled,
- mismeasurement of the data in the base period from which forecasting begins,
- inaccuracies in estimation of the model's parameters,
- changes in variances of errors over time, and
- the accumulation of future errors (or shocks) to the economy.

We address issues about model misspecification in a later section. The remaining sources are primarily relevant to the measurement of program benefits, which, for simplicity, we refer to as forecasting uncertainty. The sources of forecasting uncertainty can be either deterministic (for example, trends and shocks) or stochastic (for example, randomness in income). Theoretical research on time-series forecasts suggests that the behavior of deterministic model terms has a greater influence on forecasting uncertainty than that of stochastic terms (Hendry and Ericsson 2001).

Because environmental policy focuses on the differential impacts of environmental hazards on subpopulations, in this case children, it is important to ask whether forecasting uncertainty is different for the subpopulation than for the population as a whole. Let us first be clear about what is *not* at issue here. It is easy to slip into thinking that because the life outcomes—for example, future income—of a given child are more uncertain than those of a given adult, there is a greater uncertainty in forecasting lost income of children than adults. This is not what is at issue. The lifespan of any individual is highly uncertain at his or her birth, yet the average age at death of that individual's birth cohort is highly predictable—in fact, an entire industry is based on the ability to make this prediction. What is at issue, then, is uncertainty about predicting the average outcomes for the subpopulation as a whole.

Error in Measurement of Baseline Conditions

All health valuation starts with an estimate of the physical impacts of the environmental program. Errors in the measurement of those impacts can be propagated through the rest of the valuation exercise. There are reasons to believe that error in measuring the physical impacts of environmental programs is greater for children than for adults. For example, there is often a long latency period between exposure to environmental toxins and the resulting adverse health outcome. Even with adults this latency creates great difficulty in directly measuring the effect of environmental toxins using epidemiological studies. As a result, estimates of incidence often rely instead on projections based on animal models. Where long latency periods are involved, children's greater average longevity has several implications. First, children will be exposed to environmental hazards over a longer period of time, with potentially more complex interactions among hazards. This suggests greater difficulty in measuring health effects using epidemiological studies. Second, differences between children's and adults' biological response to environmental hazards mean that animal models that seem appropriate for assessing adult sensitivity to hazards may not accurately represent children's responses. Use of those models to assess children's rather than adults' benefits from environmental programs may therefore entail additional measurement error.

Irreversibility and Uncertainty in Estimates of Change in Health Risks

The irreversible—or potentially irreversible—effects of many children's health problems make it still more difficult to understand health states and risks, thereby making valuation more uncertain. A particularly important case is that of developmental effects in childhood that raise the risks of developing multiple future conditions, many of which are irreversible. The possibility of a premium on valuation of children's health associated with the likelihood of irreversible effects means that the use of adult values may understate the benefits of protecting children's health. To our knowledge, this premium has not been measured. We expect it to account for a large proportion of the willingness to pay to reduce risks that involve irreversible harm.

Framing of Policy Analysis and Inaccurate Estimates of Model Parameters

Sources of measurement error are compounded by the way program benefits are usually assessed—and, in particular, by methods of accounting for the influence of social and economic factors on physical outcomes experienced by children. In general, benefits are often viewed as "snapshots" of program impact (U.S. EPA 2003). The use of such a static model assumes that conditions affecting model parameters remain unchanged into the future and that modeling error is constant from period to period (U.S. EPA 2003). This is appropriate for programs with short-lived effects or where discounting significantly reduces contributions of future program impacts. But in periods of rapid technical, scientific, or social change, or in situations where program benefits are experienced over a long period, this assumption will lead to inaccurate estimates of model parameters.

Structural Change, Trends, and Cohort Effects

Certain problems are unique to the time-series setting: accounting for structural change, changes in variances of errors over time, and the accumulation of future errors (or shocks) to the economy.

The economic forecasting literature teaches us that time matters—not only because one is measuring an inherently dynamic process (for example, a child's development), but also because the process will differ depending on when it starts. Demographers and economic forecasters recognize this fact in the use of birth cohort analysis (Mason and Fienberg 1985; H. Becker 1992). Cohort effects may be important to children's health valuation for several reasons: recognizable trends may affect health and the economy over the expected program's life; structural interactions between birth cohorts may result in forecast error if ignored; and unanticipated shocks may affect health and life outcomes. It is beyond the scope of this paper to comprehensively review how cohort effects can introduce uncertainty into children's health valuation. Instead, we provide a few examples and discuss what can be done to address the concerns they illustrate.

Over the past century, medical technology has improved steadily and rapidly. There is ample evidence that this trend continues to increase longevity in OECD countries. But there is also evidence that it may be leading to increased heterogeneity in the robustness or frailty of the population (Vaupel 1998). Although this is particularly true for the elderly, it is also true for the very young. For example, significant advances have been made in the past 20 to 30 years in neonatal care. As a result, infant mortality rates are decreasing in industrialized countries, but morbidity is increasing (Draper et al. 1999). Currently, even infants weighing less than a kilo can survive, given extensive intervention. However, there is some indication that infants with very low birth weight may experience serious and chronic lung and neurodevelopmental problems (Nuntnarumit et al. 2002; McIntire et al. 1999; Anderson and Doyle 2003; Weiler et al. 2002).

This trend contributes to uncertainty in valuing benefits from children's environmental health programs in several ways. First, it may result in systematic changes in the susceptibility of the population to environmental hazards. To the extent that more infants start life with poorly developed lungs, air pollution is likely to have more widespread and serious effects. Uncertainty about the trend, coupled with modeling misspecification if the trend is ignored (as current approaches to cost-of-illness analyses are likely to do), increases forecasting uncertainty. Second, any illness—but neurodevelopmental problems in particular—can reduce the effectiveness of human capital investments in childhood, and this, in turn, can affect the cohort's expected income. Finally, the underlying trend of improvement in medical technology will affect other health treatment options as the cohort ages. It will also affect the cost of treatment, so the same disease is likely to have both different outcomes and different treatment costs at different times.

The relationship between cohorts cannot always be modeled as a simple trend. Failure to account for more complex relationships may result in model misspecification and increased forecasting uncertainty. There may be interactions between health trends. For example, if better neonatal care increases the number of children with neurodevelopmental problems associated with premature birth, it may compound the effects of childhood exposure to environmental neurotoxins. Health trends may also interact with economic trends. In the United States, as in other OECD countries, the economic return to different levels of education has grown more dispersed over the past 25 years (Cheeseman and Newburger 2002). As a result, lower educational attainment associated with exposure to environmental neurotoxins has different consequences in terms of lost income in 2003 than it had in 1980. Or the relationship between sequential birth cohorts may be nonlinear. Labor economists have long recognized that the relative size of sequential birth cohorts affects each cohort's educational and employment opportunities and, therefore, their earnings. Members of a birth cohort that is large relative to the preceding one can expect to fare worse in the labor market because of the excess supply of labor (Welch 1979; Macunovich 1998). This uncertainty about income introduces increased uncertainty into the estimation of cost-of-illness and even willingness-to-pay measures (working through the income elasticity of willingness to pay).

Trends and shocks also affect social institutions. For example, the structure of public support for disabled people affects the consequences of having a developmental disability. That structure is affected both by discrete policy changes and by trends in or evolution of social norms over time. Temporal changes in household structure operate in a similar way. Heterogeneity in household structure in developed countries was greater in 2000 than in 1950. To the extent that household structure influences investment in children's health or education, it will interact with the influence of environmental hazards to affect children's life outcomes.

In macroeconomic forecasting, the most damaging sources of forecasting uncertainty are exogenous shifts in model parameters (Clements and Hendry 1998, 168–71), with change in policy regimes an important cause of such shifts (Hendry and Ericsson 2001, 185–91). In health valuation, policy regimes affect the severity of disease outcomes and the opportunity sets in which choices are made. For example, a change in educational policy may result in a shift in marginal productivity losses from early childhood neurotoxin exposure. Natural exogenous shocks can also have significant impacts on valuation. The emergence of new immunosuppressive diseases, such as AIDS, has shifted the dose response curve for waterborne bacteria and therefore, its damage function.

We are not suggesting that program evaluation should be conducted using dynamic models. The data and analytical burden of such an approach would likely not be justified by any improvements in analysis. Rather, we are suggesting that lessons from forecasting can be applied within a static analysis. The implications of lessons from time-series analysis for static analysis of program benefits are considered in the third section of the paper. We now turn to the task of identifying ways in which uncertainty about how to measure and represent preferences affects valuation of environmental policy benefits to children.

Uncertainty about Model Specification

In general, very young children cannot provide information on their health preferences. One must therefore find a proxy for the utility children derive from programs designed to protect their health. Many suggested proxies are measures of the benefits of the programs to people other than children. It would be easy in these circumstances to undercount benefits by including a measure of an adult's benefit both as a direct measure of the adults' benefit and as a proxy for children's direct benefits. Keeping a formal model of social welfare in mind can help identify this kind of modeling error by maintaining a consistent accounting framework.

Three groups of people are potentially affected by children's health programs: children themselves, their parents, and others. Let children's own utility from their own safety be denoted $\mathbf{U}_c(\mathbf{x}_c)$. Parents' direct benefits from the impact of investment in children's health on parents' own consumption are denoted $\mathbf{U}_p(\mathbf{C}_p(\mathbf{x}_c))$, where $\mathbf{C}_p$ is parents' total consumption. Parents' benefits due to paternalistic and nonpaternalistic altruism are denoted $\mathbf{U}_p(\mathbf{x}_c)$ and $\mathbf{U}_p(\mathbf{U}_c(\mathbf{x}_c))$, respectively. Paternalistic altruism is utility derived from another's consumption. Non-paternalistic altruism is utility derived from another's own utility. Direct benefits to others in society who are not parents is denoted $\mathbf{U}_o(\mathbf{C}_o(\mathbf{x}_c))$, and benefits due to their paternalistic and nonpaternalistic altruism toward children's health are denoted $\mathbf{U}_o(\mathbf{x}_c)$ and $\mathbf{U}_o(\mathbf{U}_c(\mathbf{x}_c))$, respectively. Total social welfare from children's safety then can be denoted as

$$W = W(\mathbf{U}_c(\mathbf{x}_c), \mathbf{U}_p(\mathbf{C}_p(\mathbf{x}_c)), \mathbf{U}_p(\mathbf{x}_c), \mathbf{U}_p(\mathbf{U}_c(\mathbf{x}_c)), \mathbf{U}_o(\mathbf{C}_o(\mathbf{x}_c)), \mathbf{U}_o(\mathbf{x}_c), \mathbf{U}_o(\mathbf{U}_c(\mathbf{x}_c))) \quad (2)$$

It is possible that the model is actually even more complex. For example, older children's concern about their own health may include altruistic concerns about the impact of their health on their parents and others.

Conceptual models of the impact of programs that protect adult health or produce exclusively ecological benefits on social welfare may be equally complex, although the complexity is often ignored in measuring program benefits. Is complexity more critical in obtaining a decent first-order approximation of the benefits of programs that protect children's health than it is for other environmental programs or for the protection of other groups? Our sense, as we explain in the rest of this section, is that it is.

Uncertainty about When Children Can Be Considered "Sovereign"

It is clear from the social welfare function (eq. 2) that children's own health benefits from environmental programs need to be included in a measure of the benefits of those programs. The question is how the benefits should be represented. In social welfare terms, benefits are defined in terms of changes in utility.

Fundamental to any economic approach to program evaluation is acceptance of *consumer sovereignty*. The normative appeal of consumer sovereignty relies on individuals' ability to make informed, rational judgments about the choices they confront. The central problem here is that childhood is defined by the process of gaining the experience and developing the judgment necessary to make just such choices. This is often cast as a question of *whether* children's preferences should be counted, and the answer is assumed to be no. But more precisely, the question reveals uncertainty about *when* children's preferences should be counted. When children are deemed unable to represent their own utility gains or losses, the question then turns to what proxies are available. Although these are, in part, methodological questions, their answers are informed by underlying uncertainty about child development, social institutions, and others' behavior or preferences—that is, by economic uncertainty.

Childhood is characterized by physical, cognitive, emotional, and social development. There is a small but growing literature on children's risk perception and judgment under uncertainty (Davies 1996; Whalen et al. 1994; Hillier and Morrongiello 1998; Schlottmann 2001), and a relatively large body of literature on adolescent risk behavior and perception (for recent discussions see Millstein and Halpern-Felsher 2001 and Fischhoff and Parker 2000). Schlottmann (2001) found functional understanding of probability and expected value in children as young as five or six years of age. Yet Juniper et al. (1997) showed that children as old as 11 had trouble comprehending the standard gamble used to develop QALYs. Harbaugh et al. (2002) found that children give low-probability events too little weight and high-probability events too much weight, a tendency that diminishes with age. Fischhoff and Parker (2000) found that not only do adolescents underestimate the risk of accidents, they also greatly overestimate their likelihood of dying in the near future (contributing to a "so why not take risks, I'm going to die soon anyway" attitude). These are the types of errors in judgment that conventionally are viewed as constituting immaturity. Yet it is too early to draw generalizations from this literature.

Experience plays a significant role in children's understanding of outcomes. Concepts of death, which at some level are quite abstract, are acquired relatively slowly over time. Carey (1985), reviewing literature on children's conceptual understanding of death, finds that children under five typically view death as like sleep; elementary school children understand the finality of death but not its inevitability; by the age of nine or ten, children seem to understand death as both terminal and inevitable. As will be discussed below, in QALY studies, children seem as able as adults to convey the severity of the symptoms they are currently experiencing (Petrou 2003).

Although emerging research suggests that children develop competencies in evaluating risk and managing hazards earlier than previously thought (see, for example, Schlottmann 2001; Hargreaves and Davies 1996), none of the research challenges the position that children are developing and that their understanding of hazards and perception of risk stabilizes in early adulthood. A series of studies in the 1970s and 1980s examined the inefficiencies that arise in markets characterized by this kind of changing and incorrect risk perception (Starr 1973; Harris 1978; Hammond 1998). Hammond (1981) showed that when consumers' subjective probabilities diverge from the true probability of events or exhibit socially unacceptable levels of risk tolerance or aversion, and when the uncertainty is resolved over time, then Arrow-Debreau–contingent commodity markets lead to intertemporally inefficient allocations. Harbaugh (1999) argues that children's own immature appreciation of risk of illness and death and children's future own adult risk aversion are forms of market failure that lead children to "demand" too little safety. So, clearly, reliance on the "immature" preferences and risk perceptions of children has economic as well as ethical consequences.

This leaves open the question of how to determine when a person is deemed mature enough to be considered an adult for purposes of health valuation. At least two options suggest themselves. One is to rely on social institutions as indicators of an age at which people are assumed to have formed the capacity for judgment on which consumer sovereignty is based. The other, in a survey context, is to develop some developmental criteria based on relevant scientific studies that would allow the researcher to test whether to include a particular age group.

In democracies, an argument can be made for not including a person's preferences until she has reached voting age. One rationale—that the valuations of benefits are informing choices over public provision of health protection—is consistent with the use of a referendum format in contingent valuation studies. But voting age is also usually the age of majority for many other actions. It is usually the age at which one can be held responsible for criminal acts, enter contracts, marry, and so forth. In short, it marks a social judgment that on average, individuals of this age have the experience and maturity to make adult judgments and will no longer be protected from the consequences of their decisions.

Voting age provides a convenient cutoff. Yet, arguably, this approach is not fully compatible with social welfare theory because the class of people whose preferences “count” are not directly affected by the social decision. Ideally, one would want to count the benefits and costs to all who are affected in society. Children’s preferences are not being included because they are considered incompetent to access the outcomes of their decisions. One alternative might be to look at the nature of the protection being provided. One could then look for a social rule that defines an age threshold in terms of the capacity to evaluate risks similar to those at issue. For example, one might use the legal driving age as a cutoff rather than voting age.[3]

Alternatively, a developmental criterion could be used to determine when respondents are likely to have the cognitive ability and prudential judgment to understand the outcomes of the decision. One might use an average developmental age or, in a survey format, include a test of respondents’ ability to understand the problem and the consequences that will result. This kind of front matter is already included in surveys eliciting adult willingness to pay. Given normal adult difficulties in understanding uncertainty, considerable attention is often given in survey-based valuation studies to ensuring that the respondent understands the nature and magnitude of the risk at issue (Krupnick et al. 2002).

A more appropriate criterion might be the age at which children have developed an adequate experiential basis for evaluating the consequences of physical risks to their lives and

[3] Another source of information on competence is cultural norms and legal rules that reflect experience with the capacity of children to make judgments. Legal rules pose two related questions: first, when and why are children allowed to take on adult privileges and, second, when and why are they required to assume adult responsibilities. Obviously, these are not new questions, nor are the answers immutable. They change with time and societies. So, for example, there are religious norms about assumption of responsibility. The civil parallels to these religious norms are perhaps more instructive for thinking about when children’s judgments could be included in cost-benefit analysis of programs designed to reduce their health risks. Every country has a set of rules about when people have generally acquired adequate judgment about risks to be allowed to accept responsibility for risky activities. In many states in the United States, the long-standing rule has been that with a “learners’ permit,” a youth between the ages of 14 and 16 may drive a car with an adult present. At the age of 16 or 17, a youth may obtain a license to drive that is the same as that of any other adult. In light of high accident rates among teenagers, particularly teenage boys, many states have implemented or are considering rules that would create a more gradual transition to adult driving privileges. Similarly, jurisdictions have rules about legal drinking ages.

All legal systems have rules about the age and circumstances under which contracts entered into by children can be enforced. The ages are usually different depending on whether the contract is to be enforced against the minor or against the party contracting with the minor. Similarly, legal systems have rules about when civil actions can be maintained against minors for injuries they have caused. Many societies have debated juvenile justice systems and when and how minors should be held responsible for criminal action. The lesson from all of these rules is that there is no single age of majority, but rather, a gradual transfer of responsibility to the minor.

health and the cognitive and prudential capacity to make judgments that they are not likely to regret in adulthood. Scientifically, one might ask at what point do minors' judgments about risk begin to look like those of adults. One source of information on this issue is comparative studies of adult and child decision making under uncertainty (Hermand et al. 1999).

The question of when to include children's own evaluations likely depends on the valuation method used. Children's inexperience with financial responsibilities argues for use of adult choice in willingness-to-pay studies. Because experience with a meaningful budget constraint is central to such studies, a strong argument could be made for excluding even young adults until they are financially independent.

Even if one does not seek to have a valuation reflect a child's own evaluation of risks, hazards, and financial trade-offs, there may be situations in which it is desirable to capture their preferences about outcomes. The psychometric literature presents strong arguments for using the child's preferences when it is the child's own experience of the current condition that matters (Petrou 2003). Children have a perspective on their own condition that is distinct from the adult perspective. Furthermore, adults may not have access to this information because children may censor information they share with adults. If the purpose is to value the benefit of reducing acute illness, there is much to be said for capturing children's preferences. One could use children's own evaluation of the discomfort of their symptoms, for example, to improve parents' choices about protecting their children's health.

Clearly, no one would suggest relying on very young children's own revealed or stated preferences. Yet infants and fetuses are most susceptible to environmental toxins because the brain and other organ systems are particularly vulnerable at early stages of development; thus they are precisely those most likely to benefit from environmental health policies targeted at protecting children.

Uncertainty about an Appropriate Proxy for Children's Utility

Even if it is agreed that a child's preferences should not be counted directly, there remains uncertainty about whose judgments should stand in their place. In the United States, economists have focused on use of parents' preferences as representing children's own benefit from environmental programs. Parents have legal responsibility for their children's welfare, and children's preferences are likely included in their parents' preferences through nonpaternalistic altruism. Going back to the social welfare function as an accounting framework, however, one sees that parents' utility should be counted as representing parents' benefit from protecting children's health. Thus, using measures of parents' utility from environmental programs to count for both their own utility *and* children's utility could underestimate program benefits.

Yet an imperfect world may allow only for an imperfect measure. It would be helpful to know how large the underestimation might be, but there is considerable statistical uncertainty. From a purely theoretical perspective, nonpaternalistic altruistic preferences for children's benefits, $\mathbf{U}_p(\mathbf{U}_c(\mathbf{x}_c))$, are a transformation of children's own preferences, $\mathbf{U}_c(\mathbf{x}_c)$. If we could measure this transformation, we might have an idea of the relative magnitude of the error imposed by using measures of parental utility to account for both parents' and children's benefits. But we are aware of no studies that have estimated the relationship between the preferences of the target of the altruism (here the child) and of the altruistic party whose preferences are being measured. There is some literature comparing children's perception of risks and their parents' perception of the same children's risks (Soori 2000). The intrahousehold allocation literature has focused in only limited ways on separating children's and parents' consumption (see Gronau 1991, for example). None of this provides much insight into how to empirically measure the relationship between $\mathbf{U}_p(\mathbf{U}_c(\mathbf{x}_c))$ and $\mathbf{U}_c(\mathbf{x}_c)$.

It is difficult to conceive of a study that could measure parents' or nonparents' utility (in the form of nonpaternalistic altruism) from programs protecting children. Perhaps the best that can be said is that unlike the usual situation, where we are concerned that including nonpaternalistic altruistic preference leads to double counting, use of parents' preferences to stand both for their own benefits from children's health programs and as a proxy for their children's benefits may lead to undercounting. It might be worth considering the use of various proxies for $\mathbf{U}_c(\mathbf{x}_c)$. One possibility might be to use parental preferences alone as a lower bound on combined parents' and children's benefits and parental willingness to pay plus adults' retrospective assessment of their willingness to pay to reduce risk in their own childhood as an upper bound on public valuation of reduction of environmental risks to children's health.

Another alternative might be Harbaugh's (1999) recommendation to use adults' willingness to pay for safety as a proxy for children's. This is a way of resolving inconsistency between a person's own ex ante childhood allocation and their adult ex post allocation in favor of the ex post allocation (Harris and Olewiler 1979; Ulph 1982). Given changing medical technology, this kind of inconsistency between ex ante and ex post valuation cannot be entirely avoided, but use of adult willingness to pay as a proxy for children's, when children are deemed unable to appreciate risk or alternative health outcomes, would appear to be an improvement over present practice.

Uncertainty in Measuring Parents' Benefits

There is also uncertainty about how to measure parents' benefit from programs that protect children's health. At the simplest level there is uncertainty about how an individual parent interprets the child's health status, the implications for the child's and the parent's life, and what information the parent has about the child's own experience of illness. Risks to children, especially susceptible children, are generally perceived by parents and other adults as more "important" than risks to adults. Willingness-to-pay studies have found that parents are willing to pay roughly two times as much to protect their children's health than their own (Agee and Crocker 1996b, 2002). It is not clear whether this contextual difference (child versus adult) arises from adult preferences concerning their own children (that will be captured in preference-elicitation tasks at the household level) or whether these values are related more fundamentally to an "existence value" regarding children and/or investments in future human capital.

There is also substantial uncertainty about the appropriate way to model parents' own benefits from children's health. The structure of budget allocation and decision making within a household may affect either an individual parent's willingness to pay or household willingness to pay to protect children's health.

Theoretical and empirical research on household economics, following Becker (1974), has developed unitary and collective models of household resource allocation (see also Berstrom 2003). The few studies that value parental willingness to pay to reduce environmental risks to children's health use a unitary household model (Shultze et al. 1999; Dickie 1999; Agee and Crocker 1994). Unitary models assume a unified household preference function, complete income pooling, and, where household production is relevant, a completely pooled time constraint (Becker 1974, 1981). Two classes of bargaining models weaken these assumptions. Cooperative-bargaining household models assume a fully pooled income constraint but model individuals with distinct preference functions bargaining to Pareto-efficient decisions about household production and consumption (McElroy and Horney 1981; Manser and Brown 1980). Noncooperative-bargaining household models assume that individual preferences matter, but also assume that income or time is not fully pooled (Doss 1996).

Nonunitary household models may provide a more realistic assessment of parents' decisions affecting reduction in risk to children from environmental hazards. Evidence gathered over the past two decades shows that models of intrahousehold resource allocation (bargaining models) outperform unitary household models as predictors of policy outcomes and household expenditures. The assumptions implicit in the unitary model have failed testing in several empirical analyses. Some studies have rejected the assumption of common preferences (Phipps and Burton 1998; Cai cited in McElroy 1990; Hoddinott and Haddad 1995). Senauer et al. (1988) found that constraints on an individual's time, rather than total household time, affect the pattern of household expenditure. Several studies find that the percentage of household assets owned by women affects household expenditure patterns (Thomas 1993; Doss 1996; Browning et al. 1994).

Much of the empirical work on collective household models focuses on income transfer policies. In environmental health policies, health risk preferences and perceptions may play a larger role than they do for more general income-assistance policies. Many psychometric studies show gender differences in risk perceptions (for example, Finucane et al. 2000) and some in risk taking (Byrnes et al. 1999). In most cases males are found to have lower concerns about risk, or to perceive risks as being smaller, than females (Davidson and Freudenburg 1996; Flynn et al. 1994). In some cases male–female differences in risk perception depend on the type of risk being examined or on more complex relationships between the risk and the individual (Finucane et al. 2000). Nevertheless, risk-perception differences between men and women appear to be robust findings across various risk categories and methods of analysis. Differences in risk perception between members of a household indicate a potential need for modelers to recognize these preference differences and assess mechanisms through which such perception differences are resolved in making decisions.

Men and women also may have gender-specific responsibilities for purchases in the household. A unitary model may produce biased estimates of household willingness to pay to protect children's health in this case. For example, if women tend to have primary responsibility for children's health care or education, then a unitary model may produce biased estimates. The standard valuation studies that attempt to draw a balanced sample of men and women would also fail in cases where intrahousehold dynamics place more responsibility (or weight) on one individual's preferences.

Census data and sociological research suggest that there is significant heterogeneity in the way households structure resource allocation. Yet it is unclear how much difference it will make—to either valuation or evaluation of policy response—to more accurately reflect this heterogeneity in modeling the effect of environmental policies that protect children's health. Both theoretical and empirical research is needed to clarify this issue. We (the authors) are initiating empirical tests of the influence of benefits estimates resulting from using cooperative and unitary household models in a stated-preference context.

A final complication arises because parental preferences are usually estimated on the basis of household data. Yet household decisions also reflect the influence of children on household choices. We are aware of no empirical work that tries to measure the role of children's preferences in household decisions.

Uncertainty about When and How Utility of Adult Nonparents Counts

Adults other than parents also benefit directly from environmental health programs that prevent costly diseases or developmental disorders in children (Bergstrom 2003). In most industrialized countries, children's care includes publicly funded special education or publicly subsidized health care and medical research. Public investment in children's education reflects broad recognition of the public goods aspect of having a well-educated, productive citizenry and workforce (Folbre 1996). Uncertainty clouds the measurement of this source of program benefits, however, because of a problem of endogeneity in distinguishing between public investment in programs benefiting children and willingness to pay for those programs.

It is unclear how much of the motivation for public investment in children is due to direct benefit from children's contribution to society and how much is also motivated by altruistic preferences. Conceptually, for both nonparents and parents, there is some uncertainty about whether or when altruistic preferences should be included in measures of the social welfare derived from programs that protect children's health. Bergstrom (1982) established that when safety is a private good, including nonpaternalistic altruism in measures of the social welfare changes from public investment in safety will result in overinvestment in safety. It is Pareto superior to transfer money to people and let them purchase the amount of safety they desire, rather than to make public investments in safety. Even if the safety is nonrival, providing people with more safety than they would choose themselves effectively forces them to consume less of other goods than is optimal (Harbaugh 1999). On the other hand, Jones-Lee (1991) shows that including all paternalistic altruists' willingness to pay for others' safety is always necessary to achieve socially optimal safety levels. This conclusion holds whether safety is a private or a nonrival good (Harbaugh 1999). Harbaugh (1999) argues that for children, even the willingness to pay of nonpaternalistically altruistic adults should be counted. Bergstrom's results hold only for cases where cash transfers are less expensive than in-kind transfers. Harbaugh (1999) argues, on the basis of Bruce and Waldman (1990 and 1991), that the major expense in making cash transfers to children is their distortionary impact on children's investment and savings leading to underinvestment in human capital. In-kind transfers of safety force children to increase investment in their human capital and therefore are less distortionary than cash transfers.

Just as passive-use value in environmental issues arises from preferences for "existence" of pristine ecosystems or habitat for species, there are similar values for the existence of high-quality states of children's health. Evidence of these altruistic values may include donations and pressure for funding of child health facilities and programs. Elicitation of these values will be challenging for the same reasons that elicitation of passive-use value is difficult in environmental issues. The lack of familiarity with the good, the lack of a market structure for experience or to use as a comparative value, the potential for strategic behavior, and other reasons make elicitation complex. In the U.S. Environmental Protection Agency's recent analysis of the U.S. Clean Air Act (U.S. EPA 2004), an aspect of valuation that was judged very uncertain and potentially large was the passive-use value associated with ecosystem change. Similarly, the passive-use value arising from societal altruism toward children is uncertain and potentially large. An added complication is that the cohort of children is changing in size (generally toward smaller families in developed countries); this change in structure, as well as the potential for changing passive-use values for children's health over time, should be accounted for in valuation. We know of no research that has focused on preferences for existence of high-quality states of children's health, and it would be difficult to construct a valuation survey instrument to elicit such values.

Are Economic Uncertainties Captured by Standard Health Valuation Measures?

Two broad classes of index are used to aggregate across different types of health effects to capture the benefit of policy interventions on health. The first is monetary and relies on measures of willingness to pay for health improvements or of the cost of illness. The second is quality-adjusted life years (QALY), which, as we use the term here, encompasses a great many specific indices, such as the health-utility index (see Torrance et al. 1995, 1996), EuroQol (EuroQol Group 1990), the functional capacity index (Mackenzie et al. 1996), the disability-adjusted life years index,[4] the years-of-healthy-life scale (Erickson et al. 1995), and others. The variations in these approaches have to do with the methods used to elicit the weights assigned to various health states or functions (see Gold et al. 1996, table 4.3) and how those weights are combined into scoring equations to score the effects of specific medical interventions or policies.

[4] The approach of the disability-adjusted life years index is unique in two respects. First, 0 is perfect health and 1 is death, whereas the other indices reverse this nomenclature. Second, life years over certain ages are discounted.

Monetary Valuation

The monetary value of health improvements can be estimated in two broad ways: first, through measures of what individuals would be willing to give up to obtain health improvements, such as willingness to pay to avoid an increased risk of adverse health outcomes or, less commonly, willingness to accept compensation for an increase in the risk of adverse health outcomes; and, second, through measures of monetary outlays and forgone compensation, termed the cost-of-illness approach.[5]

Willingness to Pay

The willingness-to-pay approach is based on the trade-offs that individuals must make between health and wealth or income (or other goods). Such trade-offs are made in daily life. For example, if a person is running late to a meeting, he may drive faster, knowing that the increased speed carries with it a slightly increased chance of accident and possibly death. Or he may take a riskier job if he knows the pay will be higher to compensate him for the greater risk (or the converse: he may be content with a less risky job paying lower wages).

Willingness-to-pay values can be divided into those measuring preferences for reductions in the risk of death and those measuring preferences for reductions in morbidity. The resulting estimates of willingness to pay for mortality-risk reductions are converted to a value of a statistical life (VSL) by dividing the willingness to pay by the risk change being valued. Morbidity can be divided into acute effects and incidence of chronic disease. For valuation purposes, the acute effects are usually modeled and estimated as though they are certain to be avoided, whereas the chronic effects are usually treated in the same way as for mortality—that is, probabilistically, as a reduction in the risk of developing a chronic disease.[6] Some studies explicitly incorporate measures of severity and average duration; others leave these measures implicit but ask subjects to describe the nature of the health effects they are valuing. Beyond the direct effects of the illness, there are less obvious benefits that may or may not be measurable, such as the value of reduced anxiety about getting sick or the value of reduced effort needed to avert risk and the associated health effects.

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[5] A third approach to estimating monetary values is through considering jury awards. Such awards address specific individuals (rather than the nameless individuals usually addressed by social policy) and take an ex-post perspective (rather than the ex ante perspective of policy actions). Because data on jury awards are generally unavailable or incomplete, benefits measures based on them are not a realistic alternative and are not discussed further.

[6] In this case, the value of a statistical case of chronic illness is the willingness to pay for a risk reduction in chronic illness over the change in risk.

Health valuation studies based on willingness to pay and willingness to accept attempt to make preferences explicit either by uncovering the trade-offs people actually make (revealed preference) or by presenting people with hypothetical choices (stated preference). The revealed-preference approach involves examining behavior, either in the marketplace or elsewhere, to discern willingness to pay. The most widely used revealed-preference methods for estimating health benefits are two hedonic models, one based on choices in the labor market and the other in the housing market.

The estimation of the willingness of people to pay for reductions in their risk of death has been the most prominent topic of research in the valuation literature. There are several approaches to determining such values. The most common is the hedonic–labor market approach, which involves estimating the wage premiums paid to workers in jobs that have high risks of death (Viscusi 1992).

Stated-preference methods have also been used to estimate willingness to pay for reductions in risks of death. These methods involve placing people in realistic, if hypothetical, settings of choice and eliciting their preferences. In contingent-valuation surveys, individuals are not asked how much they value life, because willingness to pay to avoid certain death is limited only by wealth, and willingness to accept compensation could be infinite. However, as has been observed in many cases, people are willing to make trade-offs between marginal changes in risk and wealth. These choices might involve alternative government programs or specific states of nature, such as a given reduction in one's risk of death in an auto accident associated with living in one city instead of another, riskier city (see Krupnick and Cropper 1992) or choosing between two bus companies with different safety records when deciding to ride a bus (Jones-Lee et al. 1985). Therefore, attempts are made to ascertain willingness to pay to reduce the chance of death by some small probability. Framing the question in this way highlights an important point: a willingness-to-pay estimate for mortality-risk reduction does not provide an inherent value for human life; rather it illuminates the choices and trade-offs that individuals are willing to make and converts those choices into a value for a *statistical* life by aggregating the willingness to pay for small changes in risk.

Two approaches to stated preference are in use. Contingent-valuation studies pose questions about the willingness to either pay or accept compensation for a change in risk of an adverse health outcome. A newer alternative to contingent valuation is conjoint analysis (or choice experiments), a method used extensively in marketing to elicit preferences for combinations of product attributes. When such analyses involve the attribute of a price, the value of other attributes can be estimated.

An important aspect of the validity of monetary valuation is its applicability to the context in which it is used. Since coverage of all possible sites and situations is impossible, most studies are site-specific, and it is often necessary to transfer the results of a study that focuses on one specific situation to another setting. This procedure is known as benefit transfer, and there are occasions when the reliability of the resulting valuation estimates can be questioned. For example, hedonic wage studies provide VSLs based on accidental deaths of individuals of prime working age. It can be argued that this context is inappropriate for estimating the benefits of pollution control, where older and ill individuals are most at risk.

Cost of Illness

Cost-of-illness estimates typically include direct medical expenditures and measures of lost productivity—typically forgone wages—associated with illness and premature death. Often, the value of lost household services is included as well. This approach, also known as the human-capital approach, does not purport to be a measure of individual or social welfare, since it makes no attempt to include intangible but real costs, such as those associated with pain and suffering. Its advantage is that it is relatively transparent. Historically, it has been used to calculate monetary costs associated with illness and death. In the United States, the U.S. Department of Agriculture and the Centers for Disease Control, among others, feature this measure in their cost–benefit analyses (Kuchler and Golan 1999). Cost-of-illness measures are generally at least several times lower than willingness-to-pay measures for the same health effect because they exclude pain and suffering.

Preference Scales

Quality-Adjusted Life Years

The QALY approach uses the quality of a life year as the basic unit of account and aggregation. With death represented by a score of zero, living five years longer would add five life years, subject to any adjustment for impaired quality of those years. In general, the QALY index assigns numeric values to various health states so that morbidity effects can be combined with mortality effects to develop an aggregated measure of health burdens or improvements. QALYs are the product of a score for a health state and a duration spent in that state.[7] One year lived in extreme pain with a utility score of 0.5 is worth 0.5 QALY (0.5 × 1). A basic assumption

[7] It is possible to have a scale where there are states worse than death—that is, anchored on a negative number.

is that the QALY values are additive, so a treatment that eliminates extreme pain for one year for two individuals (2 × 0.5) is equivalent to a treatment that adds one healthy year of life for one individual. Life years are generally treated equally for all individuals, so a single healthy year is weighted the same regardless of age or income. A crucial decision is whose weights will be elicited: those of experts, health care professionals, affected groups, or the general population.[8]

Calculating QALYs gained from an intervention requires several steps. The first is to choose the time period of interest. The second is to identify all possible health states with and without intervention within that period. The third is to develop utility weights for each health state, either by mapping those states into an existing index or by using visual analog scales, the standard gamble, time trade-off, or another estimation approach to develop new weights. The fourth step is to determine the duration in each health state with and without intervention. The fifth step is to weight each health state by its utility weight and multiply by its duration to compute QALYs in that health state. In the sixth step, QALYs for all health states over the time period, with and without the intervention, are added together. The seventh step is to calculate the difference in QALYs attributable to the intervention.

Dollars per QALY

Another measure used to analyze government activities is the value of QALY changes. This measure converts QALYs to dollars, generally using a single dollars-per-QALY factor. The result can be used in the manner of cost–benefit analysis to calculate net benefits, or in the manner of cost–utility analysis to calculate cost–utility ratios. Several researchers have attempted to develop estimates of the monetary value of a QALY (Mauskopf and French 1991; Gyrd-Hansen 2003) for use in conducting cost–benefit analysis in a QALY framework. Such an exercise implicitly assumes a single conversion factor, as opposed to a set of conversion factors tied to the particular composition of health effects embedded in the QALY score. That assumption is problematic on theoretical grounds. Nevertheless, conversion numbers appearing in the literature range widely, with some based on values of a statistical life year, for instance. A related literature addresses what, if any, cost-effectivness cut-off should be used to decide whether a particular medical intervention should be undertaken, where, in this case, the QALY per dollar of cost is usually based on medical and other direct costs (as opposed to welfare costs).

[8] The scoring of disease states can be based on the preferences of individuals, but a recent survey of QALY studies found that often this has not been the case; in many studies, physician judgments have substituted for individual preferences (Neumann et al. 1997).

In these literatures, there is no consensus on what the appropriate value of a QALY is or on the appropriate cut-off.[9]

Uncertainties Introduced When Valuing Children's Health

All methods presently used to value children's health involve some degree of uncertainty. We will consider in turn willingness-to-pay approaches, cost-of-illness, and QALY estimates.

Willingness-to-Pay Approaches and Children

Parental valuations versus child valuations. The main practical questions in applied economic valuation are the unit of analysis (children, parents, household) and the conceptual model employed (unitary, cooperative, noncooperative). Judgments made regarding these issues will result in significant differences in the valuation effort.

"Accounting stance" or unit of analysis. If one assumes that individuals are the unit of analysis, then assumptions about whose preferences matter form a major part of the uncertainty associated with valuation of children's health. We know of no attempts to examine willingness to pay for children's health from a child's perspective or formally in a household framework. For reasons discussed above, this may not even be desirable. Use of parental willingness to pay for a child's health constitutes a form of benefit transfer. This in itself is a form of uncertainty introduced into the analysis. Several authors have elicited valuation results from parents for their child's health (for example, Liu et al. 2000). But parents are generally making decisions about children's health and about finances in the context of a larger household. Some parental valuation approaches have included household structure as factors in the analysis (for example, Agee and Crocker 1996a).

Using the household as the unit of analysis is more easily justified where the household system includes children's health as an input into the overall system and willingness to pay for children's health then can be derived from household demand. Several studies have used a unitary model to examine children's health-related expenditures (Rosenzweig and Schultz 1983; Grossman and Joyce 1990). However, use of the household as the unit of analysis raises a number of practical uncertainties. First, intrahousehold relationships and dynamics generate significant uncertainty for the analyst. It is unclear how the response of a particular adult in the

[9] There is a voluminous literature on cost-per QALY outcomes, techniques for converting QALYs to dollars and suggestions for cut-off values. See, for instance, Hirth et al. (2000).

household relates to household demand given the dynamics of the family budgeting and decision-making structure. The question of whom to ask in a stated-preference context is therefore problematic. Some research exists in which individuals and both adults in two-adult families are interviewed to identify the difference in preferences and bargaining power (Arora and Allenby 1999; van Houtven and Smith 1999). However, there remain many uncertainties in constructing the conceptual framework around stated-preference methods for groups and developing stated-preference questions for groups.

Differences between parents in preferences, perceptions of risk, risk preferences, and discount rates also suggests that it stated-preference responses may vary by individual as well as by household. An interesting example of such issues is the recent research on charitable giving (which includes an altruism component) indicating that men are significantly different from women in donation behavior (Andreoni et al. 2003). Furthermore, married couples tend to behave more like men—perhaps because men have more power over decision making in this area of spending on public goods. In many ways children are the public goods of the household, and altruism is involved in the payment for children's health. The charitable giving results show that households are not unitary and that considerations of power (relative income and education) affect willingness to pay for the public good.

Revealed-preference approaches suffer from a different challenge: the decisions made in a household framework are not easily untangled and traced back to the actions and power of the individual agents. Descriptions of the sources of income are necessary, as is knowledge of the financial management system of the household. If finances are held collectively and allocated as in a unitary preference model, the problem is relatively tractable. If finances are held individually, however, with certain budget responsibilities assigned to adult members of the household, then willingness to pay may be more difficult to calculate. Research on intrahousehold structure shows that changes in income accruing to one partner can result in different expenditure patterns than changes in income accruing to another (Browning and Chiappori 1998). This suggests that the definition of the income variable in valuation research needs to be carefully examined; moreover, more information on income, sources of income, and financial management may be important in such research.

Other uncertainties in measuring willingness to pay for children's health. Other uncertainties in measuring willingness to pay for children's health involve perceptions of risk and health, longevity or baseline future health state, latency, and irreversibilities. Since most valuation involves parental perception of the child's health status, the parents' ability to assess the implications of health risks on the child is important for valuation. Since the health research on these “dose-response” relationships is uncertain, this uncertainty transfers over to the parental perception of health effects.

Baseline health states are less well known for children because of their developmental status. This increased uncertainty in baseline health status over time makes it difficult to evaluate changes in future health states and to value such changes. Furthermore, evidence suggests that in industrialized countries, the value of nonmarket goods is increasing relative to market goods (Costa and Kahn 2003); thus the value of marginal health improvements in the distant future may be greater than the values of the same health effects today.

Valuation of health risks that involve latency is challenging in the case of adults and will be even more challenging for children’s health risks. Trade-off decisions for latent health effects involve perceptions of future health states and preferences, life expectancy, and, implicitly, discounting. Since health risks to children are less well understood, it is likely that latency issues will be more uncertain for children than for adults. Also, the additional lifespan over which latent impacts can be realized may increase the likelihood of disease, and therefore the value of preventing exposure. Compared with a 70-year-old, a 10-year-old exposed to a toxic hazard has a better chance of contracting a disease with a 20-year latency period.

Irreversible health effects are known to arise from conditions in childhood, and this irreversibility undoubtedly affects value estimates, whether these are the adult’s value or the child’s value. Examples include poor nutrition during early childhood, low birth weight, and developmental neurotoxins that may result in long-lasting health effects, including lower IQ. Avoiding these irreversible effects likely carries a significant quasi-option value. However, identification of that value requires understanding the risks of the irreversible loss and the values associated with the health states. Health valuation estimates based on parents’ or others’ willingness to pay to protect children’s health may well include a premium to avoid irreversible adverse health effects.

Cost-of-Illness Estimates and Children

Estimates of the impact of children’s health effects based on cost-of-illness approaches do not suffer from uncertainties associated with the valuation perspective (household, parent, child) because the values are constructed from the expenditures associated with the health effects. But that does not mean that complexities and uncertainties do not arise. We know there is considerable uncertainty in our measurement of the impact of environmental hazards on children’s development and on health during childhood. There is also considerable uncertainty about how this affects earnings. Perhaps the largest uncertainty is the relationship between health impacts (particularly developmental impacts) and earning capacity later in life.

The measurement of costs involves estimates of future health states relative to a baseline state. Thus uncertainties about the nature of those future states will affect cost estimates. In general, cost-of-illness estimates for children's health will be more uncertain than for adults' health because of the longer time horizon and therefore greater uncertainty about the impact of environmental assaults on children's health over their lifetime (dose-response uncertainty). This is particularly true for new contaminants. The longer timeline involved in estimating children's health effects as compared to adults makes estimation of the effects of latency more challenging for children's health than for adult health. The presence of irreversible health effects also affects cost-of-illness calculations because estimates of the probability of entering into these health states are required, as are the costs associated with the potentially chronic health effects.

The impact of sources of forecasting uncertainty on children's health valuation can be reduced through better data and more careful modeling. Once recognized, the influence of trends in critical factors affecting valuation can be explicitly accounted for in time-series modeling with a deterministic trend variable. But because appropriate time-series data may not be available, a more practical alternative might be to conduct sensitivity analysis on a set of plausible extrapolations of trends. Analysis of trends based on available data could be used to construct scenarios for these sensitivity analyses. Empirical and theoretical research on economic forecasting suggests that in situations characterized by unanticipated shocks, pooling multiple forecasts (that is, using an average of forecasts) can result in more reliable forecasts than focusing on a "best" forecast (Hendry and Ericsson 2001; Makridakis and Hibon 2000). It may be worth exploring the applicability of these results (in conjunction with sensitivity analysis) to the valuation of program benefits as a way of reducing uncertainty introduced by unanticipated shocks. Another alternative that may be useful in situations where policies are periodically updated or reviewed is to reanalyze cost-of-illness estimates, taking into account changes that may have occurred since the last analysis. Such reanalysis could also incorporate more complex relationships, such as relative cohort sizes.

QALYs and Children

The calculation of QALYs gained for a population of children from a policy intervention to reduce air pollution raises several unique methodological and empirical issues. Following Petrou (2003), the issues include the choice of health dimensions, context effects, and issues of survey-response validity.

The choice of health dimension refers to how the child's health state is described. Because developmental changes are so rapid over childhood, dimensions that are relevant for one age group may be irrelevant for another. To address this issue, one can either disaggregate children into subgroups by age or develop health dimensions that are general or generic enough to fit all ages. Some instruments, like the EQ-5D and health utility index, interview parents and children and then attempt to make the questions broad enough to apply to all ages. But even these indices perform poorly in characterizing infants' health.

The health dimensions themselves are very difficult to describe. They include information on the child's current health state, her future health state in the absence of the intervention (including life expectancy), and the effect of the intervention on current and future health states. Each of these components is significantly uncertain in ways similar to those confronted when estimating willingness to pay.

Uncertainty about the duration over which the quality-of-life improvement will be experienced is probably more serious for children's health valuations than for adult valuations. Uncertainty about future life expectancy likely lessens with age because there is less time for unexpected events to intervene.

The baseline future health state is also uncertain—and again is probably more uncertain in children's valuation than in adults'. Uncertainty about the future health state may not figure prominently in the calculation of QALY gains, since the gains are relative to future health states with and without the intervention. Nevertheless, uncertainty regarding improvements in medical practice, understanding of the role of diet in promoting health, and other factors probably make it more difficult to predict the future health baseline for individuals who start out very young as opposed to those who are exposed to the environmental hazard at an older age. Complicating the prediction of the baseline is the uncertain role of environmental hazards in raising the probability of developing illness much later in life. This uncertainty can be expected to increase with the length of time an individual has left to live.

The effectiveness of an intervention in reducing the risk of a latent health effect is also very uncertain. For example, reductions in air pollution might lengthen the latency period as well as reduce the likelihood of developing the disease. This uncertainty is also likely to be more important for children than for adults.

Some of the unique contextual uncertainties inherent in applying QALYs to children include uncertainty regarding children's perceptions of time and their ability to answer time trade-off questions and respond to preference-weighting surveys. For instance, even older children may have difficulty answering time trade-off questions because they can't really envision a lifetime in a particular health state. They may also have difficulty recalling how long they were in a particular health state. In the conduct of surveys, there is evidence that various biases are exacerbated in children. For instance, children are more likely than adults to be swayed by interviewer effects, are more likely to respond to the first answer rather than read and consider all possible answers, may get bored by a lengthy survey and lose their focus faster, and may perform better if a survey is given at home rather than in a clinical setting. Of course, if parents respond for the children, these points are not an issue, but then, it is not clear whose preferences are reflected in the parents' responses.

Most studies take preference weights from parents, on the assumption that children are not capable of making trade-offs involving their health status. For willingness to pay, that trade-off was defined in terms of money. For QALYs, it involves either time for health or a gamble of life in perfect health for a longer life in impaired health. It is assumed that these latter trade-offs are just too hard for a child to make. But as discussed above, that assumption introduces uncertainty about whose preferences are measured and the motivations behind those preferences.

Preference weights may be taken directly from existing weight tables for the index being used. Such weights are invariably based on surveys of adults. A somewhat better approach is to develop preference weights for the particular child's health effect, by asking parents to rate preintervention and one-year-postintervention health states using preference-weighting surveys, such as the visual analog scale. Taking preference weights for adults and applying them to children is an example of benefit transfer in the willingness-to-pay area, while having parents fill out special surveys to derive weights for children is akin to asking parents about their willingness to pay for reduced health effects in their children.

One particularly thorough QALY-based example of the latter approach is Cheng et al. (2000), who had parents rate their deaf child's health state before and after cochlear implants according to visual analog scales, the HUI (Mark III), and the time trade-off scale. All scores showed an increase, but they ranged from 0.22 for the TTO to 0.39 for the HUI.

It is not clear from the QALY literature that parental valuation is the appropriate proxy for children's own preferences. Because parents' views are affected by their own health status and other factors, they may not do well at representing health states that are not readily apparent. As seen in many surveys (not necessarily those comparing child and adult preferences), those with a particular health impairment see that impairment as less serious than the proxy does. All these problems are exacerbated when parents or other proxies attempt to make trade-offs leading to preference weightings across different health dimensions.

Conclusions

The valuation of children's health raises questions that are not typically addressed in traditional valuation exercises. Health valuation is complex for adults, but several factors increase its complexity for children's health issues. Some of these arise from the physiology of children relative to adults; others from the assumptions and approaches used to assess trade-offs. Economic theory suggests that two types of economic uncertainty—uncertainty about measurement of program benefits (forecasting uncertainty) and uncertainty about the relationships being modeled (modeling uncertainty)—need to be accounted for to accurately estimate policy benefits. Our examination of research on economic forecasting, child development and risk judgments, and economic research on the representation of household decisionmaking helped us identify seven major sources of economic uncertainty in valuation of children's benefits from environmental health policies. The seven sources are discussed below.

Risk context. Risks to children, especially susceptible children, are always perceived as more "important" than risks to adults. Given this stylized fact, transferring measures of the benefit to adult health of reduced risk will understate the values associated with children's health risks. An uncertainty arises here because of insufficient knowledge about the impact of the contextual difference in the valuation situation (children versus adults). It is not clear whether this contextual difference arises from adult preferences concerning their own children (in which case they will be captured in preference-elicitation tasks at the household level) or whether it is related more fundamentally to an "existence value" regarding children or investments in future human capital.

Time. Benefits to children from environmental programs occur over time. Time contributes to uncertainty in at least two ways. First, the longer lifespan of children and the latency of many environmental health impacts add uncertainty to our ability to identify and measure health impacts. Second, many trends, interactions of trends, and interactions of population dynamics and economic activities suggest that birth cohort effects introduce uncertainty if they go unaccounted for, as is currently the case with static cost-of-illness analysis. One practical approach to reducing the uncertainty introduced by time might be to conduct analysis to gain as good an understanding as is feasible of latency, trends, and other cohort effects and then to use this information to create scenarios for sensitivity analysis. Another approach that may be appropriate is to reanalyze benefits over time, taking into account changes in technology, income, population dynamics, and preferences that have occurred since the last analysis.

Irreversibility. Since many children's health issues involve irreversible or potentially irreversible effects, understanding health states and risks is more difficult, thereby making valuation more difficult. A particularly important case is that of developmental effects in childhood that raise the risks of multiple future conditions, many of which are irreversible. The possibility that children's health carries a premium associated with the likelihood of irreversible effects means that adult health values might not be adequate substitutes for those of children. To our knowledge, this premium has not been measured, but we expect it would account for a large proportion of willingness to pay to reduce risks that involve irreversible harm.

Children's preferences. For most purposes, children's own evaluation of the benefits of environmental programs on their health will not provide reliable measures of program benefits. It may be inappropriate to elicit willingness-to-pay estimates even from young adults if they are not financially independent. Research on children's risk perception and understanding of hazards and judgments about preventive activities is developing in the fields of child development and decision analysis. A more complete understanding of this research could contribute to more appropriate incorporation of children's own assessments into valuation of program benefits. For example, QALY studies show that children are able to report as reliably as adults on their experience of health states during childhood. This information could be used to inform adults' decisions about willingness to pay to reduce risks to children.

Proxies for children's preferences. If children's own evaluations of their preferences cannot be reliably used in valuation exercises, it is even less clear how to create a proxy. A measure of social welfare will be incomplete unless some measure of children's preferences is included. One recommended practice has been using parents' willingness to pay as a proxy for children's benefits. Further research is needed to evaluate whether that practice leads to substantial undercounting of benefits, since benefits to parents are a major benefit from children's environmental health programs. Another approach suggested in the literature is to use adults' retrospective willingness to pay to avoid the same health risks in their own childhood.

Household structure. Whether parents' preferences are being used to measure their own benefits, those of children, or both, household structure introduces uncertainty. Most valuation studies are conducted at the household level, but it is unclear whose preferences these studies are representing. In addition, most existing valuation studies use a unitary model of household choice. Research is needed to determine whether or how household structure affects valuation of reductions in risk to children's health. To the extent that household structure does matter, it should be taken into account in developing scenarios related to uncertainty associated with the passage of time. The structure of households has changed over the past 50 years, and those changes may affect valuation.

Altruism. The economic literature gives reasons both to include and to exclude paternalistically altruistic preferences of parents and others over children's health outcomes. To some extent, the resolution of this issue depends on reducing uncertainty about the impact of investments in children's health on their subsequent consumption and investment behavior. Altruism may also be expressed as a form of existence value, which makes valuation challenging. In addition, it is not clear whether these values are actually altruistic or are concerns about future economic and social development. This empirical question is amenable to resolution through further research.

The sources of economic uncertainties affect all three major approaches to valuation—cost of illness, willingness to pay, and QALYs and related indices. In each, sources of uncertainty have been overlooked, lowering the accuracy of measures of the benefits of environmental programs. We have suggested approaches to increase the credibility of such measures in the face of uncertainties, such as making cost-of-illness measures dynamic to better capture uncertainties over time and using QALY surveys to better describe preferences of children and then providing those descriptions to parents who are proxies for their children's valuation decisions.

A fundamental issue, one unresolved by society, is whose preferences should count—and when they should count—in economic analysis of environmental health impacts. Resolution of that issue will determine whether children and their preferences are the focus of valuation efforts or whether parental preferences matter. In considering the issue, the timing of transition from childhood to adulthood is critical.

Because uncertainties plague all the valuation approaches, it may ultimately be appropriate to choose valuation measures on the basis of their theoretical validity. In this regard, willingness-to-pay measures would seem the most appropriate. Very restrictive assumptions are needed to make QALYs a valid welfare measure (Krupnick 2004), and cost of illness has acknowledged limitations. If willingness to pay is used, it is clear that the child's willingness to pay will generally not be appropriate because children are incapable of making trade-offs between money and health and are not in a financial position to do so. The economic paradigm has resolved, at least on practical grounds, the issue of whose preferences matter, whereas the QALY paradigm has not.

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