Economic Valuation of Environmental Health Risks to Children

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Foreword

The analysis of the environmental impacts on children's health is an area receiving increasing attention in OECD Member countries: many policies and actions targeted specifically at children are being introduced. International organisations, such as the OECD or the WHO, and programmes within Environment and Health Ministries have highlighted the importance of the links between the environment and social issues. As an example, the Fourth Ministerial Conference on Environment and Health, held in Budapest in June 2004, put the emphasis on the concerning effects of a degraded environment on children's health.

However, the analysis of the effects of the environment on the health of children and adolescents has received relatively little attention. Even though this shortcoming has been recognised, very few economic studies have considered the valuation of children's health. To this end, the OECD Environment Directorate has launched a new project on the valuation of environmental health risks to children, in order to help policymakers evaluate environment-related health risks that largely affect children, and to contribute to the development of guidelines for the valuation of children's environmental health risk.

This project builds upon previous work done at the OECD, as well as research done in this area in other organisations. This report proposes a synthesis and background reports on the economic valuation of children's health. These were prepared as background materials for the workshop on "The Economic Valuation of Environmental Health Risks to Children", held at the OECD in Paris in September 2003. This workshop was organised to share information amongst experts and policymakers who work on economic valuation, environment and health economics, and other disciplinary fields related to the valuation of environmental health risks to children.

The Secretariat is grateful to the individual authors, workshop participants, and for comments provided by Member countries. In addition, the OECD Environment Directorate's Working Party of National Environmental Policies has played an instrumental role in supporting and supervising this work. The views expressed are those of the individual authors.

Pascale Scapecchi of the OECD Secretariat has been responsible for the preparation of the book. The assistance of Nick Johnstone and Carrie Delecourt in the editing and the preparation of the manuscript are gratefully acknowledged. This book is published under the responsibility of the Secretary-General of the OECD.

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Executive Summary

Recent epidemiological studies have highlighted the special vulnerability of children to environmental degradation.

There is increasing concern that the health of children is particularly affected by environmental conditions. Important examples include the aggravation of respiratory diseases (such as asthma), lung development, water-borne diseases (such as gastro-enteritis) and increased cases of premature deaths among children. For instance, the World Health Organisation (WHO) Task Force for the Protection of Children's Environmental Health reports that respiratory infections account for 20% of mortality in children under the age of five. Many OECD Member countries are also reporting asthma epidemics aggravated by air pollution: for example, in the United States nearly 1 in 13 school-age children (approximately 4.8 million) has asthma, and the rate is increasing more rapidly in school-age children than in any other group.

Because of different daily behavioural patterns, adults and children are not exposed to the same environmental risks. In addition, they do not respond to the risks in the same manner as adults. In order to guide policy making, governments and public agencies require estimates of the benefits associated with a risk reduction to children. Despite the increasing interest in the linkages between children's health and the environment, there have been few economic studies focusing on the estimation of the benefits of reducing environmental health risks to children.

A better understanding of the conceptual and practical problems associated with undertaking valuation studies in the case of children would allow policymakers to better evaluate environment-related health risks that particularly affect children, and would contribute to the development of guidelines for the valuation of children's health environmental risk. This book proposes an overview of the main methodological problems associated with the valuation of health risks to children, including environmental risks.

The valuation of benefits to children's health is more challenging than that of adults.

In many respects, the valuation of health benefits to children is associated with issues that may have serious policy implications. An important issue relates to the special vulnerability of children to environmental degradation. A focus on the epidemiological differences between adults and children underlines how important it is in policy-making not to consider children simply as little adults. Additional differences between adults and children in terms of the valuation of such impacts also highlight the need for children-specific values when designing environmental policies.

One of the most important differences between the valuation of children's health and that of adults is related to the elicitation of children's preferences. Even in the case of adults' preferences, reliable estimation is far from straightforward. In the context of valuing children's health, it is even more difficult to obtain preferences because

children cannot be directly asked about the value they place in risk reduction. According to standard economic theory, their limited understanding of trade-offs (for example, between money and health) and of budget constraints makes them unreliable decision makers. As a consequence, it is necessary to rely on a proxy to elicit children's preferences.

Parents are the most intuitively appealing proxy and are usually asked to reveal the value they place on their children's health. However, asking parents (or caregivers) about the maximum amount they would be willing to pay to reduce health risks to their children shifts the context of valuation into a household context. The choice of an intra-household allocation model then becomes crucial. In addition, household-related factors, such as the household structure and composition, or the household preferences, may significantly affect individual's values as shown in some empirical studies.

Other important issues include the differences in age between adults and children, the existence of long latency periods between the exposure to environmental pollution and the onset of an illness, the discounting of health benefits to children, as well as economic uncertainties. These additional difficulties have to be accounted for when evaluating the social benefits of the reduction of environmental health risks to children.

The literature on the economic valuation of environmental health risks to children is not as developed as that regarding adults. Important points, such as the most appropriate valuation methodology or the most relevant benefit measure, have not be completely addressed yet, although the contingent valuation approach and the willingness-to-pay values it provides appear to be quite reliable in the context of valuation of children's health. Further empirical work is necessary, both in the epidemiological and the economic fields, in order to provide a complete set of data and figures that could be used in policymaking.

Actual lack of reliable data and analysis may have serious policy implications.

Although empirical evidence is limited and data are missing, policymakers have to take decisions and set priorities. However, inappropriate consideration of epidemiological and valuation differences between adults and children could lead to inefficient policy decisions. On the one hand, ignoring risk differences between adults and children could lead to setting wrong standards, concerning, for example, the maximum allowable level of air pollution emissions. On the other hand, ignoring the valuation differences between adults and children could lead to wrong policy priorities being set within the health and environment fields. This raises questions on the validity of policies currently in place: Do they reflect the differences between adults and children? Are they appropriate?

In the light of previous considerations on the methodological difficulties associated with the valuation of children's health, further research would be necessary to determine first, the most relevant measure of benefits and then, the most appropriate valuation technique. Valuation differences may affect the values individuals would be willing to pay to reduce health risks to children, but the order of magnitude is still to be determined. In addition, it would be necessary to better understand how these values differ with the characteristics of individuals. Finally, given regional disparities, comparative economic studies carried out in different countries would contribute to generating comparative and credible values.

Introduction

by
Pascale Scapecchi[1]

The impacts of the environment on human health have been at the core of economic valuation for the last twenty years. However, much of existing research has focused on adults. More recently, there has been increased emphasis on valuation of health impacts for children. This is due in part to a widespread perception that the health of children is particularly vulnerable to the impacts of the natural environment. However, valuing such impacts raises a number of methodological concerns, distinct from valuation of impacts for other parts of the population. This chapter introduces the conceptual issues that appear to be of high importance and relevance when valuing the benefits of (environmental) health risk reduction to children and that will be discussed throughout the book.

The examination of the environmental health impacts on children and adolescents is an area receiving increasing attention in OECD Member countries, and many policies and programmes targeted specifically at children are being introduced and undertaken by international organisations, such as the OECD or the WHO, and Environment and Health Ministries. As an example, the Fourth Ministerial Conference on Environment and Health in Budapest in June 2004 focused on *The Future for Our Children* (see WHO, 2004).

Reliable estimates of environmental impacts on a child's health are important in order to help policymakers to evaluate the economic efficiency of policies aimed at reducing children's health impacts. More particularly, such measures contribute in the assessment of the effectiveness of environmental policy and social programmes currently in place. They also provide valuable input to policy design in determining environmental health priorities and vulnerable population groups, and setting optimal targets in order to improve environmental policy design.

However, there have been few economic studies with the objective of estimating the value of reducing environmental health risks to children. This is due in part to the various conceptual and practical problems associated with such studies. Efforts to value the health impacts for children also have important implications with respect to the applicability of the underlying assumptions of the methodologies used. Thus, it is not clear which is the best methodology to adopt in this particular context. Further work is therefore required in order to obtain children-specific economic values.

A research project, undertaken by the OECD, concerning the valuation of environmental health risks to children has been developed in order to help policymakers evaluate environment-related health risks that largely affect children, and to develop guidelines for the valuation of children's health environmental risk. To this end, a technical workshop was held at the OECD in September 2003, to take stock of the issues and the methodological "state-of-the-art".

The main lessons of the workshop have highlighted six main themes of high relevance and importance that should be addressed when estimating the social value of a reduction in risk to children. The first relates to the special link that has been established between **the environment and children's health,** and more particularly focuses on the evidence of epidemiological and economic differences between adults and children. More specifically, a number of issues associated with the valuation of children's health need to be resolved. They represent important topics and include the **elicitation of children's preferences** and the issue of **intra-household allocation.** The fourth theme deals with the various **methodologies** commonly used to value children's health, based either on economic grounds or on non-economic considerations. The difficulties related to **age**, **latency** and **discounting** constitutes the sixth important theme to take account for. This set of considerations will allow for the generation of **policy implications** and **recommendations** for the valuation of environmental health risks to children.

Children's health and the environment

Findings from existing studies highlight the link between environment and children's health. Some environment-related health effects are unique to children, such as birth defects related to exposure to environmental pollution. In other cases, both adults and children are affected, but to differing degrees. In many respects, adults and

children constitute two largely different populations, and disparities between adults and children can be expected in terms of risks and in terms of valuation.

Differences in terms of risk

There are many reasons to believe that there are likely to be differences between children and adults in terms of health risk. Exposure is likely to be different for children and adults. Children's activity patterns differ from adults and as a consequence some exposure scenarios that apply to one group may not apply to the other. For example, occupational exposure for adults would not apply to children. Conversely, exposure due to activities such as crawling on the ground, or excessive "hand-to-mouth" behaviour and lower comprehension of basic risk information typically does not apply to adults.

As presented in Tamburlini (2005), differences in terms of risk comprise exposure and susceptibility differences. Exposure differences refer to the total intake of pollutants per unit of body weight, while susceptibility represents the likelihood, the nature and amount of damage subsequent to exposure to pollutants.

Exposure differences can be explained by the disparities between adults' and children's activities, and, in many ways, this may result in greater levels of risk and a relatively greater exposure for children. Given their lack of full understanding of the risks around them, children's activity pattern exposes them to high levels of risk more often than adults. Moreover, metabolic activity is higher for children than for adults, which implies higher daily requirements for food, water, and oxygen per unit of body weight for children than for adults. Children can thus experience a larger effective dose than adults for equal exposure.

Conversely, children are less exposed to high level of substances that cause observable harmful effects than adults, such as potential exposure to nuclear radiation experienced when working in a nuclear plant. Therefore some exposure scenarios or conditions that apply to one of the two groups (children or adults) might not apply to the other one. For such reasons, children's exposure to environmental risk is expected to be different from that of adults.

In addition to differences in exposure, in recent years, it has become clear that children differ substantially from adults in the nature and severity of their responses to environmental exposures (Tamburlini, 2005). Susceptibility differences between adults and children can be explained in terms of outcome (qualitative difference) and in terms of severity (quantitative difference). Children's bodies are still developing and can respond differently than adults to the same apparent levels of exposure; they are less able to metabolise, detoxify or remove pollutants. For instance, it has been shown that for environmental factors which affect the nervous, respiratory, endocrine, reproductive, and immune systems, there can be critical windows of susceptibility, in which adverse impacts will be particularly significant. Thus, the timing of exposure can be significant, and in many (but not all) cases, children are particularly susceptible.

As suggested in Tamburlini (2005), a great number of uncertainties affect the epidemiological side of the valuation process. This particularly concerns the likelihood and the magnitude of health effects, mainly related to the multi-factorial nature of environment-related health outcomes, limit the ability to quantify the risk differences between adults and children This also affects the correct quantification of acute and chronic impacts of environmental exposure on children's health. This may have serious implications more specifically on the approaches used in the risk assessment process.

The current knowledge of children's vulnerability is not sufficient. More epidemiological research is then required.

Differences in terms of valuation

For reasons mentioned above, large disparities in the estimates of health benefits for children and for adults are to be expected. These differences in terms of values – or valuation differences – could be distinguished into at least four main categories: age, risk preferences, context of valuation and perspectives[2].

- Difference in age: The obvious difference between adults and children is related to the difference of age. There is empirical evidence that age matters within the adult population: young adults do not have the same WTP values to reduce fatal risks than middle-aged or older adults[3]. Therefore, we could reasonably expect that age would matter more greatly for children relative to adults. Although empirical evidence is weak, some economists have concluded that VSL for children is probably equal or greater than that for adults (Blomquist, 2003). Further research would be necessary to better understand how the VSL differs with the characteristics of individuals.

- Difference in risk preferences: Society and parents are known to be more risk averse to risks experienced by children than to those experienced by adults. The factors driving this are not clear, but could include risk aversion. Other factors that may have substantial impacts on the value include involuntariness of risk experienced by children and uncertainty associated with the risk itself. Some empirical studies have also shown that people believe that, *ceteris paribus*, a programme that protects young people is preferable to one that protects the elderly, because it delivers greater benefits related to the difference in time/age existing between these two populations (larger benefits for young adults given their larger expected lifespan). Examples include Lewis and Charny (1989), Cropper et al. (1994), Johannesson and Johansson (1997). A comparable result between the two latter studies is that the age of the respondent has no effect on his choice, which means that both young and old adults give priority in saving the life of the youngest. There is also empirical evidence that parents are willing to pay more to reduce health risks to their children than to themselves (Liu et al. (2000), Van der Pligt (1998), Blomquist et al. (1996))[4].

- Different context of valuation: In the context of valuation of children's health, people are asked to evaluate the health benefits of a risk reduction experienced by another population (not their own risk), which is quite different from the traditional context of valuation where people are asked their WTP to reduce their own health risk. As parents appear as the most relevant party to value children's health, several factors associated with that particular context may affect children's health estimates. Some factors related to the household structure and composition, such as age structure, presence or absence of the father, may be of high importance (Dickie and Ulery, 2001). Differences within and between households exist and may be associated with age, gender or health status of the child (Pitt and Rosenzweig (1990), Hanushek (1992), Liu et al. (2000)). Finally, as most studies are based upon the parental perspective, altruism from parents toward their children may significantly affect the estimates and be a source of disparity between adults' values and children's values (Dickie and Ulery, 2001).

- Different perspectives: while the relative value we are looking for is the measure of social welfare associated with a risk reduction, different perspectives to obtain this

value can be considered: society, children and parental perspective. The difference between these alternatives will be further developed (See Section 3 below).

Although few case studies focusing on the valuation of environmental health risks to children have been implemented, empirical evidence suggests that valuation differences may have a large impact on WTP estimates for reduced risks to children's health. These factors should be taken into account in order to obtain reliable estimates of health benefits used in political decision-making.

Elicitation of children's preferences

Which perspective to adopt?

While the relative value we are looking for is the measure of a change in social welfare associated with a risk reduction for children, different perspectives to obtain this value can be considered: that of society[5], that of children and that of parents. All three provide potentially valid avenues for research, but face their own unique challenges.

The elicitation of children's preferences raises a unique challenge and implicitly requires a trade-off between the benefits of a being as close as possible to the person affected (the perspective) and the costs of under or overestimation due to altruism, at the two extremes: either you adopt the closest perspective (i.e. consisting in asking directly children about their WTP to reduce a risk in their own health) in which you avoid any altruism effects, or you choose to adopt a much more distant perspective (i.e. in asking a sample representing the whole population) in which the presence of altruism will significantly affect the WTP estimates.

The theoretical measure of a change in social welfare is measured in aggregating the change in welfare of all individuals in the society. Societal perspective (i.e. asking a sample representing the whole population – all adults, both parents and non-parents) is the best perspective from a public policy point of view, but it is not appropriate for revealing children's preferences because of the difficulty in distinguishing between paternalistic and non-paternalistic altruism. Obtaining a WTP based upon responses from representatives of society as a whole would potentially present problems of double-counting due to altruism (Jones-Lee, 1991 and 1992). Therefore, given the substantial problems associated with altruism, an alternative perspective will have to be adopted from which to elicit children's preferences.

As a second best, welfare economics suggest that, in order to estimate the value of a reduction in a given health risk, the best-placed people to know the value they place in a reduction of their health risk are those who are directly affected by the considered health outcome[6]. Therefore, in the context of valuing a risk reduction to children, children should be directly asked about the value they place in a reduction of their health risk – referred to as "the children perspective". This approach would, however, clearly present difficulties in the case of children, as children have neither the cognitive capacities to have clearly defined preferences for health outcomes, nor the command over financial resources to make their preferences effective. As such, they could be considered as unreliable decision-makers. As a consequence, the basic tenets of welfare economics cannot reasonably be assumed to represent children. The children's perspective being inappropriate, another perspective has to be adopted. The natural alternative to children's perspective is the parental perspective, which consists in asking parents (or caregivers) about the value they place on their children's health.

The theoretical justification of the use of the parental perspective (or that of the caregiver) is based on various theoretical economic models, suggesting that parents' choice are the appropriate proxy for children's preferences and constitute a reliable source of information (Viscusi et al., 1987). As such, the few existing studies that have estimated a measure for a reduction in health risks to children have elicited parents' or caregivers' preferences. However, altruism remains a major concern, as for the societal perspective. Indeed, the WTP of parents may be significantly affected by altruism towards their own children as well as towards children in general. So, why is the parental perspective a better approach than the societal perspective? A first advantage of the parental perspective over the societal perspective is that it reveals preferences of individuals which are as close as possible to the population at risk – the children. Moreover, even though altruism is likely to be important in this approach, it is felt that the benefits associated with asking the persons who are actually directly affected by a reduction in the health risk of (their) children would outweigh the costs associated with a misestimation due to potential altruism.

Concerns related to altruism have encouraged the consideration of alternative parental perspectives. One of them requires adults to place themselves in the position of children, thinking back to their own childhood and the risks they were facing at that time. Although this approach allows for obtaining estimates of WTP for a risk reduction from "rational" individuals considering themselves (and not another member of their household), it makes the design of the questionnaire more complex and increases the cognitive burden of completing the questionnaire. Further research could help determine the usefulness and robustness of this approach[7].

Relatively to societal and children's perspective, the parental perspective has the advantage that literature is available – albeit sparse. A few of these studies have examined possible differences of values between adults and children, but their findings have been mixed. Some studies find that the value of children's health benefits is higher than those of adults (Lewis and Charny, 1989; Busschbach et al., 1993; Cropper et al., 1994; Liu et al., 2000; Dickie and Ulery, 2001). Other research has generated estimates of WTP for child and adult health that are similar (Blomquist, 2003; Mount et al., 2000). One study estimates the value of statistical life for a child that is lower than the value of a statistical life for an adult (Jenkins et al. 2001).

Moreover, these studies could potentially be affected by a number of limitations that suggest that careful, primary research must be undertaken in this line of inquiry. For example, in a recent study (Dickie and Gerking, 2005), the risk reduction for a child was valued by the parent within the same survey as a risk reduction for the parent. This may have created order biases in WTP, or have implicitly obliged respondent to report values for the child at least as large as those reported for himself/herself. In addition, this adds the issue that a third party is involved in the valuation. This is not the case with the adult-as-child perspective. However, there has been little research on this approach.

The choice of the perspective is crucial since different perspectives lead to different estimates of the health benefits. As an example, society and, to a greater extent, parents are known to be more risk averse to risks experienced by children than to those experienced by adults. Empirical studies[8] as well as programmes and policies undertaken in some countries[9] have highlighted that (i) health benefits to children should be considered separately from the general population and (ii) the willingness to protect children from environmental threats to a greater extent than protecting adults facing similar risks.

The choice of the perspective will probably also have methodological implications for valuation approaches (Hanemann, 2003; Nord, 2005). While several valuation techniques can be used to estimate the health benefits from a risk reduction, these are often based on economic considerations (i.e. stated preferences, revealed preferences) which are methodologically problematic for children. Therefore, changes in the conception of traditional economic valuation methodologies have to be made before being applied to the valuation of children's health.

And finally, there is also an endogeneity problem in distinguishing between public investments in programmes benefiting children, and the WTP for these programmes. Motivation for public investments in children may be due to direct benefits derived from children's future contribution to wealth production process but also to altruistic preferences. This raises issues associated with the inclusion of altruistic preferences in measures of social welfare.

Associated difficulties

Other issues related to the valuation of children's environmental health risks appear to be of high importance and require more attention from analysts. They include:

- Economic uncertainties: there may be good reasons to believe that there is greater inherent uncertainty in risk for children. For instance, while the general scientific understanding of the risks associated with exposure to pollutants is subject to a great deal of uncertainty, this may be particularly important when considering children's health. Uncertainty in general may be a greater problem for children. Knowing those uncertainties is important on the one hand because they have impacts on the significance and the validity of the values, and on the other hand, because they represent an important element in the decision-making process. This may significantly affect some of the traditional economic methodologies, as well as non-economic-based techniques of valuation of health.

- Assumptions about cognitive capacities: Some assumptions about cognitive capacities in the neo-classical theory are likely to be violated when considering children's health valuation. Therefore, the foundations of neo-classical theory may not be a good representation of children's decision-making. This generates problems, for instance, for the integration of WTP or COI estimates in the framework of a cost-benefit analysis.

- Autonomy of the decision-maker: Most important decisions concerning children are taken by their parents or their caregivers, and not by the children themselves. As noted, the few existing studies that have estimated a measure for a reduction in health risks to children have elicited parents' preferences[10]. On the one hand, this parental perspective violates the theoretical assumption underpinning many methodologies that everyone is able to behave in a manner which is consistent with their perception of their own welfare. On the other hand, even when there are no assured problems of cognitive capacity, children are not always able to express their preferences through their own behaviour. This has serious implications for some valuation methodologies, and more generally for any study relying on a decision-maker.

- Issues associated with altruism and discounting: When parents are asked about children's health improvements, the obtained values reflect both parents' preferences to reduce risks towards their own children, and altruistic concerns for children more

generally. The difficulty lies in estimating the degree and type of altruism in the values for the health of others. Some empirical studies have highlighted that altruism toward children may largely affect the WTP for reducing environmental health risks to children, which results in a greater VSL for children than for adults (Dickie and Gerking, 2005). In addition to differences in the valuation of the benefits, during the valuation exercise, it might be expected that people do not use the same discount rate when they are asked to value a reduced latent health risk for their own children, than when they are personally concerned (Dickie and Gerking, 2005).

There is little empirical evidence of the impacts of those problems on the valuation methodologies traditionally used to assess health benefits subsequent to a risk reduction. Some may have more serious consequences than others, but ignoring those issues could generate misleading values that should not be used within a cost-benefit (or cost-effectiveness) analysis framework.

These fundamental complications in valuing children's health benefits may conflict with maintained assumptions of neo-classical consumer theory. In this case, we cannot rely on children's own evaluation of a change in their own welfare and we have to rely on the most sensible proxy: their parents or their caregivers. However, this implies a shift in the context of valuation: we move from an individual context toward a household context.

Household allocation models

Irrespective of the group from which children's preferences are elicited (whether the parents of the children or other caregivers, or other members of society), seeking to obtain values of WTP for a reduction in health risk to children does not take place in the traditional individual context (where someone is asked to state a WTP for his/her own risk reduction), but rather in a household (i.e. collective) context where someone (e.g. a parent) is asked to evaluate a risk reduction for another member of his/her household (e.g. his/her child). Accepting the parental WTP as a good proxy of the WTP for reducing health risks to children then raises the issue of how decisions are made within the household, thus necessitating the consideration of intra-household allocation. While all WTP studies (even for adults) should reflect the nature of household decision-making, since the risks which children face are due in part to decisions taken by their parents (or their caregivers), it is particularly important to account for the decision-making process within the household. Thus, the focus on children necessitates considering the individual as a member of a household and not as an autonomous actor, which complicates the modelling and the estimation of the WTP value.

Unitary and collective models

Two alternative models have been proposed in the economics of the household (Dickie and Gerking, 2005). The first class of model is the unitary model in which the household is treated as a unit: it has a single utility function, and decision-making is derived directly. It also assumes that the contribution of a particular member to household income does not matter: financial resources are pooled. This is the method applied in almost all existing studies of children's health because of its attractive assumptions and ease of application (the single utility function implies the household WTP is a relevant measure of welfare). The alternative class proposes collective models in which the individual utility functions of each household member (at least the

adults) are pooled to obtain a collective decision, taking account of the differences in household members' preferences. The household decisions are modelled as the outcome of a bargaining process (cooperative or non-cooperative), or as Pareto-efficient allocation of resources (Chiappori, 1988). It also includes models where each spouse is responsible for decisions and expenditures on different goods (separate sphere models)[11].

These two types of household allocation models differ in two criteria: whether children are treated as independent decision makers, and whether the family is assumed to maximise a single utility function. Generally, children are passive participants in family decision-making. However, alternative approaches that could fit better this particular context should also be considered and examined[12].

Associated difficulties

Some difficulties are associated with using intra-household allocation models to derive parents' WTP to reduce a given health risk to their children. They include the fundamental choice of the type of model (unitary or collective) and the influence of household-related factors on the WTP.

Choice of the model: unitary or collective?

The choice of the model is practically important since different environmental-health impacts can have very different implications for household decision-making and will therefore necessitate the use of one particular model (for example the unitary model) instead of another (the collective model). For instance, a recent study has looked at the valuation of the health impacts of environmental tobacco smoke for children (Agee and Crocker, 2001). This is clearly a good example of the need to introduce and understand intra-household externalities. In this case, the utility of some household members (for instance, the parents/adults) enter the health function of the other members of the household (the children). A collective approach appears to be a good way to examine the problem, since in this case, the household could not be considered as one decision-maker. The intra-household allocation model applied will have a significant impact on the WTP estimated.

The degree of rivalry of the good within the household could also influence the choice of the model of intra-household decision-making applied. Let's consider the example of lead – contained either in wall paint or in water pipes. The lead level contained in wall paint clearly refers to a pure public bad at the household level. In this case, both models would *a priori* lead to similar results since household could be considered as one decision-maker. On the contrary, lead contained in water pipes is potentially excludable insofar as there is a private substitute good (bottled water). Some (or all) household members can thus protect themselves from adverse health impacts through personal behaviour. In this case, the choice of the household allocation model is crucial and will affect WTP estimates. In other words, the degree of excludability may affect the appropriateness of the choice of household model, and unitary and collective models would lead to different WTP estimates.

Finally, the choice of the parental perspective may also introduce additional uncertainty in the valuation exercise. As pointed out by Hoffmann et al. (2005), there is also uncertainty about how to measure parents' benefits and about the appropriate way to model parents' benefits from children's health. The parental perspective appears as a commonsense solution, since they are personally affected in many ways when their

children are ill, bearing both the tangible and intangible costs of illness. However, we do not precisely know what lies behind the parents' preferences and empirical evidence highlights preference differences within the household, i.e. mothers are more risk averse than fathers and thus more willing to pay to reduce health risks to their children (Scapecchi, 2005). Moreover, there is significant heterogeneity in the way that households structure resource allocation among the members. All these considerations may suggest that the household allocation unitary model may not be appropriate to formulate children's preferences. Further work is required to provide clear recommendations on the most appropriate household model – when the parental perspective is adopted to elicit children's preferences.

Thus factors such as the presence of intra-household externalities, the degree of excludability, and the degree of intra-household rivalry are also key factors, in which the nature of household decision-making assumed is likely to have important effects on the results. Depending upon the degree to which an impact is "public" within the household and the extent to which externalities arise, the choice of household allocation model applied can have significant consequences for estimates obtained.

Influence of household-related factors

As parents appear to be the most relevant third party to value children's health, several factors associated with that particular context may affect children's health estimates.

Some factors related to the household structure and composition, such as age structure, presence or absence of the father, may be of high importance. Differences within and between households exist and may be associated with age, gender or health status of the child (Scapecchi, 2005). Finally, as most studies are based upon the parental perspective, altruism from parents toward their children may significantly affect the estimates and be a source of disparity between adults' values and children's values. The main empirical results suggest that parents may value their children's health more highly than their own (Scapecchi, 2005).

There are empirical similarities among the few economic studies that have considered the valuation of children's health (Dickie and Gerking, 2005). First, the family structure and composition affect resource allocation and health outcomes experienced. Second, parents do not equally treat the health of all family members, but instead may allocate resources differently according to health status, gender or age. These results suggest that applying a unique value for all children would lead to unreliable estimates of children's health.

In addition, double-counting issues could arise when using the parental perspective. As suggested by Hoffmann et al. (2005), children's preferences may likely already be included in parents' preferences through non-paternalistic altruism. This may have serious consequences on the selection of efficient policies designed to reduce health risks for the whole population (i.e. adults and children). In this context, it is recommended to aggregate the WTP for a risk reduction of all individuals in society, i.e. aggregate the WTP for adults and the WTP for children. However, if the WTP for adults already includes a WTP for children, then this could lead to double-counting and thus to an overestimation of the health benefits of the policy. In contrast, assuming that the WTP of parents includes the WTP for children, considering solely the WTP for adults as a proxy of WTP for children could lead to an underestimation of the health benefits for children[13].

Valuation methodologies

Very few economic studies have considered the valuation of environmental health risks to children. However, *some* empirical evidence set in the adult-related literature highlights the valuation of health benefits associated with environmental risk reductions for children.

Based on the adult valuation literature, two types of approaches are commonly used to capture the benefit of policy interventions aimed at reducing environmental impacts on health[14]. The first one is the traditional economic framework of cost-benefit analysis (CBA), based on economic consumer theory, which can provide a monetary measure of the efficiency of a given policy/ programme/ intervention, and the multi-criteria analysis (MCA)[15] framework which relies on non-monetary considerations to provide information about the cost-efficiency of a given policy/ programme/ intervention.

The overall advantage of monetary valuation and of CBA on MCA and CEA is that it allows costs and benefits to be compared in the same unit of measure (a monetary unit) within a theoretical-founded framework. It is then possible to compare across different policies, to evaluate whether a given policy is economically efficient and to state which one is the most efficient, in order to implement it. In contrast, CEA does not allow for the assignment of a monetary value to health improvements: different health effects are assessed in the same unit of measure (a HRQOL measure) but not in monetary terms. As a consequence, costs and benefits are not commensurable. Therefore, one cannot know from the obtained values whether or not the health benefits related to an intervention exceed the corresponding costs. Since none of those multi-criteria techniques estimate the net benefits of a public policy, they cannot identify an economically efficient policy. CEA can only state which policy is the most cost-effective, i.e. which policy can achieve the objective (find a treatment for a given health problem) at least costs.

Another difference between CEA and CBA is that CEA provides useful information on the relative values of reducing risk but it does not address the question whether a particular risk reduction is worth its costs, while CBA allows for the estimation of the economic value of reduced health risk benefits[16].

A brief presentation of the valuation methodologies associated with each framework is proposed in what follows.

Monetary valuation[17]

Two economic approaches are commonly used to measure a change in utility, e.g. in estimating the willingness to pay for a reduction in the mortality risk: the techniques based on revealed preferences and those based on stated preferences.

Revealed-preferences techniques

Revealed preference studies rely on actual behaviour, analysing the trade-offs people actually make. They could include compensating wage studies, consumer behaviour studies, and hedonic pricing approaches. They rely on the assumption that individuals know exactly the risks implied by their choices of residential location, occupation, automobile, and use of risk-reducing products. They include the hedonic method, based on the underlying idea that goods are characterised by a set of attributes, and that utility comes from the value of each attribute.

Averting behaviour models (ABM), particularly associated with safety product markets, use existing data on risk reducing behaviours or on actions taken to mitigate the effects of exposure to a given health risk to determine the individual WTP for a reduction in the specified risk. Individuals' consumption choices associated with products of different safety attributes and different prices reveal the value individuals place on avoiding some bad outcome, a proxy of the WTP to avoid this outcome. In other words, health-related (directly or indirectly) consumption choices reveal the value people place in their own health or in the health of other members of the household (e.g. their children). Ultimately, the perspective underlying ABM is that of the parent. In the context of the valuation of environmental health risks to children, one must rely on risk reducing actions/behaviours parents make on behalf of their children. Three modelling approaches have been developed to incorporate these decisions: the household production model, the intra-household allocation model, and the safety product market models[18].

Cost-of-illness (COI) measure can be associated with revealed preference techniques, though it does not rely on the same assumptions and principles. The method consists in accounting for the different expenditures caused by a health-specific damage. In its most elaborate form, this method takes account for all the direct costs related to a specific illness, i.e. the direct components of the health costs (such as cost of treatment, cost of consulting, cost of hospitalisation, cost of death…) and usually the associated productive losses as well. However, COI measures do not take account of all the intangible costs associated with ill health or death, such as pain and suffering (from the ill person as well as from his/her relatives). The COI approach does not involve the estimation of the WTP to avoid illness or to reduce health risk. It only accounts for direct economic impacts, such as medical costs and productive loss associated with being ill[19]. COI measures do not take into account the change and the loss of utility related to ill health. On the contrary, revealed preference methods (and stated preference techniques as well, as we will discuss below) capture the full impact of ill health by measuring the WTP for a reduction in the health risk. In this context, the COI approach underestimates the full social costs of ill health and for this reason, COI measures are sometimes considered as the lower bound of WTP estimates. Thus, WTP values are thought to be better estimates of the health benefits associated with a reduction in a given health risk, and are most widely used in the context of valuation of health benefits.

Stated-preferences techniques

Stated preference studies[20] attempt to elicit trade-offs individuals make between health and wealth by presenting them with hypothetical choices, thus gathering their preferences. In a stated preference study, people are asked to state decisions they would take under hypothetical circumstances. In principle, they can be designed to cater to any population and any risk of interest. They include the contingent valuation method, which has undergone extensive development and now has several variants, such as choice modelling.

The contingent valuation method (CVM) usually involves the *ex ante* valuation of individual variation of welfare related to the variation of the status of individuals exposed to a particular health risk. It consists in presenting people with a hypothetical scenario (*via* telephone, postal or in person survey), and asking them about their maximum WTP to compensate for a variation in their well-being. It estimates WTP values for a reduction in health risk, or analogously, willingness-to-accept (WTA)

values for an increase of health risk[21]. This information then allows for the construction of monetary indicators on the value people attribute to different elements of their health or to any good having no market price *per se* (pain, suffering, time loss etc.). Despite underlying biases[22], the CVM is the method most frequently used to value non-market goods, in particular health benefits associated with an environmental degradation or pollution.

Choice modelling (CM) has been developed as a response to the problems of CVM, particularly in the context of environmental policy. CM is composed by a set of SP techniques that includes: choice experiments; contingent ranking; contingent rating; and, paired comparisons. CM is based on the idea that any good can be described in terms of its attributes, or characteristics, and the levels that these take. For example, a river can be described in terms of the chemical composition of the water, the quality and quantity of biodiversity, and the appearance of the water. By changing attribute levels, CM allows for the determination of the value of such changes in attributes, i.e. the WTP for each attribute. By including price (or cost) in the attributes list of the good, WTP can be indirectly recovered from individual rankings, ratings or choices.

As CVM, CM is based on hypothetical surveys and can measure all forms of value, including non-use values. The main difference between CVM and CM is that CM WTP values are relative while CV WTP values are absolute. Empirically, CM has been formerly widely used in the market research and the transport literatures (where it is referred to as "conjoint analysis"), and has been recently applied to other fields such as the environment.

Preference scales

The non-economic methodologies are based upon non-economic and non-monetary considerations. There are five main methodologies for measuring individual's quality of life, distinguished by the manner in which they are derived: the generic health utility scales, such as the Health Utility Index Mark III (Furlong et al., 1998); the rating scale or visual analog scale (also referred to as the feeling thermometer); the standard gamble; the time trade-off measurement; and, the person trade-off methodology.

The most common measure – referred to as health-related quality of life (HRQOL) measures[23] – yielded by those methods is the Quality-Adjusted Life Year (QALY), represented by an ordinal or interval-scale measure for various health states. In general, the QALY index assigns numeric values to various health states so that morbidity effects (such as severity and types of illness) can be combined with mortality effects (or likelihood of death) to develop an aggregated measure of health outcomes. Death is represented by a score of zero, whereas perfect health is represented by a score of one. QALYs are based on multiplying the duration of a health state by a score reflecting the quality of a health state. Life years are generally treated equally for all individuals, so a single healthy year is weighted the same regardless of age or income.

QALYs can be applied to the analysis of public interventions in a cost-utility analysis framework in order to determine the most effective option within a given set of alternatives. QALYs can also be converted to dollars (referred to as "value of QALY changes"), generally using a single $/QALY factor and then can be integrated either in a cost-benefit analysis framework to calculate net benefits, or in cost-utility analysis framework to calculate cost-utility ratios. However, the values used in such studies are based upon very limited evidence. There are very few studies which have attempted to develop estimates of the monetary value of a QALY (Mauskopf and

French, 1991; Gyrd-Hansen, 2003) for conducting cost-benefit analysis. The requirements needed for meaningful $/QALY conversions are very restrictive, and the simplistic conversions that are often used (e.g., from the value-of-life-year or value of statistical life year) are inconsistent with welfare economics. Thus, further research is required to better appreciate the usefulness of such an approach.

Comparison of methodologies

Comparisons between the different methodologies used to value the environmental impacts on children's health are needed in order to state their relevance. Indeed, it is necessary to compare different economic methods, as well as different non-economic methods. More fundamentally, it is also necessary to compare across economic and non-economic approaches and, indeed, the derived measures themselves. These comparisons constitute a major element of the assessment of the merits of those respective approaches and could significantly contribute to the recommendations on the valuation of environmental health risks to children.

Revealed-preference vs. stated-preference techniques

Revealed-preference (RP) and stated-preference (SP) techniques allow for the estimation of the WTP for a reduction in a specified (health) risk. However, each has advantages and drawbacks in comparison with the other. On the one hand, RP methods are based on the observation of actual choices and thus need a large number of observations, as well as well documented and (rather) exhaustive information. Data are thus difficult to collect and to validate. Moreover, RP models may require the definition of the choice set. Finally, correlation problems often arise between time and cost, two important characteristics of the models used in RP methods.

On the other hand, SP techniques also require a large number of observations to get reliable results[24]. However, as SP techniques do not rely on actual choices, they can be used in contexts in which it is not possible to observe real behaviours either for lack of data or because the alternative to be analysed is not yet used or available for use. Therefore, SP methods can design a market for non-marketed goods instead of relying on "proxy" markets. Moreover, SP techniques – more particularly contingent valuation surveys – are (relatively) easier to implement and computations needed to estimate the WTP are (relatively) less time-consuming than when applying a HP model or an ABM model.

Hanemann (2003) proposes a comparison of stated-preference techniques and revealed-preference techniques used to derive individual WTP. When examining the links between the natural environment and public health, revealed preference methodologies may derive only lower-bound estimates on WTP. If environmental factors enter directly into the household's utility function, and not just indirectly through the marketed good which is being examined, the direct loss of utility will go unaccounted for in the estimation of WTP. Since many types of environmental impact will have both direct and indirect effects on utility this is important. This leads to the conclusion that, when the household production model is employed, it is difficult to estimate valid and useful welfare measures for changes in environmental quality, based solely on the estimation of the health production function without also estimating the household's preferences, especially if environmental quality enters the household utility function directly. As such, the stated-preference techniques appear as more appropriate than the revealed-preferences techniques when valuing health risks, whether they concern adults or children[25].

However, traditional economic valuation methodologies are rarely used in health economics. Analysts in this field tend to prefer using health-related quality of life measures (HRQOL) instead of traditional WTP measures. Given the increasing use and demand at the policy making level of these non-monetary measures, a comparison of the various approaches is necessary in order to assess the most appropriate approach.

Comparison of health-related quality of life measures

Health-related quality of life (HRQOL) measures are used in a cost-effectiveness analysis framework. Because of their apparent simplicity and ease of implementation, those measures could appear as a good alternative to traditional WTP estimates. Nord (2005) reports on these measures and associated non-monetary valuation techniques in the context of children's health valuation in order to assess the different methodologies. Empirical studies tend to show that QALY values obtained from parents and children differ significantly. This suggests that when valuing children's health outcomes using QALYs, children should be asked directly. Otherwise, substantial underestimates of QALYs could arise. Empirical evidence (Apajasalo et al., 1996a and 1996b) tends to justify this assertion in showing that children older than 8 are able to answer multi-attribute utility questionnaires or complete visual analog scales[26].

The main problem with the HRQOL measures is related to the validity of the value obtained. The weight used in health-related quality of life measures often represents the *ex ante* judgement of people in good health[27], which may explain why low scores are often attributed for moderate states of illness. However, this raises the question of precisely what disutility of that specific health state is being assessed. The weights do not allow for the determination of priorities between different groups, i.e. between adults and children. Confounding factors should also be taken into account because they can have serious consequences on the values attributed to a given health impact.

Further research is therefore required in order to assess the internal and external validity of non-monetary approaches and HRQOL measures when valuing children's health. According to Nord (2005), comparable results (i.e. QALYs measures) would be obtained if parents and children were asked the same questions. Then, combining these values with the WTP estimates of parents could provide sound estimates of the social value of a risk reduction for children. However, limited cognitive capacities and little control over financial resources may restrict the number of cases where it could be done.

To sum up, two types of measure can be used when valuing health benefits subsequent to (environmental) risk reduction: WTP and QALYs. The case of children is, as we have seen, more complex than the adult context. Empirical evidence is limited and is not able at the moment to recommend one approach instead of another. Valuations obtained from economic valuation methods are likely to differ from non-monetary estimates of children's health given the differences between those two approaches in terms of theoretical foundations. Therefore, a theoretical comparison of those two measures of welfare (WTP and QALYs) could provide a good starting point in order to know which approach would be the most appropriate when assessing the social value of a reduction in risk to children.

WTP vs. QALYS

Hammitt (2005) analyses the differences between QALYs and WTP values. On the one hand, QALYs impose restrictions on the structure of individual preferences and depend only on health[28]. They also rely on several conditions, which are quite plausible but frequently violated at the individual level. On the other hand, WTP impose less restrictions on the structure of individual preferences than QALYs, but they are much more sensitive to the individual's state of mind. WTP can also incorporate other effects, including issues such as the degree of voluntariness of risk exposure.

In addition, WTP and QALYs do not represent the same type of preferences. When QALYs are determined, people are asked to consider the best treatment for affected people (i.e. for people in general, not specifically for them). In this context, QALY measures represent social preferences. However, when WTP are assessed, people are asked to evaluate a reduction of their own health risk. In this context, WTP represent individual preferences.

The comparison of WTP and QALYs does not depend on the context of valuation. With children, the perspective issues are similar. Therefore, any standard chosen is arbitrary, and the use of an approach instead of another will only depend on the setting. Any approach has pros and cons. For example, in practice, the same WTP values are often used whether it concerns a child or an adult, although large disparities exist between those populations. Concerning QALYs, the assumption of neutral risk aversion over life-span is not empirically verified, which may undermine this approach.

However, the non-comparability between WTP and QALY values at the aggregate level does not necessarily mean that the two methodologies cannot produce mutually consistent results for the relative importance of different factors within the health context. As such it is important to examine how the two methodologies address important issues associated with the valuation of children's health, such as age, latency, the choice of perspective, etc.

Difficulties related to age, latency and discounting

A number of issues when valuing children's health have been identified. They include difficulties related to age, latency and discounting. They affect the valuation of adults' health but it is reasonable to expect these concerns to be greater when considering the case of children given the differences between adults and children.

Age

Empirical evidence from the literature related to adults' health valuation highlights the large influence of age on WTP values: young adults do not have the same WTP values to reduce fatal risks than middle-aged or older adults (Johannesson et al., 1997). Therefore, we could in general reasonably expect that age would matter more for children relative to adults. Empirical evidence is mixed but many economic studies based on a unitary household allocation model have found that the VSL for children is at least as great as the VSL for adults (Scapecchi, 2005; Dickie and Gerking, 2005). Further research would be necessary to better understand how the VSL differs with the characteristics of individuals.

More recently, while Johannesson et al. (1997), and Persson et al. (2001) report results compatible with the inverted-U relationship theory[29], Krupnick et al. (2002) and

Alberini et al. (2004), in studies in the US and Canada, find that WTP is lower only for persons of 70 years of age and older. Without further documentation there is no reason to believe that older persons should be willing to pay less for a reduction in their own risk of dying.

Latency

Many environmental health risks involve a time lag between exposure and the onset of illness or death. For example, exposure to some heavy metals and chemicals (especially in childhood) are known to result in health impairments later in life. A reduction in exposure today, therefore, would result in risk reductions to be experienced later in life. This implies that, in order to value the benefits of policies that, if implemented today, would reduce future risks, it is necessary to ask people to report their WTP now for a risk reduction to be experienced in the future.

For environmental exposures which do not have immediate health consequences, life expectancy of the affected population is clearly an important factor in the determination of the perceived value of policy interventions. Thus, children are more likely to have adverse health consequences arising from equivalent exposures (even if equally susceptible), and these differences increase with the length of latency. Therefore, latency is a major concern for the valuation of environmental health risks to children, because of their particular vulnerability to environmental pollutants and given the longer lifespan of children.

Trade-off decisions that involve latent health effects may be influenced by the perceptions of future health states and preferences, which increases the uncertainty associated with the valuation of children's health. Since health risks to children are not as well understood as those to adults, it is likely that latency issues will be more uncertain for children than for adults (Hoffmann et al., 2005). Also the fact that there is more lifespan over which latent impacts can be realised increases the value of preventing exposure. As an example, there is a higher probability that the impacts of a disease with a 20-year latency period will be realised if a 10 year-old is exposed to a toxic hazard than if a 70 year-old is exposed.

An important determinant of the value of reducing future risks is that there is a chance of dying before the impact of exposure. For example, if a latent impact were uniform across the whole population, with a lag of 20 years, then approximately 25 percent of those affected would die before the damage became evident (Cropper and Portney, 1990). This adds complexity when taking account for latency effects on the valuation of children's health.

In practice, revealed preference approaches do not lend themselves easily to estimating WTP for future risk reductions[30], suggesting that empirical work in this area should employ stated preference methods. Despite the importance of this matter, very little empirical work has been conducted thus far to tackle the issue of latency. Notable exceptions are Johannesson et al. (1997), Alberini et al. (2003), Alberini et al. (2004) for the US and Canada, Krupnick et al. (1999) for Japan, Markandya et al. (2004) and Chilton et al. (2004) for the UK.

Discounting

Discounting practices are particularly important when health effects are long-lived such as those concerning children.

The main difficulty in discounting is the determination of the appropriate discount rate. Health gains are generally valued not in monetary terms but rather in "physical" terms (number of years of life gained or QALYs gained). When costs and benefits are valued in monetary terms, a common rate can be used. Otherwise, it is of general practice to discount benefits at a lower rate than that of costs[31].

In a context of discounting children's health, another difficulty makes the task more complex. The theory suggests eliciting preferences from those directly affected by the risk reductions being valued. However, as children's preferences are excluded, we must make recourse to the preferences of adults, possibly the parents of the child in question. But it is not known whether parents discount their own future health benefits at the same rate as they discount future health benefits to their children. Elicitation of time preference over future health events from adults is challenging because of the unfamiliarity with this sort of decision making, the uncertainty associated with future health events, the cognitively demanding task and the meaning of the description of future health events (Cairns, 2005).

Regarding the discount rate, it has been argued that individuals' discount rate will generally be low in the case of a mortality risk as the future disutility of a future risk of death will be fairly constant (Cropper and Portney, 1990). Moore and Viscusi (1990) use wage-risk tradeoffs from the labour market to infer that individuals make employment choices consistent with discount rates that range between 1 and 14 percent. Horowitz and Carson (1990) estimate the discount rate from discrete choice questions that ask individuals to choose between programs that save lives in the future at a cost. The median discount rate is estimated to be 4.5 percent, and a sizable fraction of the sample is found to have a very low discount rate. Alberini et al. (2003), and Markandya et al. (2004) use WTP data reported by individuals in a series of CV surveys conducted in Canada, the US, the UK, Italy and France to estimate the implicit discount rate exhibited by individuals for future risk reductions, finding that such discount rate vary across the studies, ranging from 4.5 percent (the US) to 10 percent (the UK) [32].

It is of common practice to use a constant discount rate over time and across individuals. However, results from recent empirical studies suggest this may not the case: non-constant discount rates and more generally hyperbolic discounting appears as a better model than traditional exponential discounting, which is the standard method in use applying a discount rate that is constant over time (Wietzman, 2001). This also supports direct estimation of discount rates (implicit in WTP values for future risk reduction), supplemented by sensitivity analysis to identify determinants of these discount rates, including age, gender, income, education and other individual characteristics. However, the practical validity of hyperbolic discounting is very much in question given time inconsistency problems[33].

As discussed in Cairns (2005), time preferences over future health states are difficult to elicit from adults, and this is even more challenging in the children's health context given the lack of empirical studies dealing with discounting children's health benefits. A less than satisfactory possibility would consist in using the age-discount rate relationship defined over adult populations and apply it to younger age groups to predict discount rates.

Outline of the book

In the first Chapter, Tamburlini proposes an overview of the main types of risk differences that may exist between adults and children. Particular attention is paid to exposure differences and dose-responses differences, to the description of the different steps necessary to conduct risk-assessment practice, as well as the uncertainties in risk assessment for children.

In the second Chapter, Scapecchi presents an overview of the potential sources of differences between adults and children in terms of valuation. Based upon a review of the empirical literature related to the valuation of (environmental) health risks to children, the most commonly used methodologies and the empirical results are presented in order to explore what is the right way to approach analysis for children's health value.

The third Chapter provides the comments of Dickie and Gerking on the elicitation and formulation of children's preferences. They examine the foundations for the use of third-party elicitation, and the difficulties related to third-party elicitation, such as motivation, altruism and other important parameters. They also propose a review of the literature of parents' WTP for protection of their children's health and provide new empirical estimates. In the literature review, theoretical models used as foundation for WTP estimates (i.e. unitary or pluralistic household allocation models) are presented.

Agee and Crocker provide a discussion in the fourth Chapter on the methods and difficulties associated with transferring values for adults' health to children. The report describes the background on the use of transfer values, the different steps required for transfer practice, and will explain the reasons why this practice may not be satisfactory when valuing children's health. Particular attention will be paid to show how this difficulty has been (and can be) treated empirically.

Few examples of studies discounting children's health exist. However, the extensive literature on discounting health more generally can provide insights for this specific context. In the fifth Chapter, Cairns comments on the difficulties for discounting health, and more particularly in the context of valuation of children's health. Given the disparities that exist between adults and children, several problematic points are raised.

The sixth Chapter written by Hoffmann, Krupnick and Adamowicz examines the effects of economic uncertainties on the valuation of environmental health risks to children. They consider a great number of economic uncertainties associated with the valuation of children's health. Examples could include uncertainties about the structural conditions, such as the valuation of future children's benefits, or the irreversibility of health problems, but also the uncertainties about the appropriate welfare model, such as the uncertainties about an appropriate proxy for children's utility, in measuring parents' benefits and regarding when and how others' utility counts.

Two types of measures are commonly found in the literature of children's health valuation: the WTP and the QALYs. The seventh Chapter prepared by Hammitt proposes to compare those two types of measure and their underlying methodological assumptions in order to assess which one is the most appropriate when applied to the valuation of environmental health risks to children.

Health-related quality of life measures used in a cost-effectiveness analysis framework are used as an alternative to traditional cost-benefit analysis and WTP estimates. Chapter eight by Nord compares these measures and their associated preference scale methods measures in the context of children's health valuation in order to assess the different methodologies.

Finally, considerations drawn from all the chapters raise a number of questions, including methodological issues, policy implications as well as recommendations for the valuation of environmental health risks to children, which are summarised in the final Chapter (Chapter nine).

Notes

1 OECD Environment Directorate, National Policies Division. The views expressed in this chapter are those of the authors and do not necessarily reflect those of the OECD.

2 The perspective makes reference to the person from whom we should elicit values for reducing environmental health risks to children.

3 Results are clearly mixed. Examples could include the following studies. On the one side, Johannesson and Johansson (1996) report age-differentiated WTP estimates obtained from a contingent valuation survey in Sweden. The results suggest that the WTP increases with age: on the standard basis, 8000 SEK for the 18-34 age group, 10000 SEK for the 35-51 age group and 11700 SEK for the 51-69 age group. Johannesson et al. (1997) also report a positive relationship between age and WTP. On the other side, Hammitt and Graham (1999) determine that WTP declines with age. Chilton et al. (2004) also report a negative relationship between WTP and age.

4 The difficulties associated with potential altruism from parents, and more generally adults, toward children are examined below.

5 With "society", we mean all adults in the population, i.e. parents and non-parents.

6 Welfare economics rests on the assumption that decisions are made by rational individuals. The suggestion is that individuals are the best judges of the values they place on goods and services (Randall, 1987).

7 For further details on various parental perspectives, see Dockins et al. (2002).

8 Examples include Lewis and Charny (1989), Cropper et al. (1994), Johannesson and Johansson (1997).

9 Environmental policies that explicitly address children's health are limited at the moment. Most of them, implemented in the United-States, focus on specific substances. For example, in the Clean Air Act, standards for permissible levels of toxins in air should be set in order to protect "the most vulnerable members of society", i.e. mainly children. In addition, the Declaration of the Fourth Ministerial Conference on Environment and Health (WHO, 2004) is promising and more regulations specifically aimed at reducing environmental risks to children's health should be proposed in the following years.

10 For more details on the difficulties associated with the use of the parental perspective, see Dickie and Gerking (2005).

11 For further details on unitary and collective models, see Dickie and Gerking (2005).

12 For further details, see Dickie and Gerking (2005).

13 Another issue being how to assess the value of the WTP for children included in the WTP for parents.

14 For further details, see Scapecchi (2005) and Hammitt (2005).

15 Alternatives to CBA include cost-effectiveness analysis (CEA), risk-risk analysis and health-health analysis. For further details, see Kuchler and Golan (1999).

16 For further details on the disparities between CBA and CEA, readers are referred to Dolan and Edlin (2002), Hubbell (2002), Brent (2003) and Hammitt (2005).

17 For further details on monetary valuation, readers are referred to Pearce et al. (forthcoming).

18 For further details, see Agee and Crocker (2002).

19 The COI approach is usually classified with the human capital approach since it can be considered as measuring the loss in productivity associated with ill health.

20 See Bateman et al. (2002) for a recent review.

21 In practice, WTA measures are rarely used, particularly in the health context, because they do not have an upper limit: WTA values can be extremely large, while more reasonable values can be obtained through the WTP approach.

22 For further details, see Mitchell and Carson (1989) and Hausmann (1993).

23 For further details on preference scales and HRQOL measures, see Chapter Nord (IX).

24 It is often recommended to have a sample of 1,000 observations as a minimum (see Mitchell and Carson, 1989, for more details on the design of a contingent valuation survey).

25 For further details, see Hanemann (2003).

26 For children of 8 years of age, support is, nonetheless, necessary to help children correctly understand the questionnaire and to formulate sensible answers.

27 "Community preferences" have been recommended to derive the weights used in health-related quality of life measures (Gold et al., 1996), i.e. preferences of people generally in good health, thus *ex ante* judgements. However, these weights can – of course – be elicited from any subgroup of the population.

28 With the QALY measures, there are no trade-offs between health and the other goods.

29 Shepard and Zeckhauser (1981) consider the life cycle model and show that, under certain assumptions, the relationship between WTP and age could be modelled as an inverted-U relationship that peaks when the individual is 50 years old.

30 The applicability of revealed preference techniques to estimate WTP for future risk reductions depends upon the nature of the relationship between the product under consideration and the impact which is to be valued. Examples could include purchases of bottled water (e.g. water quality) or organic foods (e.g. pesticide residues) protect against future (latent) risk reductions.

31 For more details, see Cairns (2005), Department of Health (1996) and National Institute for Clinical Excellence (2001).

[32] These figures do not converge with estimates of discount rates based on surveys and laboratory experiments. For example, Harrison et al. (2002) estimate the discount rate for money to be 28% in a field experiment in Denmark, while Warner and Pleeter (2001) peg the individual discount rates for US military personnel between 10% (for officers) and 54% (for enlists).

[33] For further details, see Cairns (2005).

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Chapter 1

Overview of the Risk Differences between Children and Adults

by

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This chapter provides an overview of the risk differences between children and adults. The knowledge of the specific susceptibility and exposure patterns of infants and young children to environmental health risks factors has improved over the last decade. There are environment-related health effects unique to children, such as birth defects related to preconceptional or prenatal exposure of parents to environmental pollution, others that may be more severe in children, due to higher exposures and/or increased susceptibility particularly during the early years. There is also epidemiological evidence of heterogeneity among children due to genetic factors and most of all due to variable distribution of social factors that modify exposure as well as susceptibility to many environmental hazards.

However, the current knowledge of children's vulnerability is not sufficient. A great number of uncertainties on the likelihood and the magnitude of health effects, mainly related to the multi-factorial nature of environment-related health outcomes, limit the ability to quantify with reasonable precision the risk differences between adults and children.

Introduction

Our understanding of the mechanisms underlying the age-related differences in the risk of environment-related disease has significantly improved over the last decades. Knowledge on windows of vulnerability during periods of rapid cell growth and organ development (Selevan, 2000), as well as insight into the exposure patterns of infants and young children (Bearer, 1995) have complemented our notions on the peculiarities of infants with respect to absorption, distribution, biotransformation, storage, and excretion of chemicals, which can all influence toxicity (Nagourney and Aranda, 1991; Roberts, 1992). "Children are not little adults" has become the *leit-motif* of International Conferences as well as of scientific meetings.

However, our knowledge is still far from being complete, and, most important, is continuously challenged by new issues arising from the release into the environment of new compounds as well as by the increasing awareness of the complex, multifactorial nature of environment-related health effects. Moreover, only in a few cases, and with a considerable degree of uncertainty, are we able to quantify the acute and chronic impact of environmental exposure on the health of children and therefore to provide decision-makers with reliable estimates for cost-benefit analysis of different policy options.

International organisations and national environment and health authorities have recently committed to protecting the health of today's and tomorrow's children from environmental threats (G8, 1997; Interministerial Conference on Environment and Health, 1999; World Summit for Sustainable Development, 2002) and this highlights the need to characterise, quantify and value risk in order to prioritise and assess child-focused environmental protection policies.

This paper is intended to contribute to this effort by providing an overview of the risk differences between children[1] and adults. First, the types of risk differences that exist between children and adults and the mechanisms and factors that influence the susceptibility and the exposure of children to xenobiotics are described. Second, current knowledge on risk differences between children and adults are illustrated with examples regarding the health effects of some of the main environmental pollutants: pesticides, environmental tobacco smoke (ETS), suspended particulate, neurotoxicants, pesticides and UV. Third, the conceptual and practical implications for the risk assessment process of current knowledge on children's vulnerability, as well as of the existing areas of uncertainty, are discussed.

The nature of the age-related differences in susceptibility and exposure: underlying mechanisms and influencing factors

The existence of important differences between children and adults with respect to environmental toxicity was first shown by studies on lead toxicity (Gibson, 1904), radiation induced leukaemia (Miller, 1956), neurotoxicity due to exposure to methylmercury (Harada, 1978) and diethylstilbestrol (DES) induced cancer in the offspring of exposed women (Herbst, 1971). These milestones in the history of children's environmental health also provide excellent examples of the many ways in which children differ from adults in their vulnerability to toxic agents.

These include differences in *susceptibility*, i.e. the likelihood, the nature and the amount of the damage produced by exposure to a defined quantity of a toxic agent, and

differences in *exposure*, i.e. the total intake of a toxic agent per unit of body weight (or body surface).

Differences in *susceptibility* may be *qualitative* or *quantitative*, i.e. they may regard the *nature* or the *amount* of the effect. Qualitative differences in susceptibility are particularly important. For example, the damage produced by lead or methylmercury to the developing brain, and the carcinogenicity of DES, are unique to specific stages of development, such as the embryo-fetal period and the early years of life and do not have a counterpart in adult life.

Differences in *exposure* are usually quantitative, although there are a few potential toxicants (for example phtalates) for which exposure is almost exclusively limited to infants and young children.

Since a thorough understanding of these differences is essential for risk characterisation, as well as for policy development, the underlying mechanisms as well as the factors influencing them will be illustrated in some detail[3].

Differences in susceptibility

Quantitative differences

In children and particularly in infants, body systems and functions, including the ability to absorb, metabolize and eliminate xenobiotic compounds are still immature and differ from those of adults. These differences are based on complex mechanisms so that metabolic immaturity may play a role in different ways with respect to toxicity. There are compounds, such as polyaromatic hydrocarbons, to which infants may actually be less sensitive than adults because the metabolic pathways that are needed for the activation of their toxic metabolites are not yet developed. In many other cases they are more vulnerable because they do not have the capacity to metabolize, and thus detoxify the toxic compounds: this is the case, for example, of organophosphate pesticides (Charnley and Putzrath, 2001). Moreover, the fact that metabolic systems are still immature does not necessary imply that they are less active. For example, for some substrates, the adult activity of P450 is surpassed by that of neonates, resulting in an increased capacity to metabolize phenytoin (Scheuplein, 2002).

The enzymes involved in biotrasformation activities can be categorized in two groups, phase I and phase II enzymes. Of particular interest are the enzymes involved in both phase I transformation through the cytocrome P450 system and phase II transformation through for example the glutathione-S transferase (GST) family. Not only does the developmental stage determine the activity of these metabolic pathways, but there may be a marked tissue specificity. Also, the activity of each component enzyme is genetically determined, as for the m family of GST (Seidegard, 1988). As a result, susceptibility may vary with age, may be organ and tissue specific, as well as depend on the individual's genetic characteristics.

Examples of the variable influence of the developmental period with respect to toxicity can be taken from studies aimed at identifying the maximum tolerated doses (MTDs) in phase II dosage protocols for anticarcinogenic drugs. These trials have revealed that the toxic effects are often similar qualitatively in children and adults, but that they may differ quantitatively (Glaubiger et al. 1982; Evans et al 1989). Children could tolerate higher doses than adults of 11 out of 14 drugs administered for solid tumours, while they showed similar tolerances to antileukemia drugs (Marsoni et al, 1985). On the other hand, some chemotherapeutic agents undergo activation to

cytotoxic metabolites, and children, with their higher metabolic capacity, can be more susceptible to toxicity by such compounds. This is true, for example, for indicine-N-oxide (Marsoni et al. 1985) but not for cyclophosphamide (Crom et al., 1987). As shown by animal models, some, but not all, organophosphate pesticides are more toxic to fetal and neonatal animals than to adults (NRC 1993; Whitney et al. 1995).

Absorption, distribution and excretion can also influence toxicity. The gastric pH does not achieve adult levels of acidity until several months of age: this will affect xenobiotic absorption from the stomach and change the ionization status of these chemicals, hence their activity (Chemtob, 1991). With low levels of acidity, bacterial growth is normally enhanced and, as a consequence, the risk of gastrointestinal diseases will be increased (EEA and WHO, 2002). Renal function, i.e. the ability to eliminate compounds and their metabolites, reaches adult capacity by the end of the first year.

Qualitative differences

Compared to adults, children are characterised by development and growth. During development, organs undergo very rapid cell growth and differentiation. These processes are particularly characteristic of embryonic and fetal life, but they may continue for months and years after birth. During these processes, organs and systems have unique development periods of high vulnerability or *critical windows of exposure (*Selevan SG, 2000*).* This phenomenon is particularly relevant to the nervous, respiratory, endocrine, reproductive, immune and visual systems. For example, if cells of the brain are destroyed or the "wiring" process is damaged during the period of critical development, there is a high risk that the resulting damage will be irreversible (Rice and Barone, 2000). Thus, exposure in early life may give rise to adverse effects that have no counterpart in adult life, such as birth defects following gonadal or early pregnancy exposure to genotoxicants (Jensen, 2002), adenocarcinoma of the vagina following in utero exposure to diethylstilbestrol, intrauterine growth retardation in babies whose mothers were exposed to cigarette smoke (Di Franza and Lew, 1995), developmental delay in babies whose mothers were exposed to PCBs and methylmercury (Walkowiak, 2001), and induced severe neurological toxicity by transplacental transfer of methylmercury to the fetus (Marsh, 1990). Such exposures produced damage in the babies, while the mothers had no clinical symptoms.

The concept of windows of susceptibility is particularly important since it shows that the *timing* of the exposure may be critical: the same exposure in a different moment would create a different spectrum of disease and could make the difference between an important effect and no effect at all. This is well known in teratology: different kind of malformations might be expected when exposure to genotoxic agents occurs at different times. The same is true for virtually all organs and systems during their development (Selevan, 2000).

Quantitative consequences of unique vulnerability windows

The existence of windows of vulnerability also has *dose-response implications* (Faustmann EM et al., 2000). The developing nervous system also illustrates effectively the role of dose-response relationships in susceptibility. For example, classic studies with radiation exposures in the rat have shown steep dose-response relationships for brain malformations where a doubling of dose (50-100 rads or 0.5 Gray) on day 9 of rodent gestation can cause a greater than 4-fold increase in rat brain malformations (Wilson, 1977). At 200 rads, a 78% incidence of brain malformations

was observed. On day 10, one day later in gestation, exposure to 50 rads does not produce brain malformations. Exposure to 100 rads produces only a 3% incidence, but exposure to 200 rads produces a 19% incidence. If exposure occurs earlier, on day 8, neither exposure to 50 nor 100 rads produces brain malformations. These observations convey the significance of evaluating both the *dose* and the *timing* of exposure to determine the stage and process of development that will be impacted. The relevance of these observations is known for radiation exposure in humans, where irradiation of the human fetus at doses of 100 rads early in pregnancy can cause brain malformations such as microcephaly and mental retardation (Mettler and Upton, 1995).

Conclusions

Differences in susceptibility between children and adults are *substance specific* as well as *developmental stage specific*.

Developing organisms may show increased susceptibility to toxicants, but also increased resistance, depending on the compound to which they are exposed, their stage of development, and the relevant metabolic route. Differences are likely to be most significant during embryonic, and fetal periods and during the first 6 to 12 months of life, when differences in absorption, metabolism distribution and excretion of xenobiotics are greater. Nonetheless, since substantial changes occur in organ size, structure, and function from infancy through puberty, they are not confined to early developmental stages. Overall, this indicates the need for a compound by compound susceptibility testing.

The existence of windows of particular vulnerability is of the utmost importance, since exposure to xenobiotics during these periods can determine effects that may be very severe and long-lasting and that have no counterpart in adult life. This also indicates the need for sensitivity testing of xenobiotics in animal models at different stages of development, including different periods of embryo-fetal development.

Differences in exposure

Differences in exposure are almost exclusively quantitative although there are a few instances in which exposure may be entirely confined to specific age groups. For example phtalates, a family of chemicals used to make polyvinyl chloride (PVC) plastic solid and flexible, are widely used in objects to which newborn babies, particularly premature and sick babies, may be exposed for long periods, such as pacifiers, intravenous catheters and tracheal tubes.

Factors that determine significant differences in exposure between children and adults include biological, psychosocial, socioeconomic and geographical factors.

Some of the biological factors have been already mentioned among the unique features of the developing organisms. They include the increased permeability of the gastrointestinal tract and skin that characterise the first months of life. As a consequence, not only the intestinal absorption of lead is higher in young children (Royce, 1992), but a higher quantity of the absorbed lead can reach the brain due to the increased permeability of the blood-brain barrier during infancy.

The most important differences in exposure result from the process of growth, since it implies a higher rate of energy consumption, and thus of food, air and water intake (see Table 1.1) per unit of body weight.

Table 1.1 Comparison of child and adult intakes[a]

Media	Child (< 1 year)	Adult	Ratio (child/adult)
Air	0.44 m3/kg-day	0.19 m3/kg-day	2.3
Water/fluids	161 g/kg-day	33.5 g/kg-day	4.8
Food	140 g/kg-day	23 g/kg-day	6.1

a.Derived from data in: US Environmental Protection Agency (1997), National Research Council (1993) and Gephart et al. (1994).

Also, children's drink and food preferences can differ greatly from those of adults (National Research Council, 1993) and children, particularly infants and toddlers, have a stereotyped diet which exposes them to higher risk if any particular toxicant is present in their everyday food. This is the case for milk and other diary products, fruit juice, cereals, and, for a variety of specific infant foods, snacks, candies, so that, overall, the "normal" dietary intake may exceed the safety threshold for some toxicants (Curl et al., 2003).

Children also have more time to develop diseases that take a long time to develop, such as cancer, cardiovascular and neurodegenerative disease. We now know that these diseases are influenced by exposure as early as in fetal life (Barker, 1998). Moreover, children may be exposed to a specific agent throughout their life while adults may have been exposed for shorter periods to chemicals that have only recently appeared on the market.

Psychosocial factors include factors related to developmental stage and culture. Infants and toddlers are characterised by exploratory behaviour and hand-to-mouth activity, which expose them to much higher quantities of toxicants that typically concentrate in dust and soil (e.g. lead, pesticides and other chemical compounds). They also spend a lot of time crawling on the floor. The floor surface and the layer of air near the floor are major sources of chemical and physical agents, including several air pollutants, ETS compounds, and radon.

Geographical factors may also influence exposure to environmental hazards, both directly, such as in the case of ultraviolet radiation (UV), or indirectly, such as in the case of vector-transmitted disease. The UV index, which measures the risk of exposure to UV radiation (WHO, 2002), varies substantially across different geographical regions, as does the risk of contracting malaria or dengue. Obviously, geographical differences in risk also relate to the adult population, but they are more relevant to children given that the incidence and the fatality rate of many environment related diseases differ significantly between children and adults, so that the ultimate effects of a particular exposure may be more important among children (WHO, 1995 and 2002). For example, lack of safe water is typically associated with diarrhoeal diseases (DD), but 85% of the Burden of Disease (DALYs) caused by diarrhoea is borne by children (WHO, 2002).

Finally, exposures are greatly influenced by social factors. Socio-economical status (SES) and its correlates such as housing features, place of residence (in terms of proximity to heavily polluted areas due to industrial emissions, high traffic load, waste

sites etc.) determine great disparities in exposure and thus in risk among population groups (Mott, 1995). This is true in developed as well in developing countries.

The 1988 Centers for Disease Control report on lead poisoning estimated that 68% of poor, inner-city African American children were lead poisoned, i.e. with blood levels above 10µg/dL, as compared to 36% of poor inner-city white children (ATSDR, 1988). In 1999-2000 the median blood lead level for children living in families with incomes below the poverty line was 2.8µg/dL, and for children living in families above the poverty line was 1.9µg/dL (US EPA, 2003). Blood levels of cotinine, a breakdown product of nicotine which is used as a biomarker for exposure to ETS, were three times higher in black than in white children (US EPA, 2003). In the UK, there are 662 polluting factories in areas with average household income of less than £15,000, and only 5 in postcode areas where average household income is £30,000 or more. The poorest families (defined as household incomes of less than £5,000) are twice as likely to have a polluting factory in their immediate area as families with an income of £60,000 or more (McLaren and Cottley, 1999).

The prevalence of the two main environment related childhood diseases, i.e.acute respiratory infections and diarrhoea, are much higher in the poorest 20% than in the richest 20% in countries such as Bangladesh, Vietnam, Benin and Tanzania (Gwatkin, 2000).

International differences are even more striking: the BoD related to exposure to lead in developing countries is much higher than in developed countries and the same is true for the health effects of lack of safe water and sanitation (WHO, 2002).

It is not only the economic dimension of poverty which matters. SES is also strictly associated with the educational level of parents, which influences risk awareness and life styles. Social exclusion is also a powerful determinant of exposure: children in particularly vulnerable circumstances such as orphans, street children, children involved in illegal activities and in hazardous forms of labour are at much higher risk of exposure to practically all the environmental hazards (microbiological, chemical and physical agents as well as injuries and abuse) (WHO, 2002).

In poor countries and in disadvantaged communities the consequences of higher environmental exposure cumulate with those deriving from decreased access to quality preventive and curative services. This has been, for example, well documented for lead (Weiss, 2000) pesticides (Eddleston, 2002) indoor air pollution (Black, 2003) and can be easily drawn by estimates of environmental related BoD (WHO, 2002; Ezzati, 2002). Children are the most vulnerable age group as shown by the fact that the highest risk difference for the probability of dying between the richest and the poorest 20% of the world population is observed in the under five age group (Gwatkin, 2000; Victora, 2003).

Conclusions

Exposures in children may be higher as a consequence of biological factors (increased air, water and food intake per body weight and increased intestinal absorption) and of development related behaviours such as hand-to-mouth activity and crawling on the floor. Children also have more time to develop long latency diseases. Social and geographical factors also play a major role in influencing exposures, and poor children are typically at higher risk.

Cumulative effects

So far, we have dealt with differences in susceptibility and exposure to *single* agents. But for several potentially toxic agents the increased age-dependent susceptibility may combine with an increased age-dependent exposure, thus increasing the difference in the overall resulting risk of toxic effects with respect to adults. Lead is a typical example of the combination of increased susceptibility and exposure, but other toxicants, such as some organophosphate pesticides, may also show a similar pattern.

What is even more important, since it has profound implications for risk assessment and for policy development, is that children may be exposed to the same chemical from multiple sources (aggregate exposure) but also be exposed simultaneously to several compounds with similar modes of action (cumulative exposure) with additive, or multiplicative, toxic effects. This is also true for adults but, due to the differences in both susceptibility and exposures described so far, there are several circumstances in which the cumulative risk deriving from combined exposures may be greater for children than for adults.

For example, multiple residues present in baby foods represent a specific concern, particularly for pesticides that share a common mechanism of toxicity (e.g., cholinesterase inhibitors such as carbamates and organophosphates). Up to 16 different pesticides were found in a group of baby foods among the most commonly sold in the US and many of them, when tested, contained multiple pesticides (EWG, 1995). A later analysis based on more than 80,000 U.S. government laboratory tests and detailed data on children's food consumption, revealed that every day, 9 out of 10 American children between the ages of 6 months and 5 years were exposed to combinations of 13 different organophosphate insecticides in the foods they eat (EWG, 1998).

Another example of combined exposure concerns air pollutants. A young child who spends most of its time at home can be exposed to ETS and combustion products from heating and cooking devices, as well as to outdoor air pollutants such as particulate matter and others which concentrate indoors. This, combined with the higher intake of pollutants caused by their increased air intake per body weight and the increased susceptibility of developing lungs, ultimately leads to a much higher risk of respiratory effects: a much higher incidence of acute lower respiratory infection (ALRI) in children exposed to high concentrations of indoor pollutants has been documented (Bruce, 2000; Ezzati, 2002).

These additive and potentially synergic effects are not confined to toxicants but include social factors as well. For example, the exposure to neurotoxicants is typically associated with low socio-economic status which in turn implies a higher risk of lack of cognitive stimulation. Thus, the risk of being deprived of adequate cognitive stimulation frequently combines with the risk of being exposed to neurotoxicants, producing an overall higher risk of intellectual impairment in children from disadvantaged communities (Mott, 1995). Poor children, due to decreased host resistance mechanisms and reduced access to health services, are at higher risk of bearing the health consequences of environmental degradation (Gwatkin, 1999; Ezzati, 2002).

The implications of combined effects and multicausality and their links with the unequal distribution of environmental risk across population groups - i.e. what has been called the “environmental justice” issue (Stephens, 2002) – are quite relevant to

children's environmental health and will be discussed below in relation to risk assessment.

Risk differences between children and adults with respect to some environmental pollutants

Pesticides

Pesticides are used world-wide and can contaminate the environment and enter the human food chain. Infants and children are exposed to pesticides by ingestion, dermal absorption and inhalation. They can ingest pesticide residues in food, drinking water, and soil. In addition, they can be exposed to pesticides used in households, schools, playgrounds etc. They differ from adults with respect to sensitivity as well as exposure to pesticides. The large number of potential exposure sources is particularly important because it can lead to cumulative exposure.

Age related differences in susceptibility

Overall, current knowledge on age-related differences in susceptibility to specific pesticides is very limited since many of the testing protocols do not adequately address the toxicity and metabolism of pesticides in neonates and adolescent animals or the effects of exposure during early developmental stages and their sequelae in later life (NRC, 1993; SCF, 1997; EEA and WHO, 2002).

Differences in toxicity of pesticides between children and adults have been found to be quantitative and occasionally qualitative[4].

Quantitative differences are partially due to age-related differences in absorption, metabolism, detoxification, and excretion of toxic compounds as well as to differences in size, to the immaturity of biochemical and physiological functions in major body systems, and to variations in body composition (water, fat, protein, and mineral content). These differences also apply to other chemicals and have been briefly summarised above. The NAS Committee on Pesticides in the Diets of Infants and Children reviewed the available information on sensitivity and exposure of children to pesticides (Bruckner, 2000) and concluded that susceptibility of rats, as measured by lethality rates, is age dependent but also compound specific, with younger animals being more sensitive to parathion and methylparathion but less sensitive to dieldrin which must be converted to toxic metabolites. Age-dependent differences varied no more than 10 fold. Acute lethality, however, is not an adequate predictor of the age dependent target organ toxicity: doses of chemicals which are not high enough to cause death may produce a variety of adverse effects (Bruckner, 2000). Age was not found to be a significant factor in the toxicity of all pesticides. However, very few animal and human data were available to the Committee. Developmental neurotoxicity, for example, is tested only for a few chemicals, including pesticides, and delayed toxicity resulting from exposure to low levels of toxicants during a particularly sensitive developmental period may not be adequately addressed by current testing procedures. Neurotoxicity testing in animals has been mandatory only for known neurotoxic pesticides such as organophosphates (OPs) and carbamate which inhibit acetylcholinesterase in the nervous system. We know, for example, that animals during their fetal and neonatal development are often more sensitive than adults to acute and chronic cholinesterase effects and to other potentially more serious brain and nervous system damage (NRC, 1993; Whitney et al., 1995). Infants may be particularly

vulnerable to reductions in brain acetyl cholinesterase given that acetylcholine plays an important role in normal brain development, and resting levels of plasma and erythrocyte cholinesterase do not reach adult values until 6-12 months of age (US EPA, 1997a). Thus, exposure to OPs can produce long term behavioural and functional damage to the nervous system in the absence of observable signs of toxicity, and with little correlation to cholinesterase levels (US EPA, 1997a). Further, functional impairment of the nervous system can occur after exposures that produce no apparent neurologic toxicity, no gross morphologic changes in the brain and no overt toxicity to the mother (NRC, 1993).

Of special concern is the fact that the susceptibility of the developing fetus, neonate, infant or child to delayed functional toxicity (as a result of exposure to apparently sub-toxic doses of pesticides during a critical window) may not become manifest until adulthood (SCF, 1997). Developmental functional toxicity is especially relevant for the developing central nervous system: for example, perinatal exposure to any of the major classes of synthetic insecticides often results in perturbations in the nervous system, which may affect the behaviour of the developing organism (Mactutus and Tilson, 1991). Particularly, some OPs have been found to be more toxic to fetal and neonatal animals than to adults (NRC, 1993; Whitney et al., 1995).

A number of pesticides (the so-called "endocrine-disrupting" chemicals) have been shown to interfere with endocrine functions even at extremely small doses (EPA, 1997b). Dieldrin, toxaphene, chlordane, and DDT have been found to be estrogenic, as has endosulfan, a pesticide still used in agriculture (Soto et al., 1994). Interactions of pesticides with specific endocrine receptors during fetal and infant development may have profound effects on the morphological and functional development of the child. For instance, there is increasing evidence that exposure to certain synthetic compounds, including dioxins and polychlorinated biphenyls, during the perinatal period can impair normal thyroid function and also learning, memory and attention processes in offspring (Hauser et al., 1998).

Finally, numerous pesticides, including dieldrin, aminocarb, captan, carbaryl, lindane, malathion and dichlorophos, can induce changes in the immune system, which shows an increased sensitivity to chemicals during infancy and childhood (NRC, 1993; Barnett and Rogers, 1994).

Age related differences in exposure

Infants and children also differ both quantitatively and qualitatively from adults in their exposure to pesticides, due to specific patterns of behaviour: among toddlers and young children, hand-to-mouth behaviour is an important mechanism of potential exposure to certain pesticides. Also, infants and children spend more time at home than adults, often crawling or playing at ground level where pesticide residues in household air, dust, carpets and even toys may be higher (NRDC, 1998). Pesticide residues persistent in household soil and dust have been considered significant sources of exposure for young children (Lewis et al., 1994). Children who live on or near farms will ingest significant amounts of pesticides by playing and crawling at ground level and touching surfaces inside the home which contain pesticides either from window dust from nearby lawns, or from indoor applications (Simcox et al., 1995; Zartain et al., 1995).

The main difference in pesticide exposure among adults and children is in their respective diets. Children consume more food per kg of body weight than adults do.

Their diet is less diverse and thus they have a relatively higher intake of some food items than adults. In addition, average water consumption, both as drinking water and as a food component, is relatively higher in children than in adults.

The European Union (EU) and Norway collected data on pesticide residue levels in fruit and vegetables in 1996 and in fruit, vegetables and cereals in 1997. Pesticide residues were present in 36% of the vegetable, fruit and cereal samples. Maximum residue levels (MRLs) were exceeded in 3.4% of the cases, mainly in fruits and vegetables, and multiple residues were detected in about 16% of the positive samples (EEC, 1999).

Detectable residues of organophosphate pesticides were found in 19 to 29% of fruits, vegetables and grains which have been part of the diet of American children for the last decade (US EPA, 2003).

Thus, total intake of pesticides in children may be much higher than in adults and, what is more important, may be above safety thresholds (Curl, 2003). As a consequence of the limited knowledge, risk differences can not be quantified and protective policies, recognizing the differences between the susceptibility of children and adults to pesticide toxicity and the unique patterns of exposure are essentially based on the adoption of maximum residue limits (MRLs) or of additional safety factors for children.

Neurotoxicants

Environmental exposure to a large number of substances has been associated with developmental disabilities, many of which involve the nervous system. Neurotoxic substances usually cause adverse effects on the nervous system through direct toxic actions on the nervous system cells. The neurotoxic effects on attention span, concentration, motor speed, memory, and language functions would be expected to affect cognitive skills, education, social abilities and career. When produced early on in life, such developmental effects are likely to be permanent and may therefore affect an individual's lifetime prospects with regard to quality of life and social success.

Age related differences in susceptibility

During fetal development, the placenta offers limited protection against unwanted compounds, but it is not an effective barrier against environmental neurotoxicants (Andersen et al., 2000). For example, methylmercury easily crosses the placenta, and its concentration in cord blood is considerably higher than in maternal blood (Hansen et al., 1990). As previously mentioned the blood brain barrier is not completely formed until about six months after birth and therefore provides no protection during sensitive developmental stages. Absorption of lead and methylmercury are augmented in infants. In addition to these toxicokinetic factors, the developing central nervous system is more vulnerable due to the combination of immaturity and windows of susceptibility to toxic interference. Based on these features, a large number of chemicals can be classified as neurotoxic. Since neurotoxicity testing is not part of the current requirements for the classification of new chemicals, except for organophosphate pesticides, the total number of industrial chemicals with a neurotoxic effect is very likely to be much higher than those for which detailed human evidence is available.

So far only three environmental chemicals have been documented as definite causes of brain dysfunction following exposure before birth or during early childhood. These are lead, methylmercury and the polychlorinated biphenyls (PCBs). Some

evidence, though much less definitive, is available on mercury vapour, certain solvents and pesticides (Grandjean and White, 2002).

Lead is probably the best-known example of a neurotoxicant to which children are more susceptible than adults. Most of the early studies on developmental lead neurotoxicity described the adverse effects in terms of IQ results. A systematic review has been carried out on 26 epidemiological studies from Europe, New Zealand and Australia regarding the lead-IQ association Needleman and Gatsonis, 1990 (Needleman and Gatsonis, 1990). The geometric mean for blood-lead concentrations in children aged 6-14 years ranged from 74µg/l to 189 µ/l. The evidence strongly supported an inverse association between body lead burden and the IQ of the child. A typical doubling of body-lead burden was associated with a mean deficit in full-scale IQ of about 1-2 points. Recognising that there is no known threshold for developmental neurotoxicity of this metal, the Centers for Disease Control (CDC, 1991) recommended that the blood-lead concentration be kept below 100µg/l (0.5µmol/l) in children. Recent evidence suggests that the association between increased blood lead concentration and decreased IQ can be extended to lead concentrations well below 10 µg per decilitre (Canfield et al., 2003).

In healthy male workers, blood-lead concentrations below about 300 micrograms per litre (µ/1) (1.5-2.0 micromoles per litre (µmol/l) are thought to be relatively innocuous. The occupational limit for adults of 60µg/dl, at which no encephalopathy is noted, may impair kidney function, fertility, and peripheral nerves (Royce, 1992). In the UE biological limits were established between 50 and 70 in males and between 30 and 40 in females to account for reproductive effects. The American Conference of Governmental Industrial Hygienists (ACGIH) indicated a level of 30 (µ/D1) under which practically no adverse health effect could be observed in adults with the exception of an increased incidence of hypertension in selected population groups (Apostoli and Alessio, 2002)

Age related differences in exposure

Lead exposure may begin prenatally, when lead is transported across the placenta, perhaps originating from occupational exposure or from release of maternal lead stores in the skeleton (US EPA, 1986). Increased exposure potential in children derives from their behavioural and activity patterns, which are likely to place them in close proximity to different types of lead, with the subsequent risk of ingesting or inhaling it. Infants may continue to be exposed to lead-contaminated air, dust and water from many sources, included leaded petrol where it has not been phased out. As mentioned previously, body levels of lead resulting from exposure to a given concentration is higher in children than in adults due to higher absorption.

Populations with low socio-economic status may be subjected greater exposures to pollution than affluent populations, as shown most clearly by studies in the United States. Children from deprived households may also have a decreased capacity to compensate for these effects (Needleman and Gatsonis, 1990) as a result of the lack of access to educational tutoring to overcome learning difficulties, for example. In addition, these children may suffer from inadequate nutrition, which can increase the fractional lead absorption and the toxicity. Thus, as lead tends to be absorbed in inverse relationship to the availability of iron, calcium, phosphorus, zinc and copper in the diet (Mahaffey, 1990), children with deficiencies in these minerals are at a greater risk of developing lead toxicity.

Quality of parenting and socio-environmental factors is known to have substantial effects on childhood development. A recent study assessed child performance at 30 and 42 months of age in children prenatally exposed to small quantities of PCBs from environmental sources (Walkowiak et al., 2002). At 30 months of age, the deficit associated with PCBs on Bayley Scale scores for mental development (9.9 points) was not much smaller than the one associated with low parental HOME scores (17.7 points). At the older age (42months), the difference between the effects associated with PCB exposure and HOME scores was even smaller. Thus, these data show that the effects of prenatal PCB exposure persist over the course of the child's development and are similar in size to the well-known and substantial effects associated with quality of parental intellectual stimulation.

ETS

Environmental tobacco smoke (ETS) is a diluted mixture of mainstream smoke. The peculiarity of ETS is that over 4000 compounds have been identified in laboratory-based studies as components of mainstream smoke. Forty-two of these were classed as carcinogenic to laboratory animals and of these many are known or suspected human carcinogens (NRC, 1986). Children are exposed to ETS when people smoke at home or in other venues where people smoke.

Age related differences in susceptibility

Similarly to pesticides and other compounds, the differences between adults and children with respect to the toxicity of ETS are both qualitative and quantitative.

Qualitative differences are once again dependent on the peculiar susceptibility of developing organs and give rise to a variety of adverse health effects which are unique to fetuses, infants and young children. These effects include intrauterine growth retardation, miscarriage, perinatal mortality, sudden infant death syndrome and developmental delay (Courage et al., 2002).

For health effects that are common to adults and children, such as respiratory diseases (von Ehrenstein, 2002) and carcinogenesis (Terracini, 2002), studies directly comparing these health effects in adults and children are lacking, but useful information can be derived from studies that investigated the respiratory effects of the same exposure to ETS using similar endpoints in children and adults. Effects of exposure of adults to ETS were for example recently evaluated by the European Community Respiratory Health Survey, which included subjects from 16 countries (Janson et al., 2001). Some of the health effects which were assessed included wheeze and asthma. Several meta-analyses of studies assessing the effects on asthma and wheeze are also available for children (Strachan and Cook, 1998; DiFranza and Lew, 1996) so that an indirect comparison of the effects can be attempted (Table 1.2).

Table 1.2 comparison of studies on respiratory symptoms after exposure to ETS[a]

	Children (metanalyses) OR	Adults (ECRHS study) OR
Wheeze	1.24 (95% CI :1.17 – 1.31),	1.11 (95% CI: 0.91 - 1.35)
Asthma	1.21 (95% CI: 1.10 – 1.34)	0.99 (95% CI: 0.70 – 1.40)

a: Quantification of exposure to ETS is not comparable.

Overall, the findings suggest that the effects of ETS on these two specific health outcomes are similar, or only slightly greater, in children with respect to adults.

However, it is worth noticing that decrements in childhood lung function may be associated with reductions in pulmonary functions throughout life, because childhood and adult functions are known to track (Weiss and Ware, 1996). Permanent effects of parental smoking on lung function were found in adults of 30-59 years of age (Upton et al., 1998). Moreover, the respiratory effects of exposure to ETS in children are not confined to asthma and wheeze but include recurrent otitis and adenotonsillectomy, both of which are significantly higher in exposed with respect to non exposed children. This, once again, points to the essentially qualitative nature of risk differences between children and adults with regards to the health effects of ETS, and thus to the difficulty of a quantitative comparison of these effects.

Age related differences in exposure

Two approaches are used to estimate exposure to ETS. Firstly, data on the smoking habits of people in environments where the child spends time, for instance in the home, can be collected using questionnaires. The second approach involves measuring the components of ETS, or their metabolites; the most frequently used is cotinine, a metabolite of nicotine, which can be measured in the blood, serum, urine, saliva or hair. Cotinine levels increase with increased exposure to ETS.

Since many ETS components reach higher concentrations near the floor, infants and young children may be at increased risk of exposure with respect to older children and adults (Bearer, 1995).

Particulate matter

The classic air pollutants are particulate matter (PM), nitrogen dioxide, sulfur dioxide, ozone and other photochemical oxidants. Children as well as adults may be exposed outdoor to various mixtures of contaminants, depending on factors such as proximity to polluting industries, power plants, areas with high traffic load, etc. Indoor pollution is mainly caused by heating and cooking devices, release of chemicals from building materials and furniture and environmental tobacco smoke. Particulate matter includes solid particulates resulting from combustion of organic matter and dusts, originating from the mechanical breakdown of solid matter such as in the construction industry or due to sand particles carried in by wind. The particle size is the primary determinant of the level at which they are deposited in the respiratory apparatus, and include particles smaller than 10 and 2.5 micrometres (mm) in diameter respectively ($PM_{10,}$ $PM_{2.5}$), such as those produced by motor vehicle exhaust. The smallest particles cause the greatest and long-lasting damage to the respiratory and cardiovascular system. PM10 is the air pollutant for which evidence of association with health effects is more abundant, and its concentration is routinely monitored in many countries.

Similarly to other contaminants, there may be differences between children and adults in susceptibility and exposure. Qualitative differences include the fetal effects of mother's exposure to polluted air such as intrauterine growth retardation and the resulting low birth weight (Rogers et al., 2000; Dejmek et al, 2000) as well as the possible genotoxic\teratogenic effects of any of the thousands chemicals that are released into the air, or of any combination of them, also taking into account that genetic susceptibility may make some women more sensitive than others to genotoxicity (Perere et al., 1998).

The biological and psychosocial factors that influence exposure differences have been described previously. It might be useful to add that, due to the very high concentrations of PM10 caused by biomass fuel burning that can be reached indoors (as high as 4000 μ/m^3), and to the fact that children, particularly infants, can spend quite a lot of time crawling close to the source of contamination (Bruce et al., 2000), the exposure to PM10 as well as to other gasses and chemicals including polyaromatic hydrocarbons, may be particularly high under some circumstances.

We will briefly review current knowledge on risk differences between children and adults with respect to mortality and morbidity attributable to PM10, including information which is available on dose-response differences.

The effects of different concentrations of PM10 on mortality and respiratory morbidity in the overall population, as well as in children, have been investigated in several studies. An overview of the health effect of air pollution has been recently published (Brunekreef and Holgate, 2002).

Overall mortality

The short-term effects of PM have been addressed by hundreds of studies, using daily data of mortality and measured concentrations. Taken together, these studies suggest a fairly linear association between the PM10 and the percent increase in mortality (Daniels, 2000). A threshold below which effects do not occur has not yet been identified. Meta-analyses of these studies suggest that the overall effects on mortality are very consistent (Ostro, 1993; Pope and Dockery, 1994; Schwartz, 1994). The effect of a 10 μ/m^3 change in PM10 is of the order of 0.5 to 1.0 % increase in mortality. While the use of daily mortality and concentration data has the advantage of reducing confounding and exposure measurement error, there is uncertainty regarding the extent of prematurity of mortality resulting from acute exposure (some of the deaths could be displaced by only a few days).

Long term exposure studies (Pope at al, 1995; Dockery et al, 1993; Abbey et al., 1999; Krewski et al., 2000; Hoek et al., 2002; Pope et al., 2002) used a prospective cohort design and individual-level data. This way, other factors that have an impact on mortality (such as smoking, occupational risk, alcohol, age etc.) can be characterised and controlled for, so that the effects of long term exposure to PM can be evaluated. All studies reported a significant association between exposure to particulate matter and mortality: the Dockery study showed mortality effect of 8.5% and the Pope study indicated an effect of 3.8%. An overall estimate was proposed by combining the results of several studies and weighing each study by the inverse of the variance of each of the study estimated coefficient (Kunzli et al., 1999). This combined analysis indicates a relative risk of 1.043 (95% CI = 1.026 – 1.061) for each 10 μ/m^3 of PM 10.

A clear association between concentration of PM (2.5 and 10) and other air pollutants with infant under 5 respiratory morbidity and mortality has been shown by several studies (see reviews in Smith, 2000, and Bruce, 2000). However, these studies are very heterogeneous, use different air pollutants and exposure variables, refer mostly to indoor air pollution and are inadequate to provide an overall quantitative dose-response risk estimate for mortality comparable to the risk estimate for adults. Studies directly comparing children and adults are lacking. A recent study in Kenya estimated the dose-response relation for PM10 generated by biomass combustion, using the frequency of ARI as outcome variable: increased exposure to indoor PM10 increased the frequency of ARI and the increase was significantly greater, on average

two-fold, in children under 5 with respect to older children and adults (Ezzati and Kammen, 2001).

An indirect approach, however, may provide some clue. Globally, it has been estimated that 60% of the 2.2 million deaths a year caused by acute respiratory infection in children under 5, which is 20% of the deaths in this age group, is associated with *indoor* air pollution (WHO, 2002). Using a comparative risk assessment approach, the BoD study (WHO, 2002) shows that out of the global BoD (as measured by DALYs, which include mortality and morbidity) caused by air pollution, 73% is attributable to children under 5, suggesting that the increase in mortality caused by air pollution among infants and young children is much higher than in adults. This is very likely to occur only in developing countries or in very deprived areas and populations in developed countries: it has been shown that an effect on infant mortality of outdoor air pollution may be observed also in developed countries, but this effect is relatively small (Bobak et al.,1999; Woodruff et al., 1997).

It should also be taken into account that the ultimate effect on mortality of exposure to air pollution depends not only on exposure but also on access to and quality of health care. Given that almost all deaths attributable to air pollution in children (98%) occur in developing countries, and that the most likely proximal causes of these deaths are acute lower respiratory infections (ALRI), the excess infant and child mortality due to air pollution will be largely affected by the cause-specific mortality for ALRI which is in turn greatly influenced by the quality of primary and secondary health care (Black, 2003; Victora, 2003). The different susceptibility between children and adults is also due to host factors which are much more prevalent and hazardous in children than in adults: for example, malnutrition, which contributes to over 50% of the overall under 5 mortality (WHO, 2002; Black, 2003). This is another example of how risk differences between children and adults depend on a variety of factors and cannot be analysed and quantified outside the specific context.

Asthma

There still is much debate about the role of air pollution in the increasing prevalence of asthma in industrialised countries. Several studies, recently summarised by von Mutius (von Mutius, 1998), found a significant increase in the prevalence of childhood asthma , ranging from a slight increase up to a three-fold increase over the last two-three decades. Wide variations exist across countries, with low-prevalence countries such as Albania, China and Indonesia (range from 2 to 4%), to high-prevalence countries such as Australia and the UK (from 29 to 32%) (ISAAC, 1998).

While air pollution contributes to asthma exacerbation in asthmatic children, exposure to ambient air pollution in concentrations that occur in western Europe is not believed to be a likely explanation for the observed increase in asthma prevalence, since asthma and allergies are less frequent in eastern parts of Europe, although the level of air pollutants are in many cases higher than in western Europe (von Mutius, 1992).

Other environmental factors linked to the western affluent lifestyle, such as increased and earlier exposure to dietary allergens and decreased exposure to microbes (for a complete review, see von Ehrenstein, 2002), are likely to be involved in the increase of asthma prevalence. Thus, the attributable risk of outdoor air pollution with respect to asthma remains to be established, and the extent to which reduction of air pollution would reduce prevalence of asthma remains unknown.

While the contribution of air pollution to asthma prevalence remains unclear, a number of studies performed in children and in adults allowed to develop, using varying concentrations of PM10 as the exposure variable, dose-response functions and associated relative risks for asthma exacerbation.

For asthma attacks in adults (defined by wheeze or shortness of breath) three European panel studies are available, two from the Netherlands (Dusseldorp et al., 1995; Hiltermann et al., 1998) using PM10, and one from Paris (Neukirch et al., 1998) using PM13. Two studies are available from the US (Pope et al., 1991; Ostro et al., 1991). To combine the study results into one central estimate with associated confidence intervals, a meta-analytic approach similar to that used for mortality was used. Heterogeneity among the studies was also examined (Kunzli et al., 1999). The joint risk estimate for a 10 μ/m^3 PM 10 increase from European studies was 1.039 while the US studies provided a relative risk of 1.002. The overall estimate, generated through a random effects model, was 1.004 (95% CI = 1.000 – 1.008).

With regards to asthma exacerbations in children, several panel studies of asthmatics have been conducted in Europe and the U.S. Three (Roemer et al., 1993; Gielen et al., 1997; Ségala et al., 1998) were conducted in Europe. The Roemer and Gielen studies were conducted in Weningen and Amsterdam, Netherlands, respectively and used PM10. The Ségala study was conducted on mild and moderate asthmatics in Paris using PM13. The studies used either asthma attacks or lower respiratory symptoms as measures of asthma exacerbation. The European studies generated a risk estimate of 1.044. Evidence from the United States is provided by Pope et al. (1991) in Utah and by Ostro et al. (1995) in Los Angeles. These studies were conducted using lower respiratory symptoms and shortness of breath as indicators of asthma exacerbation.

All of the studies combined provide a relative risk of 1.051 (95% CI=1.047-1.055) for a 10 μ/m^3 change in PM10.

On the basis of these studies we could conclude that the percentage increase in asthma attacks for each 10 μ/m3 of PM 10 is 1 order of magnitude higher in children than in adults.

The most likely explanation of this risk difference is that asthma in adults is, at least partially, a different physiopathological phenomenon than asthma in children. For example, in children, the threshold for bronchial responsiveness is typically lowered by concurrent viral or bacterial infections, the incidence of which strongly decreases with age, or by allergic sensitization, which tends to slightly increase with age but may peak during childhood; as a consequence, lower concentrations of air pollutants may be sufficient to trigger an attack in children, or to make it more severe. For example, high exposure to NO2 in the week before the start of a respiratory viral infection, and at levels within current air quaity standards, is associated with an increase in the severity of the resulting asthma exacerbation (Chauhan et al., 2003). Therefore, the observed risk difference between children and adults may be explained by a difference in target organ sensitivity combined with other factors to which children may be particularly exposed, such as viral infections.

Ultraviolet radiation

Sun exposure in both childhood and adult life represents the main environmental risk determinant for cutaneous melanoma (for a complete review, see Rehfuss and von Ehrenstein, 2002). We know that sun protection during childhood reduces melanoma

risk during adulthood (Autier et al., 1996) thus confirming that exposure during childhood is a risk factor for developing melanoma during adulthood (EEA and WHO, 2002).

Little is known about the relative contribution of exposure to UV during adulthood and during childhood. Some insight into risk differences between children and adults is provided by a study that attempted to explore the mutual influences of sun exposure during childhood and during adulthood on melanoma risk (Autier and Doré, 1998). By constructing composite indices of sun exposure during childhood and during adulthood and assuming additive combinations of melanoma risk associated with different levels of sun exposure, the authors showed, using logistic regression models, that the melanoma risk associated with a given level of sun exposure during adulthood increased with higher sun exposure during childhood, and that the increase in risk was higher than the simple addition of melanoma risk associated with sun exposure during childhood or adulthood. These findings suggest that the melanoma risk during adulthood is higher among those adults who were intensely sun exposed during childhood than among adults with low or moderate sun exposure during childhood (OR 2.0; 95% IC 0.7 – 5.6). On the other hand, adults with low or moderate sun exposure but high sun exposure during childhood may be at higher risk to develop a melanoma than adults with a high sun exposure, but with low sun exposure during childhood (OR 1.4, IC 0.6-3.0). Conversely, high sun exposure during childhood represents a significant risk factor for melanoma only if there is a substantial sun exposure during adult life. Thus, the study suggests that sun exposure during childhood and during adulthood is interdependent as far as their impact on melanoma risk is concerned, and that sun exposure during childhood may provide more than just an additive effect. Another study suggests that sun exposure taking place before the age of 20 years is more influential on melanoma occurrence than sun exposure later in life (Weinstock et al., 1989)

Injuries

Although not related to specific chemical or physical agents, injuries are usually included among the health effects of environmental exposures (EEA and WHO, 2002). They provide a useful example to explore another dimension of risk difference between children and adults, regarding health effects arising from exposure to complex factors. For injuries, these include not only hazardous home or outdoor environments, but also existing information and warnings, level of parental and societal guardianship, lifestyles etc.

Differences in the risk of injuries between children and adults are essentially quantitative but there are also significant age-dependent differences in the proportion of the main causes of injuries for different age groups. For example, home or playground accidents (burns, falls, poisonings) prevail in the 1 to 4 years age group, while transport related injuries become prominent afterwards and represent more than half the total toll by age 14 and remain so for most of the rest of adult life (EEA and WHO, 2002; US Vital Statistics Report, 2003) .

Quantitative differences are both age dependent and social context dependent.

An insight into quantitative differences is provided by the international Road traffic and Accident database (IRTAD - OECD, 2003). Death rates per 100.000 population of the same age group in 1999 were always lower in OECD countries than in non OECD countries, with death rates on average 3 to 4 times less, while the rates among

adolescents and youth (15 to 24 years) were on average 1.5 to 2 times higher in OECD countries than in the others. The risk for lethal injuries varies greatly across and within Regions. For example, mortality rates (per 100.000) from external causes were in 1992-3 3 to 4 times less in western European countries than in NIS countries and the traffic dependent rates were on average two times lower (Koupilova et al., 2002). Various types of injuries can occur more frequently in certain contexts depending on factors such as legislation but also societal values and lifestyles. In general, the overall risk for injuries in children tends to reflect the risk in adults within the same geographical area but there might be exceptions. Most risk differences in the case of injuries are due to exposure factors although some differences in sensitivity, for example for brain injury, may play a role.

Overall environment related burden of disease (ERBoD)

Estimates of health effects of environmental exposure have been made available recently. These estimates include: estimates of the ERBoD for the main environmental risk factors (WHO, 2002; Ezzati et al., 2002), estimates of the health effects of air pollution (Kunzli et al.,1999) and estimates of the effects of exposure to neurotoxicants (Landrigan et al., 2002). In a few instances economic costing has been attempted as well. These estimates have been obtained through quite different methodologies.

For the environmental burden, the comparative risk assessment methodology was used (Murray and Lopez, 1999; WHO, 2002).

Globally, the environmental portion of the BoD is around 25 to 40% (Smith et al, 1999; Ezzati et al., 2002), but 43% of the total ERBoD falls on children under 5 years, even though they make up only 12% of the population. It has also been estimated that up to 80% of the BoD in children under 5 has an environmental origin[5]. Thus, globally, the proportion of overall BoD attributable to environmental factors is at least 6 times greater in infants and young children than in the remaining population of older children and adults. While confirming that, on a global scale, children, and particularly young children under 5, are more vulnerable to environmental threats, this estimate should be considered preliminary. It should also be emphasized that the burden of disease due to environmental factors varies dramatically by region, in both quantitative and qualitative terms, and this is particularly true for children. For example, in the so-called established market economies, only 1.6 per thousand disability adjusted life years (DALYs) in persons under 5 is attributable to major environmental factors as compared for example to 44 in transition countries and to 751 in sub-Saharan Africa (Smith et al., 1999), where diarrhoeal diseases and ALRI account for most of the ERBoD under 5 years of age.

A further insight on risk differences can be provided by the difference in the relative contribution of specific environmental risk factors (ERF) to the total BoD for each age group (WHO, 2002). For example, lead is causing, globally, about 3% of the total BoD in children and about 0.2 % BoD in adults. It can also be provided by a direct comparison of the ERF specific BoD for the two age groups. For example, the estimates for the total DALYs lost yearly which is attributable to *indoor* air pollution from solid fuel is 38,539 and is mainly confined to the 0-5 years population (83% of attributable events) while the 7865 DALYs attributable to *outdoor* air pollution mostly concern adults (89% of attributable events). These estimates lead to an overall 4.6 to 1 children (0-5 years) to adult ratio with respect to the total burden attributable to air pollution, which represents approximately 3% of the total BoD, i.e. 46405 out of 1,455,473 DALYs (WHO,2002).

Once again, it is necessary to point out that the BoD attributable to environmental risk factors is disproportionately borne by the poorest children, i.e. children living in poor countries and in disadvantaged families in more affluent countries. This stresses once more the importance of socio-economic factors in environmental risk, and thus emphasizes the need to take into account these powerful determinants of risk and of risk differences among children and adults when characterizing risk and developing and assessing policy options.

Overview

Table 1.3 provides an overview of qualitative and quantitative differences between children and adults with respect to the health effects of exposures to some environmental contaminants. The table must be seen as temptative, given the lack of data, the many uncertainties existing on the available data, and the fact that, as previously emphasized, children are not a homogeneous population.

Table 1.3 Overview of the qualitative and quantitative differences between children and adults with respect to some environmental contaminants.

Agents	Qualitative difference (i.e. effects observed in children which have no counterpart in adults)	Quantitative difference: Sensitivity	Quantitative difference: Exposure
Neurotoxicants (lead)	Yes (neurodevelopmental effects)	From 5 to 10 times higher for acute and chronic toxic effects which are also observed in adults	up to 10 times higher (increased absorption and accumulation, combined exposures) in exposed groups
Pesticides	Likely (immune and endocrine effects)	Variable (children can be more or less sensitive), usually 2-fold, up to 10-fold; differences are limited to first 6 to 12 months	up to 10 times higher (increased per body weight food intake and combined exposures in children) in exposed groups (occupational exposure not considered here)
ETS	Yes (prenatal and perinatal effects, some respiratory effects)	Not significantly different (wheeze and asthma)	Variable
PM10	Yes (pre and perinatal effects)	Up to 10 times higher for asthma exacerbations; twice as much for acute lower respiratory infections and up to 10 times higher for ALRI mortality	Variable, can be much higher for indoor air pollutants
UV	No	Maybe higher	Likely to be higher (more frequent sunburns during childhood)

Existing uncertainties in assessing risk differences.

A key issue to be addressed in dealing with public health is what level of proof is to be used when making a decision. Traditionally the scientific approach requires a high level of proof, such as that provided by the coexistence of:

- valid experimental studies;
- consistency and coherence of results among different studies on the same subject;
- evidence of a dose-response relationship (the greater the exposure, the greater the effect); and,
- plausible biological rationale to explain the investigated causal link.

In the context of environmental health, the above requirements may be not met due to a variety of factors, which include the continuous development of new chemicals and technologies, the pressure to introduce them on to the market before completing rigorous scientific scrutiny, and the difficulties entailed in this scrutiny: there are major difficulties in making detailed and accurate assessments of risk and hazards, as there may be uncertainty both in the probability of an event occurring and in the scale and nature of its consequences.

These uncertainties may arise from a variety of factors (Tamburlini and Ebi, 2002):

- the emergence of new technologies (e.g. genetically modified organisms) for which there isn't a sufficient body of experience;
- the complexity of the interactions between humans and the environment leading to many possible causes for any given effect, and to difficulties in establishing the role of each single factor;
- separation of cause and effect over space (e.g. widely dispersed pollution) and time (e.g. intergenerational effects) which makes it difficult to establish causal connections;
- synergistic and cumulative effects (e.g. failure to take into account pre-existing body burdens of toxic substances or of the combined effects of toxicants);
- unpredicted sources of hazards;
- varying susceptibilities among populations due to genetic, social or environmental factors.

Examples given in the previous sections have illustrated how, due to imperfect knowledge concerning the likelihood nature and magnitude of the health effects on children as well as the actual risk in different exposure scenarios, a considerable amount of uncertainty still characterizes many issues with few, and still partial, exceptions such as the neurotoxic effects of lead. New knowledge is acquired every day, but it must be recognised that the methodological complexity of research aimed at gathering new information in this specific field requires a significant investment.

Areas of uncertainty that may be particularly relevant, if not exclusive, to children are summarised in Table 1.4, and framed according to the traditional risk assessment steps.

Table 1.4 Main areas of uncertainty regarding the assessment of environmental health risk for children.

Risk assessment steps	Reasons for increased uncertainty
Causality	Effects which may arise only for exposure during very narrow susceptibility windows, particularly *in utero,* may be missed by toxicology testing due, for example, to differences in sensitivity and to different (i.e. more closely spaced) susceptibility windows between animals and humans. Effects that have a very long (i.e. several decades) latency period, that are prolonged into adult life or that can be observed only in the offspring (intergenerational effects) may also be missed.
Susceptibility	Existence of great variability in susceptibility to different toxicants among children of different age groups due to rapid changes in metabolism, distribution, excretion etc. Existence of genetic variability in susceptibility. Existence of biological factors (ex. nutritional status) that can modify susceptibility
Exposure	Variability in exposure among children of different age groups due to both biological factors (i.e. increased absorption, usually limited to the first 6 months, but possibly extending to later ages in particularly susceptible children) and behavioural characteristics. Wide variability in exposure among children with different socio-economic and cultural background
Risk characterization	When exposure to an hazardous agent is sufficient to produce toxicity, the ultimate health effect can be magnified by factors that, in children to a much greater extent than in adults, can increase susceptibility (i.e. concomitant disease or malnutrition) and/or overall vulnerability (i.e. lack of adequate care seeking and/or access to quality health care) or modify the ultimate effect (ex. quality of parenting on neurotoxicants). This is particularly important because it introduces further factors of variability with respect to socio-economic and cultural factors. Further uncertainty may result from the possibly multiplicative effect of all the above uncertainties.

As we can see from the many examples provided in the previous sections and from the above summary table, uncertainties about susceptibility and exposure as well as about the magnitude of the effects may be, and often are, greater for children than for adults and therefore we could state that a further aspect which makes children differ from adults with respect to environmental health is the amount of uncertainty, which is greater for children. This has some obvious policy implications.

Implications for the risk assessment process

What we have been briefly summarizing carries some profound conceptual and practical implications for the RA process. Some of these implications have already prompted various suggestions for improving the current toxicological risk assessment approaches, as well as discussions on the approaches and practices that will ensure safety or at least minimize risk.

We will briefly review these implications starting from the most familiar approach to toxicological risk assessment, which has been primarily applied to chemicals. We will then attempt to take a broader view to address the issues of complexity, i.e. uncertainty, which characterize this field.

Adaptation of the toxicological risk assessment to better cover the specific needs of developing organisms

The standard four-step risk assessment paradigm – hazard identification, dose-response assessment, exposure assessment and risk characterization – is shown in Box 1.1. Under this paradigm, the evaluation of information on the hazardous properties of environmental agents and on the extent of human exposure to them results in a quantitative or qualitative statement about the probability and degree of harm to the exposed population(s). Policy judgments on the choice of scientific approach are made in each of the four steps. For example, the choice of one dose-response model over another is a "science-policy" choice (Bernard and Ebi, 2001).

Box 1.1. The toxicological risk assessment process

Step 1. Hazard identification

Determine whether exposure to an agent has the potential to cause adverse health effects.

Step 2. Dose-response assessment

Determine the possible severity of the adverse effects at different levels of exposure to the agent.

Step 3. Exposure assessment

Estimate the exposure of individuals, including potentially sensitive groups such as children, to the agent.

Step 4. Risk characterisation

Combine the information from the previous steps to determine the level of potential risk to humans and the environment.

The first implication is that toxicological risk assessments must incorporate explicit assumptions about children's susceptibility and exposure, which, as we have seen, differ in many cases from those of adults.

Steps 1 to 4 of the risk assessment process should therefore be carefully reconsidered to include the following set of questions for substances dispersed in the environment (Tamburlini and Ebi, 2002).

For steps 1 and 2:

- Did the toxicity assessment include the reproductive and early developmental stages or did it extrapolate from data on adults?

- Did laboratory tests and epidemiological studies consider adequately sensitive end-points (e.g. the impact on learning capabilities when assessing potential neurotoxicants)?

- Have the long-term effects (e.g. cancer or cardiovascular disease or chronic lung disease) of exposure very early in life been evaluated?

Box 1.2. Adequacy of the toxicological tests for risk assessment of pesticide toxicity in children (modified from Tirado, 2002)

In many countries the introduction of pesticides in the market requires the submission of toxicological data to derive the acceptable daily intakes (ADIs) and most recently the acute reference doses (ArfDs) where appropriate. For example, the toxicological tests relevant to risk assessment in infants and young children are included in the core toxicological dossiers required for new applications for EU authorizations for pesticides under the Council Directive 91/414/EEC. However, the EU SCF in 1998 stated that it is not in a position to know whether all the core tests relevant to risk assessment in infants and young children have been conducted for every pesticide currently in use in the EU or in countries outside the EU.

The EU SCF considers that there are relatively new areas of pesticide toxicity that deserve special attention in relation to infants and young children such as developmental neurotoxicity, immunotoxicty and endocrine and reproductive toxicity. The core toxicological tests might indicate potential impacts on the developing nervous, immune, reproductive or endocrine systems and suggest further studies which may need to be undertaken in order to establish an appropriate ADI. However, some pesticides could affect these systems in the absence of any sign from the results of existing core studies (EU SCF, 1998). Thus, even if core studies are routinely done, they do not fully ensure pesticide safety for infants and children.

Currently, developmental neurotoxicity tests are rarely conducted on chemicals in general, including pesticides. For example, behavioural, memory and learning deficits are rarely examined in conventional studies, and delayed toxicity resulting from exposure to low levels of a toxicant during a particularly sensitive developmental period may not always be addressed by current testing procedures (EU SFC, 1997)

In the US the developmental neurotoxicity test has been proposed as part of the core toxicology database and the Environmental Protection Agency (EPA) is now requiring registrants to conduct developmental neurotoxicity studies for a number of neurotoxic pesticides. In the EU the SCF recommended that this issue be addressed by appropriate experts with a view to setting criteria which can be applied in the future to decide when developmental neurotoxicity studies are necessary (EU SCF, 1998). Most data packages for pesticides include a multigenerational study in one species and developmental toxicity (teratology) studies in two species. These are adequate to identify substances acting as reproductive toxicants in adults and substances causing malformations or affecting growth, postnatal survival and reproductive capacity in offspring, but they are not adequate to detect all endocrine-disrupting effects (EU SFC, 1998). The OECD test guidelines for both the two-generation reproductive study and for the teratogenicity study (with a new title "Prenatal developmental toxicity") are in the process of being updated to cover these issues.

It has been recommended that, in the context of risk assessment for infants and young children, immunotoxicity to infants and children is addressed since some chemicals may interfere with the developing immune system and give rise to persistent adverse effects, such as reduced ability to respond to immune challenge (EU SCF, 1998; US NRC, 1993).

To provide adequate answers to these questions, the scope of animal assays should be expanded to incorporate perinatal exposure and early developmental stages (Box 1.2). Epidemiological studies on *in utero*, perinatal and childhood exposure are also needed. Data on whether children are more vulnerable to the adverse effects of a particular agent, including whether the target organ in children is more vulnerable, should be collected and incorporated into risk assessments.

For steps 3 and 4:

- Were exposure patterns at different stages of development, from conception to adolescence, included in the exposure assessments?

- Did exposure assessment models and estimates specifically consider children's unique modes of exposure, such as children's hands-to-mouth behaviour and the additional time children spend on floors and on the ground?

- Were all sources of exposure, such as diet, water, home, day care and school, neighbourhood and working places (for parents) taken into consideration?

- Did the exposure assessments reflect 'real world' experiences, including factors such as multiple sources of exposure (aggregate exposure), simultaneous exposure to several compounds with similar modes of action (cumulative exposure) and additive, or multiplicative toxic effects ?

- Did the exposure assessment consider different exposure scenarios, in order to take into account geographical and socioeconomic factors that may influence exposure?

- Did risk characterisation consider biological, psychosocial and social effect modifiers, such as level of cognitive stimulation for neurotoxicants or quality of health care for morbidity and mortality for common childhood diseases?

Risk assessments for agents to which children are exposed must be based on children's exposure patterns. Child inhalation rates and food and water consumption rates must be used. Food consumption surveys should include adequate sample sizes of ages with specific consumption patterns, such as less than 12 months, from 1–3 years, 4–10 years and 11–18 years.

The 1997 Geneva Joint FAO/WHO Consultation on Food Consumption and Exposure Assessment of Chemicals recognized the importance of issues such as aggregated exposure (i.e. multiple routes of exposure and multiple residues) and additive effects of pesticides with common toxicity (i.e. cholinesterase inhibitors such as carbamates and organophosphates), and recommended that these should be considered by both risk assessors and risk managers (WHO, 1997). In addition to estimating dietary intake, other possible sources of exposure such as drinking water, occupational, environmental exposure should also be considered. The report recognized the greater exposure of children to pesticides and recommended that dietary exposure assessments should be based on the best use of available data, and where appropriate, risk assessors and risk managers should consider the differences in food consumption patterns and in vulnerability to toxicants across and within populations, and the potential human health consequences resulting from exposures to chemicals in foods.

Adapted exposure measurement and especially biomonitoring are of particular relevance for children (Box 1.3.).

Current perspectives include the establishment of large prospective cohorts to be followed over time.

Box 1.3. Exposure assessment techniques in children

Exposure assessment in children is necessary because of the many differences between children and adults, which make extrapolation from adult data potentially flawed. Several tools can be utilized for exposure assessment.

Traditionally, exposure assessment relied on external or ambient exposure monitoring of airborne toxicants. This involves measuring a chemical in the air either by area sampling with the monitor in a fixed location, or by personal monitoring in which small pumps are worn by the monitored participants. There are a number of advantages to airborne exposure assessment. Standard assay methods with reference levels, both in the workplace and, in some cases, environmentally, are available for many different chemicals. In addition this kind of monitoring allows todetermine the effectiveness of any exposure controls in use. Airborne exposure assessment has limitations. Monitoring may not be representative when a wide variation in exposure occurs. Airborne exposure assessment measures only one route of exposure, so exposure from chemicals that can be absorbed through the skin or ingested can not be excluded. Another important limitation is that exposure indicates only the current level of chemical present in the environment. Finally, there remains a significant variation in the severity of outcomes among individuals exposed at the same level.

Biologic monitoring has some advantages that are unique in the case of children. It can be divided into two types: internal dose, which is measurement of a chemical or its metabolites in biologic specimens such as breath, blood, or urine; and biologically effective dose, which is the amount of chemical or its metabolites that has interacted with critical cellular macromolecules of the target or surrogate tissue. Biologic monitoring is best used in conjunction with a questionnaire or with air monitoring to identify a population with a wide enough exposure range to allow meaningful interpretation of biomarker results. Because all exposures potentially contributing to body burden, and thus to adverse health effects, are of interest regardless of exposure source or route, an integrated exposure assessment approach is the ultimate goal (Lioy, 1990). More recent studies are beginning to consider cumulative exposures across both multiple media and pollutants (Weaver et al., 1998).

Biomarkers integrate exposure from all routes and sources. This is especially valuable for chemicals with two or more substantial routes of exposure from multiple media such as air, food, and water. Their measurement assesses the amount of a chemical that is ultimately absorbed into the body taking into account also exposure factors such as behaviour, contact rates, protective measures, and differences in respiratory rate. An example of a successful internal dose biomarker is blood lead, which has had an enormous impact on the prevention and treatment of lead exposure in children (US EPA, 2002).

Expanding the scope of risk assessment

The limitations of risk assessment, as currently practiced, should be recognized and understood. The assumptions underlying traditional risk assessment limit its applicability to complex environmental problems (Bernard and Ebi, 2001). One of these assumptions is that a defined exposure to a specific agent (generally, xenobiotic) causes a specific adverse health outcome to identifiable exposed populations, including specific people at particular risk. In general, the health outcome is distinctive and the

association between immediate cause (e.g. exposure to asbestos) and health impact (e.g. mesothelioma) can be fairly clearly determined. Even when the health outcomes are less specific than in the asbestos example, there may be data from animal or human studies demonstrating an increased risk associated with a well-defined exposure. However, most diseases associated with environmental exposures have many causal factors, which may be interrelated. We have seen for example that lead poisoning can be one of the many factors which contribute to determine a cognitive impairment in young children. These multiple, interrelated causal factors need to be addressed in investigating complex disease/exposure associations, because they may limit the predictability of the health outcome and even the ability to estimate the degree of uncertainty in any risk estimate (Bernard and Ebi, 2001).

Early risk assessments approaches narrowly focused on determining the probability of harm resulting from exposure to single agents, which were mainly derived from animal models in the laboratory. The general approach and philosophy have evolved and become more concerned with complex environmental problems and consider social, economic and political factors in describing risk**.** If risks are to be assessed in the real world and not in a laboratory it is necessary to take into account all the factors that contribute to modify the risk or the ultimate health effect. This issue is not confined to children, but since children bear a greater proportion of the consequences of environmental degradation and since the number and influence of modifying factors may be greater, the issue is of particular relevance for them.

The extent to which socioeconomic and geographical factors influence the relative importance of each specific risk factor as well as the ultimate health effect, the different perception of risk across population groups and cultures, the different contexts in terms of exposure and vulnerabilities as well as opportunities for intervention, make it necessary to develop models for risk characterisation (as well as for cost benefit analysis of policy options) that take into account the socioeconomic and geographic variables.

Therefore, the risk assessment process must not only take into account the issue of combined exposures and the possible synergic effects of various contaminants, but must include every other factor that may influence the way that any specific environmental exposure produces or contributes to produce a specific health effect. Stakeholders including communities, parents and the youth are expected to be involved throughout the risk assessment process to ensure that the risk characterization addresses a broad range of concerns and that the context in which the assessment will be used is taken into account (Tamburlini and Ebi, 2002).

Dealing with uncertainties

As we have seen, there are several uncertainties both regarding the probability of an adverse effect occurring and the scale and nature of its consequences; these uncertainties may be greater in children due both to limitations in our knowledge and to the intrinsic greater difficulty to assess sensitivity and exposure.

Dealing with the considerable amount of uncertainty which characterizes the field implies three different, but complementary, approaches:

- Risk assessment and testing protocols for existing and new chemicals which focus on the unique factors exhibited by infants and children and particularly on the qualitative differences due to susceptibility windows during the embryonic and fetal development, and on exposure assessment through biomonitoring.

- Epidemiological research to examine and better quantify the association between environmental factors and health effects, in different exposure scenarios, (Landrigan, 1998) and to assess the efficacy of single-factor and possibly multifactor interventions (Ezzati, 2003) including long-term effects.

- Risk regulation approaches, which include the adoption of extra safety factors[6], the precautionary principle and other precautionary approaches (EEA, 2001; Tamburlini and Ebi, 2002).

- Preventive policies aimed at decreasing the emissions of and/or reducing the exposure to potentially toxic compounds. These policies cannot be effective without a wide collaboration of all stakeholders including the legislator, communities, and the industry (Carlson and Tamburlini , 2002)

The discussion of these approaches goes beyond the scope of this paper, which will have reached an ambitious result if it achieves to at least contribute to make these needs clearer and more widely recognized. Criticism towards an exaggerated concern about children's special vulnerability has been recently expressed on the basis that children are *not necessarily* and *not always* more vulnerable. While we agree with this statement, we must also remember that children *are* more vulnerable to a variety of known toxic agents, and that they may be also particularly or even uniquely vulnerable to any of the thousands of chemicals that are released into the environment without adequate testing. This is even more likely if periconceptional, prenatal and immediately postnatal periods are considered and if long term effects are taken into account.

We know that, on the basis of existing data and quite conservative estimates, today's children bear a greater proportion of environment related BoD than adults. Underestimating the environment related burden of disease for today's and tomorrow's children, as well as for future adults, is at odds with the knowledge, although imperfect and incomplete, that we have gathered so far.

Summary points

Conclusions can be summarized in the following points:

- Although our understanding of the mechanisms funderlying differences between developing organisms and adults has greatly improved, current knowledge in many cases is not yet sufficient for a precise quantification of risk differences with respect to specific contaminants.

- What we know about children's vulnerability to environmental toxicants is sufficient to state that, from both a biological and a psychosocial point of view, "children" do not constitute an homogeneous population group. Differences between young infants and older children, both in sensitivity and exposure can be even greater than differences between "children" as a whole and adults. Thus, all attempts to compare adults with children as a whole are intrinsically flawed.

- Despite these limitations, some generic features that make developing organisms differ from adults in their susceptibility and exposure to xenobiotics can be identified. They are the following :

- the younger and more immature the subject, the greater the difference in overall vulnerability, and the greater the uncertainty about the nature and amount of the health effects. This is also due to the fact that many potential toxicants have not been adequately tested (i.e. with sensitive endpoints and adequate assessment of potential long-term effects) for toxicity during early developmental stages.

- the most important differences are qualitative and arise from the existence of windows of susceptibility during the early development of the nervous, respiratory, immune, endocrine and reproductive systems. Exposure to toxicants during these critical periods produces biological effects, many of which do not have counterparts in adult life. As a consequence, for many health outcomes, and particularly for those regarding the prenatal and perinatal period, it is particularly difficult or simply impossible to evaluate risk differences with respect to adults.

- as a result of the immaturity of the metabolism, but also of different absorption distribution and excretion, the susceptibility of infants especially up to 6 – 12 months of age may be increased but in some instances also may also be decreased. The net effect of differences in physiology on ultimate toxicity is difficult to predict and has to be assessed on a compound by compound basis and taking into account the different developmental stages.

- from the limited amount of data which is available regarding pesticides, lead, ETS, PM10 and UV, age-dependent differences in sensitivity may be as large as 1 order of magnitude and, for many chemicals, up to two or three fold. In most cases infants and children are more sensitive but there are also classes of chemicals towards which the sensitivity of children is lower. Differences are compound specific and are greater in infants and young children.

- the differences in exposure may reach 1 order of magnitude and more, particularly for food contaminants and air pollutants, due to the peculiar behaviours and exposure patterns of children, to their greater intake of air, fluids and food, and to the likelihood of combined exposures.

- overall, children bear a greater proportion of the environment related burden than adults, but there are enormous geographical differences, with a much greater proportion of the environment related burden of disease borne by children in developing countries.

- Social factors, as determinants of exposure and as health effect modifiers, are of particular relevance for children due to their increased vulnerability, which in many instances enhances the ultimate health effect of environmental exposure, and to the particularly strong influence of the psychosocial environment. Geographical factors may play a role at least as important as age dependent factors in influencing exposure and in contributing to the ultimate health effects.

- The qualitative, developmental stage dependent nature of the differences in susceptibility, the variability in sensitivity and particularly in exposure during infancy and childhood, the multifactorial nature of many health effects, the lack of adequate and comprehensive testing of many chemicals, all contribute to a considerable amount of uncertainty about the existence, likelihood and magnitude of

the health effects of environmental contaminants in developing organisms. Uncertainties must be dealt with by adopting distinct but complementary approaches including child focused toxicological testing, epidemiological and policy research, precautionary approaches and preventive policies.

Notes

[1] Istituto per l'Infanzia IRCCS Burlo Garofolo, Trieste, Italy.

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[3] For extensive reviews on this subject, refer to Environmental Health Perspectives (vol. 103, 1995), to Bruckner (1999) and to Scheuplein (2002).

[4] For a more complete review, see Tirado (2002).

[5] For a definition of environment in a health context we refer here to the rather broad definition adopted by Smith (Smith et al., 1999) which includes most man dependent factors such as injuries and malnutrition; a stricter definition including only chemical and physical agents has been adopted, for example, by Landrigan (Landrigan et al., 2002)

[6] For a thorough discussion on the concepts and science basis of safety (uncertainty factors), see Dourson et al. (2002): the review concludes that "a high percentage of the population, including children over 6 months of age, is protected by using a 10-fold uncertainty factor for human variability. The same may not be true for children younger than 6 months of age in the absence of adequate or systemic toxicity testing."

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Chapter 2

Valuation Differences between Adults and Children

by
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Adults and children constitute two different and heterogeneous populations. Therefore large disparities in the estimates of health benefits for children and for adults can be expected. This chapter proposes an overview of the potential sources of differences between adults and children in terms of valuation. Four sources of valuation differences are more specifically examined: differences in terms of age, in terms of risk preferences, in terms of context of valuation and in terms of perspective. A review of the literature helps understand the importance of these valuation differences between adults and children and how they can affect benefit estimates expressed in terms of willingness-to-pay.

Although several valuation techniques can be used to estimate the health benefits from a risk reduction (stated-preferences and revealed-preferences techniques, cost-of-illness method and non-monetary approaches), they are often based on considerations which are methodologically problematic for children. The chapter also describes the main conceptual and methodological issues that may be associated with the valuation of children's health.

Introduction: Why should we pay attention to children?

Recent epidemiological studies have increased public awareness of the harmful effects of pollution on human health, on wildlife and flora. In order to evaluate the relative social and economic importance of these effects, and thus the benefits associated with their reduction, various methodologies have been applied[3]. The results of studies undertaken using such methodologies - and most particularly cost-benefit analyses - have brought more clearly into focus the social importance of these adverse health impacts.

Consequently, international and national organisations of several countries have shown growing interest in children's health, and particularly the effects of the environment on the health of children and adolescents. This is an area which has received relatively little attention from health services researchers, environmental policymakers, as well as health and environmental economists. This shortcoming has been recognised, and interest and support for research on the links between the environment degradation/pollution and children's health is increasing.

Some children's environmental health problems may be more inherently of concern in developing countries, while other issues are a problem both in developed and developing countries. Some of the most important environment-related impacts on children's health that are widely recognised as being of significance, and whose link with environment has been proven relatively unambiguously include:

- Respiratory infections: the World Health Organisation (WHO) Task Force for the Protection of Children's Environmental Health reports that respiratory infections account for 20% of mortality in children under the age of five. Respiratory infections are linked to a number of indoor and outdoor environmental exposures, such as home cook stoves in developing countries, second-hand smoke and outdoor mobile and stationary sources in all countries.

- Asthma: in the United States nearly 1 in 13 school-age children (4.8 million) has asthma, and the rate is increasing more rapidly in school-age children than in any other group. Other OECD Member countries are reporting similar asthma epidemics. Asthma attacks are caused by different kinds of triggers, including some environmental pollutants, strongly generated by air pollution related to road-traffic. Asthma is the leading cause of U.S. school absenteeism, and is responsible for one-third of all paediatric emergency visits.

- Lead and other neuro-toxicants: they are major health hazards for children. Removal of lead from gasoline resulted in a dramatic drop in the number of lead poisoned children in many countries. However, other sources of exposure can also be significant – such as lead paint in older homes, and lead pipes in potable water delivery services.

- Water-related diseases: according to the WHO, water-related disease kills approximately 2 million children under five years of age annually, and most of these deaths are related to unsafe drinking water and lack of sanitation and hygiene. While less important than in developing countries, water-related health impacts in OECD countries remain significant.

Further work in valuing children's environmental health risks is thus important. While it is relatively "easy" to obtain estimates of the benefits induced by a reduced health risk for an adult, obtaining estimates for the impacts on children's health are more problematic. Indeed, very few economic studies have considered the valuation of children's health. The scarcity of empirical studies specific to children can be explained mainly by conceptual and practical problems.

Reliable estimates of impacts of environmental conditions are required in order to help policymakers to examine the economic efficiency and effectiveness of policies aimed at reducing children's health impacts. Child health measures can be used for three purposes:

- Measuring the effectiveness of environmental policy and social programmes;
- Prioritising environmental policies and target groups; and,
- Setting optimal targets to improve environmental policy design.

Findings from studies undertaken have highlighted the link between environment and children's health. Part of the reason for the importance of environmental impacts on children's health is related to differences in terms of risk, which can be separated into exposure differences and dose-response differences (EPA, 2002).

Exposure differences can be explained by the kind of activity: adults and children do not have the same daily activities and, in many ways, this may result in greater levels of risk and a relatively greater exposure for children. For instance, children spend a greater proportion of their time outdoors, closer to the ground or floor, often playing in dust and dirt. They often put objects and hands in their mouth. Given their lack of full understanding of the risks around them, all of these actions expose children to high levels of risk more often than adults. Moreover, metabolic activity is higher for children than for adults, which implies higher daily requirements for food, water, and oxygen per unit of body weight for children than for adults. Children can thus experience a larger effective dose than adults.

Conversely, children are less exposed to high level of substances that cause observable harmful effects than adults. Therefore some exposure scenarios or conditions that apply to one of the two groups (children or adults) might not apply to the other one. In many respects, children's exposure to environmental risk is expected to be different from that of adults'.

Dose-response differences between adults and children can be explained in terms of outcome (qualitative difference) and in terms of severity (quantitative difference). Children's bodies are still developing and can respond differently than adults to the same apparent levels of exposure; they are less able to metabolise, detoxify or remove pollutants. Therefore, exposure to toxic substances may lead to totally different health outcomes, depending upon whether it concerns a child or an adult, the age of the subject etc. (Wilson et al., 1991).

Risk differences can affect risk perception and may lead to biased estimates if they are not taken into account correctly in the evaluation task. In addition to the differences in risk between children and adults, there may be good reasons to believe that there is greater inherent uncertainty in risk for children. For instance, while the general scientific understanding of the risks associated with exposure to pollutants is subject to a great deal of uncertainty, this may be particularly important when considering

children's health. Uncertainty in general may be a greater problem for children. Knowing those uncertainties is important on the one hand because they have impacts on the significance and the validity of the values, and on the other hand, because they represent an important element in the decision-making process[4].

The applicability of the underlying assumptions of the methodologies used must be borne in mind when seeking to value the health impacts for children. While several valuation techniques can be used to estimate the health benefits from a risk reduction, these are often based on economic considerations (i.e. stated preferences, revealed preferences) which are methodologically problematic for children. Children are not subject to a budget constraint and they do not usually make trade-offs between health and money (or are not aware of making such trade-offs). Therefore, changes in the conception of traditional economic valuation methodologies have to be made before being applied to the valuation of children's health. As such, it is not clear which is the best valuation methodology to adopt in this particular context.

Therefore, further research is needed to define and assess the relative merits of different approaches for the valuation of children's health environmental risk, and to help policymakers identify health and safety risks that largely affect vulnerable groups, and more particularly children, in order to implement public environmental health policies.

The remainder of this report is organised as follows. The first section considers the potential valuation differences that can be expected between adults' and children's health benefits. Then, the methodologies most commonly used to value the environmental health risks to children will be presented, with a special emphasis on the conceptual and/or methodological issues implied by this particular context of valuation. The third section will propose a review of the literature on children's health highlighting the potential valuation differences between adults and children[5]. A discussion will conclude the paper.

Sources of differences in valuation

Adults and children constitute two largely different and heterogeneous populations. Therefore we could expect large disparities in the estimates of health benefits for children and for adults.

These differences in terms of values – or valuation differences – could at least be distinguished into four main categories:

- Difference in age
- Difference in risk preferences
- Different context of valuation
- Different perspective

These potential sources of disparity between adults' and children's health valuation need to be more thoroughly examined.

Difference in age

The obvious difference between adults and children is related to the difference of age. The literature that explicitly controls for the effects of age on the value of health benefits is mostly based on the valuation of reduction fatal injuries/risks and lead to the estimation of the value of a statistical life (VSL). The valuation of own health risk reduction is almost always founded on adult population and the specific context of children has never been addressed so far. However, the results from those studies show that WTP increases with age until age 40 or 45 and then decreases with age (Jones-Lee, 1998; Rowe et al., 1995; Chanel et al., 2004). The relationship between the WTP for a reduction of the mortality risk and age is often represented as an inverted U-shape curve[6] such as in the following figure:

Figure 2.1: The relationship between age and the WTP for a reduction in mortality risk[7]

There is empirical evidence that age matters for adults: young adults do not have the same WTP values to reduce fatal risks than middle-aged or older adults. Therefore, we could in general reasonably expect that age would matter more greatly for children related to adults.

Only a few studies have tried to base the VSL for a child on that for an adult. As policymakers require values to assess the efficiency of existing environment/health policies and given the lack of children-specific data and information, an alternative consists in transferring and adjusting VSL for adults to children. The problem with this practice is that there is no striking empirical evidence on which model is the most appropriate.

A common intuition leads economists to think that VSL for children would be larger than VSL for adults. Blomquist (2003) proposes a meta-analysis of empirical studies founded on averting behaviour models that estimate the VSL for different populations[8]. He comes to the conclusion that the VSL for children is at least not less than VSL for adults. Further research would be necessary to better understand how the VSL differs with the characteristics of individuals.

Another related uncertainty that affects children's health valuation is related to the expected life span. Children have a greater number of expected life years remaining

than adults. Thus, when a child is affected or dies, the number of lost years will be larger than when an adult dies, all else being equal. However, because we have yet no idea about what the medical advances would be, there is a great deal of uncertainty about precisely how many additional years would be lost. For this simple reason, the value of a child's life is much more uncertain than that of an adult's life. And this could partially explain why we may expect a larger VSL for children than that for adults.

There may be important factors that could have significant effects on the values between adults and children health benefits, such as risk preferences and the valuation context, that need to be taken into account for during this extrapolation of values: differences in risk preferences, differences in the context of valuation and differences in perspective.

Difference in risk preferences

Society's preferences toward children are well known. Society is indeed more risk averse to risks experienced by children than to those experienced by adults. Good examples are provided by the different laws and regulations aimed at protecting children's health more particularly. In some countries, the manufacture, exchange, import and export of toys or childcare products for infants made with soft plastics have been suspended, given the high risk of ingestion by infants. In many countries, and particularly in Europe, the use of safety car seats for children under the age of 3 is obligatory. A detailed action plan will be presented in the next few months by the European Commission, aimed at reducing health risks related to environmental pollution for children, especially vulnerable to environmental harms. Finally, the effects of lead on health are now well known, for children and not just for adults: in some countries, leaded petrol is banned; measures have been taken to apply standards to the level of lead content in paint, resulting in stricter standards to nursery and primary schools, and to child-minding places where children could be more exposed to lead.

Some empirical studies have also shown that people believe that, *ceteris paribus*, a programme that protects young people is better than one that protects old people, because it delivers greater benefits related to the difference in time/age existing between these two populations (larger benefits for young adults given their larger expected lifespan). Examples include Lewis and Charny (1989) who found that people prefer saving the life of a 35-year-old than the life of a 60-year-old. Cropper et al. (1994) estimate the trade-off between saving lives at different ages. They find that saving one 30-year-old is judged equivalent to saving eleven 60-year-olds. This could mean that people place more interest on saving young persons. Johannesson and Johansson (1997) asked a sample of individuals about their choice between saving their lives now and in the future. Their results are comparable to those of Cropper et al. (1994): saving five 50-year-olds or 34 70-year-olds is judged equivalent to saving one 30-year-old. Another comparable result between the two studies is that the age of the respondent has no effect on his choice, which means that both young and old adults give priority in saving the life of the youngest.

At the individual level, parents are also known to be more risk averse when the health of a child is affected by a given (environmental) risk. This can be explained in two ways. On the one hand, risk preferences may affect values parents place in their child's safety. The results from Liu et al. (2000) suggest that parents are likely to be more risk-averse when the reduction of minor health risk concerns their own children[9].

Parents are indeed more willing to pay to reduce children's health risk than to reduce their own health risk. The results from Blomquist et al. (1996) also suggest that there may be differences in valuation depending upon who is making choices regarding risk avoidance activities, meaning that individuals feel more concerned when a child is at risk, and even more when this is about his/her own child. On the other hand, risk perceptions can determine risk-reducing behaviour and imply higher WTP to protect children's health than to protect adults' (parents') health. A good example is when parents perceive their children as being exposed to a higher risk. If the parents think their children are at high risk, they are more likely to adopt behaviours aimed at reducing those risks to their children (Van der Pligt, 1998). Therefore, their WTP to reduce health risks experienced by their children will be greater than their WTP to reduce similar risks to their own health.

Involuntariness of risk is also an important issue that may largely affect valuation of children's health. Researches in psychology and economics have shown that individuals generally prefer voluntary risks to involuntary ones and that the degree of risk voluntariness could have impacts on the WTP (Fischhoff et al., 1978; Slovic, 1987). In the context of valuation of children's health, this can have a greater impact on the estimates obtained because children are not aware of all the risks surrounding them, around them. This is explained by the fact that all risks to children are involuntary since risk exposure decisions are made for them by their parents. Therefore, parental WTP to protect their children's health may be largely affected by the degree of voluntariness of risks faced by the children.

Uncertainty associated with the risk itself may also have impacts on the estimates of WTP values. Individuals prefer risks that are certain to those that are less certain (Viscusi et al., 1991). Given that little is known about responses of children to exposures to some pollutants, it is reasonable to expect that children's risk assessment is much more uncertain than that of an adult. When parents have to make trade-offs between money and health risks, they would prefer to reduce the more uncertain risk. Therefore, the uncertainty surrounding the perception/measurement of the risk faced by the children may have substantial impacts on the value attributed to the reduction of the risk expressed by the individuals.

Different context of valuation

When valuing children's health, it is generally the parents who are asked to reveal the value they place on a reduction of a given environmental risks to their children's health. Therefore, someone is asked to evaluate the health benefits of a risk reduction for another population, not for themselves. The context is therefore very different from the classic valuation of adults' health where the respondent is asked to estimate a reduction in his/her own health risks. While empirical studies suggest that parents are the best placed to estimate the value of a risk reduction on their children's health (see for example Viscusi et al., 1987), this adds another source of disparity between adults' and children's valuation of health: parents are not asked to value their own health but the health of other members of the household. This may largely affect the estimates. Several factors appearing to be of relative importance are examined in what follows.

Potential importance of household structure and composition

Some important factors related to the household, such as divorce, presence or absence of the father, biological or step-mother, age structure, can have an effect on the

value individuals place on the reduction of an environmental risk for their children's health.

The role of the family composition and structure is rather significant and can greatly affect the WTP for reducing environmental health risks to children. For example, Dickie and Ulery (2001) show the importance of family composition on the WTP: single parents are willing to pay more than married parents for a reduction in acute illnesses for a child. Their results also suggest the importance of household characteristics on the WTP. Curtis et al. (2001) also find that the lone-mother status is negatively associated with children's outcomes measures, with the exception of cognitive problems.

A recent survey on children's deaths in India (Hughes and Dunleavy, 2003) pays attention to the role of household environment on the valuation of children's health. The quality of the household environment, especially in developing countries, can have a substantial impact on the health of infants and young children. Changes in defensive behaviour by households in response to a better household environment are important, but they are outweighed by the direct benefits of a lower exposure to disease associated with improvements in the household environment.

Differences within the household

Differences in parents' preferences relative to their children may be associated with age, gender, or health status of the child (Pitt and Rosenzweig, 1990). Some empirical studies have shown that the premium for children declines with age (Pitt and Rosenzweig, 1990; Dickie and Ulery, 2001), which means that parents are willing to pay more for younger children in the household than for the older ones. This issue is often referred to as a "quantity/quality" trade-off: the WTP declines with the number of children in the household. When the number of children in a household is large, the youngest are more often "preferred" by the parents to the oldest (Hanushek, 1992; Dickie and Ulery, 2001).

Differences between households

Some empirical studies have also shown that the WTP to avoid acute illnesses is greater for parents whose children suffer from asthma than for parents whose children do not suffer from asthma, meaning that the health status of the child could affect the WTP revealed by the parent (Dickie and Ulery, 2001).

Cultural differences may play an important role in the valuation of health benefits for children. In some countries, cultural and historic customs involve gender preferences. For example, in Taiwan, mothers are willing to allocate more resources to the health of their sons than to that of their daughters (Liu et al., 2000). Some empirical studies have shown differences in terms of valuation between different ethnicities. In Joyce et al. (1989) and also in Dickie and Ulery (2001) for example, black parents are willing to pay more than white parents, even though the average income is greater in white households than in black ones.

Differences in terms of socio-economic status can also affect the valuation of children's health. Low socio-economic status families less actively undertake actions or reveal avoidance behaviour to reduce the effect of air pollution on childhood asthma (Neidell, 2001). Income and cultural effects, and more particularly permanent income, may impact the determination of children's health (Curtis et al., 2001). Consequences for children are much more strongly related to low-average income than to low-current

income. Money income may therefore constitute an important influence on child health and development.

Altruism

As noted above, most of the economic studies that have estimated the WTP for a reduction of environmental health risks for children are based on the parental WTP. The problem is that this WTP may be greatly affected by altruism for own children as well as for other children or children in general.

A traditional distinction is made between "pure" altruism (parents take account for the utility of their children in their own utility function) and "impure" altruism (related to the donation act – also referred to as "warm glow effect" as proposed by Kahneman and Knetsch, 1992). The parents' WTP should only be included in the valuation of children's health benefits in case of pure altruism because that's the only case where parents' preferences matter for determining the level of society's resources that should be devoted to children's health and safety. The problem associated with warm glow is that we have no idea about the motivations that lie behind the act of donating. WTP values expressed by these individuals do not depend on what is being valued and very similar values could be obtained, irrespective of the precise nature of the impact. As Kahneman and Knetsch (1992) explain, if warm glow motives values of WTP to reduce risks to children, these responses do not represent a measure of WTP in its usual definition and are therefore not valid to be used in a cost-benefit analysis.

One way to measure the degree of parents' altruism or selfishness toward their children is to estimate the marginal rate of substitution (MRS) between child and parent health, as proposed for example in Dickie and Ulery (2001). Parental preferences are hypothesised to be neutral, which corresponds to the case where this MRS equals to 1. When the MRS is greater than 1, this means that this is a situation of greater degree of parental altruism toward the children. Dickie and Ulery (2001) estimate the MRS between child and parent health and lead to the rejection of neutral parental preferences, meaning that there is parental altruism toward children. Parents are willing to pay significantly more to avoid illness episodes affecting their children. Liu et al. (2000) show Taiwanese mothers are willing to pay more for their child's health than for their own health. These results support the idea that parents are more willing to pay to reduce health risks that concern their child rather than their own health. In other words, parents assign a higher value to their child's health than to their own, which is one reason why we can reasonably expect greater VSLs for children than for adults.

Decisions within a family

The prevailing model used in family economics to analyse the resource allocation within a family, based on Becker (1991), assumes parental consensus (i.e. common preferences), with active parents and passive children, which means that the parents perceive environmental health risks to their children and take decisions related to these risks on behalf of their children according to those perceptions. The utility function of the household is assumed to be unitary, which means that the family maximises a single utility function for the whole family. This approach has been often adopted in economic studies dealing with the valuation of children's health because it's a straightforward way to obtain the parent WTP for reducing health risks to children. However, as mentioned above, some issues may undermine the use of this model. Examples of issues could include: the inexistence of common preferences between the

parents (i.e. parents do not have the same preferences for their children); the contribution of this approach when the child in the household is adolescent and become able to make and take decisions on his/her own that can affect the entire household. All these concerns have stimulated interest in pluralistic models of household preferences. Those models treat household decisions as individuals making collective decisions. Two models in this category have been used in non-market valuation: the Nash cooperative bargaining model (Manser and Brown, 1980) and the collective approach (Chiappori, 1988)[10]. Further work is needed in order to assess the validity of the use of such models in the context of valuation of children's health.

These results suggest that the context of valuation may largely affect the values individuals place on child's safety and this may imply large disparities between adults' and children's health benefits values. Various motivations may lie behind parents' decisions and influence the values parents place on a reduction of environmental health risk to their children. But this goes beyond the scope of this report and will constitute material for further research.

Different perspectives

While the relative value we are looking for is the measure of social welfare associated with a risk reduction, different perspectives[11] to obtain this value can be considered:

- Society's perspective;
- Children perspective; and,
- Parental perspective.

The applicability and reliability of each one will be examined and detailed below.

Society's perspective

From a public policy point of view, the most desirable measure of welfare is social welfare, i.e. a measure that represents the value individuals place on their own health and safety, as well as the value they place on reducing health and safety risks to other. The measure of social welfare to reduce environmental health risks to children can be obtained from a representative sample of the population, including parents and non-parents. This measure may then be more or less affected by altruism both from children's own parents but also from people in general. Empirical studies have shown that people always value the life of a child larger than the life of an adult, for the same apparent risk (see for example Moore and Viscusi, 1988). Then, when valuing health benefits for children, one could face a major issue: how to deal with altruism?[12] Models taking account of altruism exist but, as noted above, one should know the type of altruism that is considered, or at least make some assumptions about it.

However, in the case of children, altruism can take two forms: paternalistic and non-paternalistic. This makes the problem even more complex, because we still do not know exactly how to distinguish between these two types of altruism, how to consider the nature of altruism in the health and safety valuation context. Separating out altruistic preferences for other's health from individual preferences for own health is problematic. Given this complexity, benefits may potentially be subject to double-counting, which results in an over-estimation of the health benefits for children

associated with a risk reduction. Therefore, the society's perspective is rendered impractical to be applied to reveal children's preferences due to the difficulty in distinguishing between paternalistic and non-paternalistic altruism. In order to value children's health benefits, another perspective has to be taken.

An alternative is naturally proposed by economic theory: welfare changes are often measured by aggregating individual WTP for one's own health, and do not explicitly account for the altruistic component.

Children perspective

According to welfare economics, the best way to approximate the value individuals place on reducing risks is by using the value that affected people themselves place on these risks reductions. This comes from the principle of consumer sovereignty: as individuals are best placed to know how they allocate their own resources, the most reliable way to obtain estimates of values individuals place on risk reduction is to ask them directly for those values. In the specific context of valuing children's health benefits, applying this principle would imply that children are asked about the maximum monetary amount they would be willing to pay to avoid or reduce the environmental health risks they experience daily.

But this is neither appropriate nor applicable, for a large number of reasons. The main ones are related to the cognitive capacities of children. Children are not usually considered as "rational" decision makers as adults mainly because they do not have well-defined preferences over the choice set. Moreover they are not fully aware of the budget constraint to which they are subject and they do not have control of the financial resources required. This does not allow them to make trade-offs between health and money as they would be required to do. As a result, children have to rely on their parents (or their caregivers) to take and make all the important decisions, such as those related to schooling, health, safety, education, etc., on their behalf.

Therefore, adults would appear to be the most reliable persons from which values of risk reductions faced by children should be elicited. When this approach is related to parents and other primary caregivers, it is referred to as "parental perspective".

Parental perspective

The parental perspective seems to be the most appropriate manner to reveal children's preferences. This is the natural alternative to children's perspective for risk reduction valuation concerns. The few existing studies that have estimated a measure for a reduction in health risks to children have elicited parents' or caregivers' preferences.

The theoretical justification for the use of the perspective of the parent (or caregiver) is based on various theoretical economic models, suggesting that parents' choice are the appropriate proxy for children's preferences and constitute a reliable source of information (Viscusi et al., 1987). The most commonly considered theoretical models include utility maximisation models, household production models and intra-household allocation models.

- In utility maximisation models, the individual or parent's utility function depends on consumption, the health of the child and other goods and is subject to a budget constraint. These models allow for the estimation of individual/parental WTP to reduce health risks to children. Empirical examples include the studies implemented

by Viscusi, Magat and Hubert (1987), Carlin and Sandy (1991), Liu et al. (2000), and more implicitly in Jenkins, Owens and Wiggins (2001).

- In household production models, the household is the relevant unit. These models allow obtaining values the household places on risk reductions to their own children's health. They estimate a WTP decided by the household and subject to the household budget constraint. The children's health risks are specified in those models as outputs of the household production. Empirical applications include the studies implemented by Joyce, Grossman and Goldman (1989), and Agee and Crocker (1996).

- The intra-household allocation models examine the relationships within the household and seek to determine how this may affect the allocation of resources among the household members. As in the household production models, these models allow to estimate parents' WTP to reduce health risks to their own children. However, trade-offs made within the family associated with illness and injuries are taken implicitly into account. This approach appears as a complete and intuitive way to estimate children's health benefits related to risk reductions. An empirical example on the applicability of these models is proposed in Mount et al. (2001).

Intuitively, it is clear that health decisions, and more generally most important decisions concerning children, are made by their parents or their caregivers, and not by the children themselves. Empirical studies (see Viscusi et al., 1987) have shown that the household is the relevant decision-making unit regarding children's health. The advantage of the parental approach is that it relies on behaviour of persons that have more experience than children and that are likely to have the child's best interests at heart. However, the disadvantages are the introduction of a third party into the valuation exercise (parents or caregivers) and, the dependence upon the behaviour of people who are considering risk reduction for others. As mentioned previously, parents' value for reducing environmental health risks to their children may be potentially affected by altruism.

An alternative of the parental perspective has been proposed to value environmental health risks to children. It is referred to as the "adults-as-child perspective". Introduced by Tolley and Fabian (1999), it requires adults to place themselves in the position of children. They are then asked to reveal their preferences as they think back to their own childhood and the risks that they faced. The advantage of this approach is that it does not rely on values obtained from "non-rational" decision-makers (children), but on values reported by individuals considering themselves. However, this raises problems for the analyst in terms of the design of the questionnaire and for the respondent in terms of providing meaningful responses. A great deal is demanded of the respondent in terms of cognitive capacity and this might lead to biased estimates. Further research is required to determine the robustness of this approach.

Despite substantial concerns related to altruism, the parental perspective seems the most legitimate approach to be used to formulate and elicit children's preferences[13].

Discussion on the potential valuation differences

There is no consensus on how benefit values from risk reductions for children's health may differ from adults' values. There is empirical evidence that those values

may greatly differ but the results from empirical studies are not consistent (difference in magnitude or even in the sign). However, because of considerable heterogeneity between these two populations, large disparities between adults and children values may be expected.

The main results obtained from empirical studies highlight two issues of great importance: altruism and perspective. Altruism may largely affect WTP values for reducing health risks to children, especially when those measures are elicited from parents. Therefore, analysing parental altruism toward own children and children in a more general manner could contribute a lot. There is empirical evidence that altruism from parents toward their children is significant (Dickie and Ulery, 2001). This suggests that parents are more willing to pay to reduce health risks that concern their child rather than their own health, meaning that parents assign a higher value to their child's health than to their own. We can therefore reasonably expect differences between children's and adults' values.

The choice of the perspective – i.e. the persons asked to elicit children's preferences concerning environmental health risks – is another important aspect of the valuation of children's health and must not be neglected. The parental perspective is more theoretically founded than the society's or the children's perspective. Empirical studies estimating benefits of environmental risk reductions to children's health mostly derive the WTP from parents or caregivers. There is however no empirical evidence on the importance of the choice between the parental and the adult-as-child perspectives. Further research on the alternative models and the validity of the results obtained is needed in order to know which perspective is the most appropriate to be pursued in this specific context of valuation.

Although few case studies focusing on the valuation of environmental health risks to children have been implemented, empirical evidence suggests that valuation differences may have a large impact on the values individuals place on a reduction of health risk experienced by children and must be taken into account in order to obtain reliable estimates of health benefits used in political decision making. A review of this literature will be proposed in the fourth section.

Overview of the methodologies used to value children's health

There have been few economic studies with the objective of estimating the value of reducing environmental health risks to children. This is due in part to the methodological problems associated with undertaking such studies. It remains unclear how precisely such studies should be undertaken.

However, as reliable estimates are required for public policy purposes, analysts often have to transfer the results from studies valuing health impacts for adults to children[14]. This practice is not satisfactory and given the potential differences that exist between adults and children, this could lead to biased estimates and therefore result in inefficient policy decision making. An alternative consists in using analytical frameworks or valuation techniques that are not based on economic or monetary considerations. In any case, economic values specific to children are required.

A brief overview of the valuation methodologies – based on economic considerations or not – most commonly used in the context of reducing (environmental) health risks for children follows.

Economic valuation methodologies

Three main valuation approaches can be used to value the health benefits subsequent to the reduction of a given risk factor:

The first methodology is based on observed economic values, from the productivity of those affected (production loss method, loss of consumption method) and/or from the direct costs related to a specific illness (the cost-of-illness method (COI));

The second approach uses indirect methods which value the monetary amount required to accept a variation in the risk level. It assumes that individuals reveal their preferences through consumption and expenditures which are related to health impacts. These preferences can be captured either by the WTP for an *ex ante* reduction in risk, or by the willingness-to-accept (WTA) for an *ex ante* reduction in risk. This is done by using information available on different markets, such as the labour market, the housing market, the safety products market etc. The hedonic method and the averting behaviour methods are revealed-preferences techniques; and,

The last approach infers the *ex ante* valuation of individual variation of welfare related to the variation of the status of individuals exposed to a particular health risk. It consists in presenting people with a hypothetical scenario (*via* telephone, postal or individual survey), and asking them about their maximum WTP to compensate for a variation in their well-being. It provides estimates of WTP values for a reduction in health risk, or analogously, willingness-to-accept (WTA) values for an increase of health risk. They are referred to as stated preferences methods (the contingent valuation method, the conjoint analysis methods). Stated-preferences techniques are not specific to mortality risk valuation, and can be also used to value morbidity events.

As COI estimates are often considered as lower bounds of WTP estimates[15], WTP values are thought to be better estimates of the health benefits. Since they allow the integration in the computation of intangible costs, which cannot be directly evaluated using the COI method. This is a great advantage since intangible costs are in general more important that the only financial costs of illness (Loehman et al., 1994). Moreover, this approach is more flexible and easier to implement than most of the traditional economic approaches. However, it can be costly since it depends upon primary data collection and be subject to a large number of inherent biases (Mitchell and Carson, 1989) that can invalid the estimates (Hausmann, 1993). Nonetheless, the WTP measure is recommended and widely used in the context of valuation of health benefits[16].

Non-economic valuation methodologies

The non-economic methodologies are based upon non-economic and non-monetary considerations. Their estimates are integrated in a multi-criteria analysis, a (partial) substitute for CBA. The most common frameworks used are cost-effectiveness analysis[17] and cost-utility analysis.

Cost-effectiveness analysis (CEA) is a technique for comparing the relative value of various clinical strategies. It consists in ranking the different alternative programmes by the cost per unit of a given type of benefit. In its most common form, an alternative strategy is compared with current practice (the "low-cost alternative") in the calculation of the cost-effectiveness ratio (CE ratio):

$$CE\ ratio = \frac{\text{cost}_{new\ strategy} - \text{cost}_{current\ practice}}{\text{effect}_{new\ strategy} - \text{effect}_{current\ practice}}$$

The result might be considered as the "marginal price" of the additional outcome purchased by switching from current practice to a new strategy. The CE ratio is compared with a threshold value, in general between $20,000 and $100,000 per QALY[18]. That can be viewed as the social WTP per QALY gained. If the price is low enough, the new strategy is considered "cost-effective" and implemented. However, in any case, the CE ratio cannot determine which action should be undertaken. In terms of health, the most cost-effective policy is the one with the lowest cost per (statistical) life saved or the lowest cost per (statistical) case of illness averted.

There are five main methodologies for measuring individual's quality of life[19]. They can be distinguished by the manner in which they are derived.

- The generic health utility scales have been developed in recent years. They are also referred to as "multi-attribute utility instruments". In this approach, the health of an individual is evaluated by asking the opinion of experts, such as medical doctors, to describe health states in their of their level on several attributes, such as vision, hearing, speech, ambulation, dexterity, emotion, cognition and pain for the Health Utility Index Mark III (Furlong et al., 1998).

- The rating scale, also referred to as "visual analog scale" (VAS), is based on self-rating from individuals. Individuals are asked to rate the specified health status, relative to the endpoints, on a discrete ladder scale labelled, for example, "perfect health" at one end and "death" at the other.

- The "standard gamble" (SG) presents respondents with a hypothetical choice between their present health status and a treatment, with two possible outcomes associated with two probabilities. The gamble proposes a given odds of success which would return them to full health if it succeeded, but kill them if it failed. The odds derived indicate the point at which the respondent decides the gamble is not worth taking.

- The time trade-off measurement (TTO) consists in asking individuals to make a choice between the present health status for T years or perfect health for (T-k) years. In other words, they have to estimate how many of their remaining years of ill health they would be willing to sacrifice in order to be returned to be full health.

- In the "person trade-off" methodology (PTO), the respondent is asked to consider the relative value of improving health for people in different health states. For example, he or she might be asked to judge the relative value of extending longevity for people in different health states. The PTO is conceptually different from the other methods because it focuses on preferences for community health in general rather than on an individual's preferences for his or her own health.

The choice of the method used may matter. Empirical evidence has drawn a general rule of thumb, according which values for the same health states obtained from SG are greater than those obtained from TTO, which are in turn greater than RS values (Nord, 1992).

These five methods yield totally different outcomes. The meaning of the measure depends on the method used. The most common is the quality adjusted life year (QALY). Most recent alternatives include concepts such as the disability adjusted life year (DALY) and healthy-years equivalent (HYE). Each of these techniques can be used to measure the utility of a specified health profile in terms of equally valuable length of time lived in full health.

QALYs are health outcome measures that take into account both the quantity and the quality of the extra life provided by a health care intervention. They are numerical weights assigned to each possible health state and can take the form of ordinal or interval-scale measures. They measure an individual's preferences for her/his own health and longevity and therefore reflect the strength of preference. These preferences are represented by "utility values", ranging from 0 (health equivalent to death) to 1 (perfect or excellent health), obtained by asking people about their preferences for various health states. By adding QALYs across people, the social value of health improvements is measured. QALYs simply consist of a method for eliciting health state utilities.

DALYs measure the burden of disease. They represent a societal measure of the health rather than an individual one. They incorporate an age-weighting factor such that years lived in young adulthood and middle-age contribute more to a society than years lived as a child or in old age. As QALYs, they are expressed on a severity scale ranging from 0 to 1, scoring health states and life years.

HYEs represent the number of years lived in perfect health that the individual judges as indifferent to a specified health profile. HYEs incorporate the individual's likely improvement or deterioration in future health status. HYEs are conceptually identical to QALYs elicited using a time trade-off format question (OECD, 2001).

Multi-attribute utility (MAU) instruments allow indirect assignment of individual utilities to various health states. They consist of questionnaires where respondents describe a number of various dimensions of health. These descriptions are then transformed into a single number, based on weight values obtained from previous studies. Most common examples of multi-attribute measures include the health utilities index (HUI) in Canada (Feeny et al., 1995); the quality of well-being scale (QWB) in the United States (Kaplan and Anderson, 1988); and, the EQ-5D in Europe (the EuroQol Group, 1990). These measures are also referred to as health-related quality of life (HRQOL) measures.

These alternative measures to WTP values allow for a direct comparison of various medical interventions. They provide useful information on the relative values of reducing risk for different populations but they do not address the question whether a particular risk reduction is worth its costs.

Comparison WTP-QALYs

Comparisons of QALY and WTP approaches are more and more proposed in the literature (see for example, Hammitt, 2002 and 2005; and Hubbell, 2002). Hubbell (2002) proposes a table explaining the main differences between the two approaches. This table is reproduced below.

Parameter	QALY	WTP
Risk aversion	Risk neutral	Empirically determined
Relation of duration and quality	Independent	Empirically determined
Proportionality of duration/quality trade-off	Constant	Variable
Treatment of time/age in utility function	Utility linear in time	Empirically determined
Preferences	Community	Individual
Source of preference data	Stated	Revealed or stated
Treatment of income and prices	Not explicitly considered	Constrains choices

Most of the parameters associated with the WTP approach need to be determined empirically. The QALY approach imposes much more conditions *ex ante*. It's worth noting that QALYs measures represent social preferences, while WTP measures represent individual preferences. This disparity between the two approaches is related to recommendations made by the Panel on CEA, stating that "in general, community preferences for health states are the appropriate ones for use in reference case analysis". They also add that "when adequate information is unavailable regarding community preferences, patient preferences may be used as an approximation". The Panel on CEA recommends the use of the societal perspective, although using patient preferences would be preferable, since the patient knows more about the health state than the community as he/she experienced it.

However, this mainly explains why we should expect that estimates derived from QALYs-based valuation techniques may be substantially different from those obtained with WTP-based approaches. The comparison between economic and non-economic measures of health outcomes would constitute an important element of the assessment of the merits of the respective approaches and would contribute a lot to appreciate their respective utility to political decision-making[20].

This overview raises the question of which technique is more valid. As few empirical studies have considered the issue of valuation of children's health, there is no consensus about the right methodology to adopt when valuing children's environmental health, whether it is a traditional economic method or one of the techniques used to assess quality of life measures. WTP values obtained from traditional economic methodologies are rather scarce, and validated methods for assessing the HRQOL measures of children are also critically lacking. Experience from empirical work focusing on the valuation of adults' health may provide significant contribution and should therefore constitute the starting point of any study on children's health valuation. The validity of the use of those methodologies in this specific context of valuation need to be further examined. Moreover, conceptual and/or methodological issues in the valuation techniques used to value children's health need

to be further analysed and addressed in order to obtain reliable estimates of children health benefits subsequent to a reduction in a given environmental risk. Some of the most relevant are examined below.

Conceptual and/or methodological issues in the valuation methodologies used to value children's health

Very few studies have explicitly sought to value environmental health impacts for children. In the absence of estimates, analysts have been forced to adopt a second-best option, which is to transfer benefit values estimated for adults to children. This information is then applied in cost-benefit analyses.

As previously mentioned, we can reasonably expect there to be large disparities between the valuation of adult's and children's health benefits. Transferring values for adults to children will therefore necessarily produce biased estimates. The alternative consists in asking the parents or caregivers of children about the value they place on their children's health. However, as noted above, this violates the main hypotheses of neo-classical consumer theory, which are:

- Everyone is the best judge of her/his own interests;

- Everyone is fully informed of all relevant alternatives; and,

- Everyone's choice reveals his/her preferences.

Therefore, the foundations of neo-classical theory may not be a good representation of children's preferences and decision-making. This may imply conceptual and practical problems that can lead to serious shortcomings in the application of the different valuation methodologies. This also generates problems for the integration of the estimates in the framework of a cost-benefit analysis. As a consequence, it is important to reflect on the relevance of the aforementioned valuation methods in the specific context of valuation of children's health benefits.

Demographic and economic uncertainties

The economic uncertainties related to the valuation of children's environmental health constitute one of the main conceptual problems of this exercise[21]. The main uncertainties that affect children's health valuation are related to the expected life span and the expected health benefits. This implies much more uncertainty on the value of a child's than on that of an adult's life. This may largely affect some of the traditional economic methodologies, as well as non-economic-based techniques of valuation of health.

As an example, the COI method is based on the production losses related to a disease or death. In the context of valuation of children's health, it requires the determination of future earnings considering child's educational choices and career path, etc. which is a significant undertaking. This method seems rather difficult to apply within this particular context. This problem may also have serious implications for techniques based on the productivity of the individual, for CVM and QALYs/DALYs measures, subject to discounting. The choice of the discount rate becomes even more important since, in the face of such uncertainty, small changes in the discount rate can introduce considerable variation in the values of children's life obtained.

Assumptions about cognitive capacities

Some assumptions about cognitive capacities in the neo-classical theory are likely to be violated when considering children's health valuation. Therefore, the foundations of neo-classical theory may not be a good representation of children's decision-making. This generates problems for the integration of the estimates in the framework of a cost-benefit analysis.

For instance, this can lead to serious shortcomings in the application of hedonic methods or COI, since they are based on individuals' earnings, and in general children do not work for wages. Analogously, they may not be able to understand trade-offs between consumption choices which have implications for environmental health. This approach cannot, therefore, be used to estimate the value of a reduced risk for children.

The same applies for the WTP approach for children-specific health valuation. It may be impossible to design a hypothetical scenario which is meaningful for children. Moreover, the contingent valuation method explicitly entails a large number of inherent complications such as discounting, risk perception, anchoring bias, embedding effect etc., which may be particularly problematic for children to take into account. All of those elements are related to how the information is given to the respondents in the questionnaire and the extent to which they are able to internalise those elements of information. In a contingent valuation study, the design of the questionnaire is usually very important to get reliable estimates, but it is even more particularly important in the context of children's health valuation.

Studies which seek to measure QALYs and DALYs are not theoretically founded in neo-classical economic theory in the same way as WTP studies. As such, issues of cognitive capacity do not appear to raise the same conceptual difficulties and potential for bias. However, in fact, in practical terms this issue is equally relevant for such studies. For instance, all methods which rely upon direct elicitation have the same shortcomings. Even if not immediately evident, most of the time, QALYs measures are derived from parents who respond on behalf of their children.

Decision-makers' autonomy

Most important decisions concerning children are taken by their parents or their caregivers, and not by the children themselves. The few existing studies that have estimated a measure for a reduction in health risks to children have elicited parents' preferences. Unfortunately this parental perspective violates the theoretical assumption underpinning many methodologies that everyone is able to behave in a manner which is consistent with their perception of their own welfare. Thus, even though there are no problems of cognitive capacity (see 3.2 above), children are not always able to express their preferences through their own behaviour. This has serious implications for some of the aforementioned valuation methodologies and more generally for any study relying on a decision-maker.

The implications that this shortcoming has for studies based upon hedonic methods is clear. Children do not decide where they live or what they eat. However, it also affects other methodologies. For instance, the averting behaviour method is based on risk-reducing behaviour and children are not the primary decision-makers when it concerns certain types of risk reduction. This approach relies on the observation of values from parents or caregivers for a reduced health risk. Thus, the validity of such methods which derive their valuation estimates indirectly on the basis of actual behaviour on the market, in the specific context of children's health valuation, is

undermined by the fact that, generally speaking, children are not always the relevant decision-makers and that decisions are taken on their behalf by a third-party.

Altruism and discounting

When parents are asked about children's health improvements, the obtained values reflect both parents' preferences to reduce risks towards their own children, and altruistic concerns for children more generally. The difficulty lies in estimating the degree and type of altruism in the values for the health of others. Some empirical studies have highlighted that altruism toward children may largely affect the WTP for reducing environmental health risks to children, which results in a greater VSL for children than for adults (see for example, Agee and Crocker, 1996, and Dickie and Ulery, 2001).

Differences in terms of risk perceptions may have implications for all methods that estimate the WTP to reduce health risk as the revealed-preferences methodologies, for techniques based upon stated preferences such as CVM, and those which measure QALYs and DALYs, i.e. every method which relies on parents as respondents (applying the parental perspective). It should also be kept in mind that uncertainty around risk estimation in itself may have outcomes on the value that parents put on that specific risk. This can have serious implications for values obtained from CVM and for non-monetary measures such as QALYs, DALYs and HYEs.

Discounting children's health is another challenge and may have consequences on the estimates that need special treatment [22]. In addition to differences in the valuation of the benefits, during the valuation exercise, it might be expected that people do not use the same discount rate when they are asked to value a reduced latent health risk for their own children, than when they are personally concerned. This difference in the implicit choice of discount rate applied in the two cases is suggested by empirical studies showing that people often value more children's life than adult's life (see for example Liu et al., 2000). Other empirical studies have however found that parents do not necessarily use a different discount rate for themselves from the one applied to their children (Agee and Crocker, 2001).

Discussion on conceptual and methodological problems

Four different issues related to the valuation of children's environmental health risks appear to be of high importance and require more attention from analysts and economists. They include the economic uncertainties, the assumptions about cognitive capacities, the autonomy of the decision-maker and the issues associated with altruism and discounting. There is little empirical evidence of the impacts of those problems on the valuation methodologies traditionally used to assess health benefits subsequent to a risk reduction. Some may have more serious consequences than others, but ignoring those issues could generate misleading values that should not be used within a cost-benefit (or cost-effectiveness) analysis framework.

Review of the literature on valuation differences

Very few studies have considered the valuation of children's health. The scarcity of empirical studies specific to children can be explained mainly by the aforementioned conceptual and practical problems associated with such an exercise. The three most frequent measures for children's environmental health estimated in the empirical studies are WTP, QALYs and COI estimates. These values are explicitly focused on

the valuation of children's health but very few among them are related to environment degradation or pollution. However, given the need for estimated values for policy purposes, empirical studies which are not related to the environmental context may provide useful insight in the valuation of children's health and highlight the differences between adults' health valuation and children's health valuation, supporting the need for further research and action in this area of growing interest.

The most relevant and significant empirical studies highlighting valuation differences between adults and children are reported in what follows[23].

Studies showing differences in the context of valuation

Joyce et al. (1989) estimate mothers' WTP to reduce air pollutants levels (a 10% reduction in SO_2 concentrations) from which they derive the VSL for infants. They found that black mothers are willing to pay more than white mothers for a reduction in air pollution. This generates larger VSL for black infants than for white ones. This may be partly explained by the fact that the estimated marginal effects of prenatal and neonatal care are lower for blacks than for whites and because air pollution reductions are more productive for blacks.

Viscusi, Magat and Huber (1987) estimate the WTP to prevent the risk of injury associated with household pesticides. Their results show that parents of young children tend to be willing to pay more than adults without children and that the WTP to reduce risks to children is greater than the WTP to reduce the other risks considered.

Agee and Crocker (1996) estimate the parental WTP to reduce the risk of neurological impairments due to exposure to lead on children. Their results show differences between parents, according to the treatment they chose to assign to their child: parents who chose chelation are willing to pay approximately ten times more than those who chose another type of treatment.

Studies showing differences in risk preferences

Blomquist, Miller and Levy (1996) estimate the implied values of reducing fatal and non-fatal injuries risks for different road user populations: adults, children and motorcyclists. They found that, as parents value the life of their children more than their own, the VSL for a child is greater than the VSL for an adult. This suggests that parents are more risk-adverse when the child is affected. This may lead to substantial disparities in the values depending upon who is affected and also who makes the choices that imply risk reductions.

Mount, Weng, Schulze and Chestnut (2000) estimate the VSL of different age groups (children, adults and the retired). They found that the VSL of a child is quite similar or slightly larger than that of adults but greater than that of an elderly.

Jenkins, Owens and Wiggins (2001) estimate the VSL for a child according to different age categories: ages 5 to 9 and ages 10 to 14. The results show that the VSL for a 5- to 9 years-old is higher than the VSL for a 10- to 14 years-old but the VSL for an adult is higher than the VSL for the two child age categories.

Liu et al. (2000) estimate a mother's WTP for preventing her from a minor disease (a cold) and her WTP for preventing her child from this minor disease. They found that the mother's WTP for her child is approximately twice as large as her WTP to prevent herself from getting a cold of comparable duration and severity. This suggests that mothers are valuing more their child's health than their own.

Agee and Crocker (2001) estimate the annual WTP to increase own and children health services as well as the parental WTP to reduce their child's daily exposure to environmental tobacco smoke. The results suggest that parents value their children's health twice as much as their own health. The respondent marginal rate of substitution between adult's health and child's health is positive, meaning that disparities exist between adult and child health valuation.

Dickie and Ulery (2001) evaluate parental WTP to avoid acute illnesses. They found that WTP for avoiding episodes is less for parents than for children. The value parents are willing to pay to avoid acute illnesses in their children is about twice the value for themselves, which reflects a high degree of altruism from parents toward their children. Based on the same data, Dickie and Brent (2002) improve the analysis in accounting for the endogeneity of family behaviour. Their results are similar to those of Dickie and Ulery (2001): the WTP to avoid one day of symptom is greater for the child than for the parent. This suggests that ignoring the endogenous aspect of family behaviour toward illnesses may lead to an under-estimation of the value of children's health relative to parent's health.

Dickie and Gerking (2001) estimate the parental WTP to reduce skin cancer from solar radiation exposure, for their children and for themselves. The results show that parents are willing to pay 2 times more to reduce non-melanoma skin cancer risks to their children than to themselves. This suggests differences in risk perceptions, as well as altruism from parents toward their children.

Apajasalo et al. (1996a) introduce a health-related quality of life (HRQOL) measure of adolescents aged 12-15. The innovative approach consists in asking adolescents to perform the assessments by themselves: they are asked to fill in the questionnaire. The questionnaire was also sent to the parents of these children and the parents were asked to complete it from the point of view of their child in order to compare the results. The profiles obtained differ significantly according to the diagnosis. The measures obtained from the children and the parents differ on a certain number of points and the authors also highlight differences between boys and girls. They conclude that reliable HRQOL measures of adolescents' health should be based on data collected from the adolescents themselves.

Conclusion on the review of the literature

The number of empirical studies that have considered the valuation of a reduction of health risks to children is limited. Surprisingly, valuation of children's health has been more frequently considered through empirical studies based on the traditional economic valuation approaches than through techniques based on non-monetary considerations. The estimates are rather incomplete, and only few studies provide estimates for acute effects. As suggested by Tolley and Fabian (1999) and Agee and Crocker (2002), well-conducted contingent valuation surveys provide promising values of parents' WTP to reduce health risks experienced by children. Although they are considered as a lower bound of the WTP values, the COI estimates constitute nonetheless a good starting point for the valuation of health benefits for children. Concerning the valuation of a reduction of the mortality risk among children, the results of the economic case studies do not converge and are more troublesome. The majority tends to suggest that the VSL for a child is greater, or at least not less, compared to the VSL of an adult.

Most of the studies do not consider a health risk reduction set in the environmental context but provide nonetheless useful results for further empirical work. Concerning the studies that estimate QALYs and HRQOL measures for children's health, their results should be used in further work required to assess the validity of such methodologies.

General discussion

Children are particularly vulnerable to the impact of environmental degradation and/or pollution. In order to reduce environmental risks to children, a better understanding of children's situation and of the relationship between their health and the environment is required.

Given risk differences between adults and children, whether it be in terms of exposure or in terms of dose-response, we can reasonably expect large disparities in estimates of health benefits associated with a given risk reduction between adults and children. Four types of valuation difference can potentially affect those values: differences in time/age, in risk preferences, in context of valuation and in perspective. There is no consensus based on empirical evidence about how those differences affect the values individuals place on child's safety and health. The main empirical results suggest that parents may value their children's health more highly than their own (Agee and Crocker (2001), Dickie and Ulery (2001), Liu et al. (2000)). Plausible reasons for these disparities are altruism and the context of valuation, which is very different from that of adult's valuation in the way that the unit considered is the household and not the individual. Valuation differences may thus affect WTP or QALYs but further analysis is required to determine the order of magnitude.

Some conceptual and practical difficulties arising from the valuation differences that exist between adults and children appear to be of high relevance and importance. Examples could include the formulation and revelation of children's preferences, the use of transfer values obtained for adults to children, the practice of discounting children's health, and, the economic uncertainties related to the valuation of children's health. These issues may significantly affect the traditional valuation methods used to value the health benefits associated with a given policy. They need to be addressed in order to help policymakers design efficient environment and health policies aimed at reducing health risks for children.

Policy Implications

Public decision makers require estimates of the effects of policy interventions on social welfare in order to implement new policies or reforms. For that purpose, economic valuation has become a central tool and empirical studies have stressed the need for a better understanding of how to value the environmental health risks faced by children. However, we need to better understand the major threats, challenges and opportunities that exist in the field of children's health and the environment.

There is a pressing need to support and encourage research on children's health, in the economic field as well as in the epidemiological field. Much more information and research data are necessary to provide efficient policy advice. The scarcity of empirical studies dealing with valuation of children's health takes on even more importance as they represent the only material available to policymakers to found their decisions concerning the design and reform of existing policies to reduce risks to children. Moreover, the uncertainties associated with the valuation process itself may

significantly affect the estimates, which may lead to inappropriate policy decisions. As such, further work on the analysis of those uncertainties is recommended in order to provide policymakers with reliable estimates of health benefits for children.

In the absence of such contributions, inefficient policy decisions could be undertaken. On the one hand, ignoring risk differences between adults and children could lead to setting wrong standards, concerning for example the maximum allowable level of air pollution emissions. On the other hand, ignoring the valuation differences between adults and children could lead to wrong policy priorities being set within the health and environment fields, which, in the long run, could generate an important social welfare loss.

The growing concern for children's health-related issues has encouraged the implementation of a great deal of studies in the United-States as well as in Europe, most of them being funded by their respective government or public agencies (United States Environmental Protection Agency (US EPA), European Commission (EC), etc.) and important international organisations. Examples of such empirical ongoing work include:

- In Europe, one of the main particularly relevant work on children's health is the Pan European Programme (PEP), an agreement passed between five European countries (Austria, France, Malta, the Netherlands, Sweden and Switzerland) in order to assess the transport related health impacts and their costs and benefits, with a special emphasis on children. The objective being to contribute to the development of WHO-Guidelines for the economic valuation of transport related health effects.

- In the United-States, the U.S. Environment Protection Agency (US EPA) has funded a great deal of empirical studies related the valuation of environmental health risks to children. For example, a survey among a population of children diagnosed with asthma is being made to measure the WTP to avoid asthma incidence (conducted by Hanemann and Brandt). Another survey is focusing on the transfer of adults' values to children's values (assessed by Crocker, Agee and Shogren). A last example considers a contingent valuation study realised in order to estimate the WTP to avoid skin cancer for oneself, children and the population as a whole (Dickie and Gerking).

All these projects are promising and will probably contribute a great deal to a better understanding of how to correctly value the benefits associated with a reduction of environmental health risks experienced by children. Then, economists could inform policymakers about the most efficient environment and health policies to implement in order to reduce such risks to children.

Questions for discussion

This report raises a number of questions to be discussed.

The main point is related to the availability of data. From a more practical point of view, more data are necessary, and more specifically data on specific endpoints, such as chronic morbidity risk, asthma morbidity and inference of a child's environment-related VSL, as it has been made for adults. Taking account for the latency/delay between exposure and illnesses would also highlight the work on long term effects of environment degradation on health. The lack of data precludes an evaluation of the efficiency of existing environment-related health policies. This should be considered as a priority.

Another important point concerns the valuation methodology. Economic standard valuation techniques seem to be adapted to measure parents' and/or individuals value (WTP or QALYs) for reducing health risks to children in a household setting. However, valuations obtained from CEA are likely to differ from WTP estimates of children's health given the differences between those two approaches in terms of theoretical foundations. Therefore, what is the most appropriate method to value environmental health risks to children? What about transferring values for adults to children? If one adopts the parental perspective, which one would provide the most reliable estimates: the parental or the adult-as-child? Concerning the health outcomes measures, what could we say about their internal and external validity when valuing a reduction in environmental health risks to children? All these questions need to be further examined in order to help policymakers assess the economic efficiency of existing health and environmental policies and design new policies specifically aimed at reducing environmental health risks to children.

Notes

1 OECD Environment Directorate, National Policies Division.

2 The views expressed in this chapter are those of the authors and do not necessarily reflect those of the OECD.

3 The *Technical Guidance Document on the Use of Socio-Economic Analysis in Chemical Risk Management Decision Making* (OECD, 2002) provides a detailed overview of the theory and principles underlying the different methodologies used in socio-economic analysis, and how these are then put into practice by economists and other policy analysts who undertake such analyses.

4 It is important to emphasise that this report is not concerned with such risk differences, but with differences in values attributed to such impacts, holding risk constant. More details on risk differences can be found in Tamburlini (2005).

5 For a review of the literature on children's health valuation, see Annex.

6 Rowe et al. (1995) examine the implications of the choice of the model and assumptions on VSL estimates according to age. They used four different studies published in the literature and show how the slope of the curve changes according to the nature of the study. They found that the slope of the curve is sensitive to the nature of the study and changes accordingly.

7 Source: Department of Health UK DETR (1999) (p 67) and direct information from M. Jones-Lee (1998). Note that this graph displays the total relationship between WTP and age, including all the other factors associated with age.

8 These studies will be presented more thoroughly in the third section devoted to the review of the literature (see below).

9 The Liu et al. study (2000) constituted a first try in valuing children's health through CVM. Results from this study should therefore be considered cautiously.

10 The interested reader could refer to those articles to get detailed presentation of the pluralistic models.

11 The perspective makes reference to the person from whom we should elicit values for reducing environmental health risks to children.

12 See above.

13 See Dickie and Gerking (2005).

14 See Agee and Crocker (2005).

15 The COI approach does not allow estimation of the WTP to avoid illness or to reduce health risk. It only measures *ex post* costs associated with being ill.

[16] Hanemann (2003) proposes a comparison of stated- and revealed-preferences techniques to valuing children's environmental health.

[17] Several alternative frameworks can be considered. The first one, referred as "breakeven analysis", estimates the number of cases at which overall net benefits become positive, or the point at which the policy intervention will "break even". The bounding analysis provides bounds relative the state of well-being being considered, from hypothetical endpoints representing the "worst" (e.g. dead) and "best" (e.g. perfect health) states of health. Finally, risk-risk (or health-health) analyses consist in enumerating and comparing the different risks (or the number of deaths) that are reduced and those that are increased by a specific policy. However, these alternative frameworks are not widely used due to their weaknesses as compared with CEA.

[18] See definition below.

[19] A comparison of the techniques used to derive HRQOL measures is proposed in Nord (2005).

[20] For further details, see Hammitt (2002, 2005).

[21] Further details on economic uncertainties associated with the valuation of children's health can be found in Hoffmann et al. (2005).

[22] See Cairns (2005).

[23] For a full presentation of empirical studies related to the valuation of children's health, see Annex.

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Annex 2.A
Review of the literature on the valuation of children's health

WTP measures

The valuation of health benefits largely supports the use of WTP values to obtain reliable estimates. Little is known about the valuation of children's health but experience with research on adults' health suggest that WTP is likely to be considered as the best way to evaluate risk reductions on children's health. Dickie and Nestor (1999) propose a survey of the economic studies evaluating WTP values to reduce health risks to children. Blomquist (2003) made a meta-analysis of the studies on self-protection and averting behaviour in consumption that estimate values of statistical life for children.

Mortality

Joyce et al. (1989) measure the impact of air pollution on race-specific neonatal mortality rates using a health production function and therefore estimate the WTP to reduce air pollutants levels. This leads to the estimation of the VSL for infants. The figures presented in $ 1997 are taken from Dickie and Nestor (1999).

Whites

$43,000-$750,000 *per birth*

$70,000-$1,250,000 *per mother*

Blacks

$59,000-$1,450,000 *per birth*

$130,000-$3,375,000 *per mother*

There are two ways to measure the marginal cost of improving infant health: use the cost of prenatal care of the cost of neonatal intensive care. This leads to two separate estimates. The lower bound is based on prenatal care while the upper bound is based on neonatal intensive care.

Black mothers are willing to pay more than white mothers for a reduction in air pollution, generating larger VSL from black mothers than VSL from white mothers.

Carlin and Sandy (1991) calculate the implicit value of a young child's life as revealed by the decisions of the mother about using a child car safety seat. The data come from a survey implemented in 1985 and are used in a utility maximisation approach. The value of a child's life is derived from the mother's probability of purchasing and properly using a car seat. Fatality risk reductions are considered along

with time and money costs of raising a child to the age of 18. The VSL of a child under the age of five, in $ 2000 (Blomquist, 2003), amounts to $0.8 million.

Blomquist, Miller and Levy (1996) estimate the implied values of reducing fatal and non-fatal injuries risks for different road user populations: adults, children and motorcyclists. They incorporate time and disutility costs associated with car seat belt and motorcycle helmet use. The data come from a survey implemented in 1983 and the sample includes parents with children under five years of age. The VSLs in $ 2000 proposed by Blomquist (2003) are:

SL for a child under 5: $3.7 - $ 6.0 million

VSL for an adult: $2.8 - $4.6 million

VSL for a motorcyclist: $1.7 - $2.8 million

The VSL for a child as implied by their parents' actions is greater than the VSL for an adult. Parents value their children's life more than their own, which suggests that parents are more risk-adverse when the child is affected and that we can expect differences in the values depending upon who makes the choices that imply risk reductions.

Mount, Weng, Schulze and Chestnut (2000) examine the family automobile purchases to estimate the amount of money spent on safety to derive the VSL of different age groups (children, adults and the retired). They apply a hedonic price function on data from a survey implemented in 1995 (aggregated data). They analyse the motor vehicle prices with fatality risks. The VSLs in $ 2000 (Blomquist, 2003) are:

VSL for a child: $7.3 million

VSL for an adult: $7.2 million

VSL for an elderly: $5.2 million

The VSL of a child is quite similar or slightly larger than that of adults.

Jenkins, Owens and Wiggins (2001) estimate the parental values of reduced fatality risk to children by examining the market for child bicycle helmets. The value of reducing mortality risk is computed for two age categories: ages 5 to 9 and ages 10 to 14. The data come from a survey implemented in 1997 and are used in a utility maximisation model. The VSLs in $ 2000 proposed by Blomquist (2003) are:

VSL for a child of 5-9 age: $2.9 million

VSL for a child of 10-14 age: $2.8 million

VSL for an adult: $4.3 million

The VSL for a 5- to 9 years-old is higher than the VSL for a 10- to 14 years-old but the VSL for an adult is higher than the VSL for the two child age categories.

Acute morbidity

Liu et al. (2000) implement a contingent valuation study in Taiwan to estimate a mother's WTP for preventing her from getting another case of the cold she typically gets and her WTP for preventing her child from getting another case of the cold the child typically gets. This is in line with a model of utility maximisation.

WTP to prevent a recurrence of the cold for the child: $57

WTP to prevent a recurrence of the cold for the mother: $37

The mother's WTP to prevent her child from suffering a cold is approximately twice as large as her WTP to prevent herself from getting a cold of comparable duration and severity. This can suggest that mothers are valuing more their child's health than their own.

Agee and Crocker (2001) estimate the annual WTP to increase own and children health services as well as the parental WTP to reduce their child's daily exposure to environmental tobacco smoke. They focus on parents who are currently smoking, because smokers and non-smokers make different health and safety risk – wealth trade-offs. They analyse parents' consumption of tobacco products and their assessment of their child's home exposure to environmental tobacco smoke. They use a household production model to derive the smoker's substitution rates between own consumption and own health, between own consumption and their children's exposure to tobacco smoke, and between own health and their children's health.

WTP for a 10% increase in

Child health status: $452

Respondent health status: $249

WTP for a 1% reduction in child's exposure to tobacco smoke: $10.19

The respondent marginal rate of substitution between own health and child health equals 0.549, which means that discrepancies exist between adult and child health valuation. The results also suggest that parents value their children's health twice as much as their own health.

Dickie and Ulery (2001) implement a stated-preference study to evaluate the parents' WTP to avoid acute illnesses. WTP for avoiding episodes is less for parents than for children.

Mean WTP to avoid one symptom for one day: ≈$50

Mean WTP to avoid seven days of one symptom

For the child: $150 to $350

For the parent: $100 to $165

Mean WTP to avoid one-week incident of acute bronchitis:

For the child: $400

For the parent: $200

The value parents are willing to pay to avoid acute illnesses in their children is about twice the value for themselves, which reflects a high degree of altruism from parents toward their children.

Based on the same data, Dickie and Brent (2002) take account for the endogeneity of family behaviour and obtain the following estimates of the WTP to avoid one day of first symptom:

Mean WTP to avoid one day of symptom

For children: $94

For parents: $35

The WTP to avoid one symptom day is greater for the child than for the parent. Ignoring the endogenous aspect of family behaviour toward illnesses may lead to an under-estimation of the value of children's health relative to parent's health.

Chronic morbidity

Viscusi, Magat and Huber (1987) implement a contingent valuation study to estimate the individual WTP to prevent the risk of injury associated with household pesticides. This is in line with a model of maximisation of utility. Two types of injury are considered: poisoning from insecticide and poisoning from toilet bowl cleaner. Injuries are proposed depending upon the respondent has young children or not. The values presented below are in $ 1986.

Reduction of risks from insecticide

Skin poisoning: $1233 (individuals without young children)

Inhalation: $1428 (both subsamples)

Child poisoning: $2860 (individuals with young children)

Reduction of risks from the toilet bowl cleaner

Eyeburns: $610 (individuals without young children)

Chloramine gassings: $912 (both subsamples)

Child poisoning: $1010 (individuals with young children)

Adults with young children tend to be willing to pay more than those without young children for eliminating risk of insecticide inhalation (Viscusi et al., 1987). The WTPs to reduce risks to children are greater than the WTPs to reduce the other risks considered.

Joyce et al. (1989) estimate the benefits associated with a ten percent reduction in sulphur dioxide concentrations on neonate mortality by using a household production approach. The values presented below are in $ 1997 taken from Dickie and Nestor (1999). The results are used to derive the VSL for an infant (see above).

WTP for a 10% reduction in SO2 concentrations:

Whites: $3 - $42 per mother

Blacks: $11 - $291 per mother

Black mothers are willing to pay more than white mothers for a 10% reduction in ambient pollution, mainly because the estimated marginal effects of prenatal and neonatal care are lower for blacks than for whites and because air pollution reductions are more productive for blacks.

Agee and Crocker (1996) estimate the benefits associated with children morbidity risks related to a low-level lead exposure. The *ex ante* welfare losses associated with the child's body lead burden are valued by the household's WTP. The authors infer the parents' WTP to reduce the risk of neurological impairments due to exposure to lead on children, i.e. the WTP for reduced child body lead burdens. They apply a household production model based on the data obtained from 256 households. The values are proposed for two different sub-samples: parents who chose chelation as treatment for their child and parents who did not choose chelation as treatment for their child. The values presented below are in $ 1997 (Dickie and Nestor, 1999).

WTP from parents who chose chelation: $155 per child

WTP from parents who did not choose chelation: $16 per child

Overall mean: $24 per child

Parents who chose chelation are more willing to pay to reduce the risk of neurological impairment to their child than parents who did not chose this treatment.

These results reflect parental trade-offs between care expenditures and their perception of future bad health status for their children. The authors also note that the parental *ex ante* WTP for a one percent reduction in child body lead burden exceeds the estimated cost-of-illness caused by the same reduction.

Maguire, Owens and Simon (2002) measure the value of reducing babies' exposure to pesticide residues. They use hedonic methods and analyse data from observed consumption behaviour in the baby food market. They infer the consumers' premium for organic baby food. They obtain a WTP equal to 12 cents per jar more for organic

food than for conventional varieties. This premium reflects a desire to avoid pesticide residues.

Dickie and Gerking (2001) implement a contingent valuation survey to estimate the parental WTP to reduce skin cancer from solar radiation exposure, for their children and for themselves. Melanoma and non-melanoma skin cancer risks are considered.

WTP for a 1% point reduction in non-melanoma skin cancer risk

To the child: $3.18

To the respondent: $1.29

The results show that parents are willing to pay more to reduce non-melanoma skin cancer risks to their children than to themselves.

COI estimates

Schwartz et al. (1985) estimate children's health-related costs and benefits associated with a reduction of lead in gasoline. The health costs considered include medical care related to children exceeding the blood-lead levels "standard" (25 µg/dl) as well as costs associated with hypertension (elevated blood-pressure).

Costs associated with blood-lead levels above 25 µg/dl:

Medical testing and treatment costs: $ 900

Compensatory education for cognitive effects: $ 2,600

Costs associated with hypertension: $ 228

Weiss et al. (1992) estimate the cost associated with the prevalence of asthma, for children under 18 years old, in the United-States. The values obtained are presented in 1997 dollars in the following table.

Direct costs (excluding medicine): $231 per case

Indirect costs: $410 per case

Estimate medicine: $122 per case

Estimated total costs: $641 per case (excl. medicine)

The estimated total costs amount to $1.92 billion for the whole US population.

Landrigan et al. (2002) estimate the costs for four categories of illness for children in the United-States that may be attributable to chemical pollutants present in the ambient environment: lead poisoning, asthma, cancer and neurobehavioral disorders. This is the first study that assesses the total costs of pediatric disease and disability of environmental origin. The value they obtain constitutes a conservative figure of the "true" costs because the authors do not take into account all the intangible costs related

to childhood illnesses, such as the costs of pain, the deterioration in quality of life or the emotional suffering of the families or affected children.

Costs of pediatric lead poisoning: $ 43.4 billion

Costs of pediatric asthma of environmental origin: $ 2.3 billion

Costs of pediatric cancer of environmental origin: $ 332 million

Costs of pediatric neurobehavioral disorders of environmental origin: $9.2 billion

Total annual costs: $ 54.9 billion ≈ 2.8% of total US health care costs

QALYs measures

A survey of empirical studies from 1972 to 2000 on the use of QALYs and DALYs for interventions related to children was made by Davis and Meltzer (2001) but none of the 13 retained studies deals with environment-related risks. However, this provides a great deal of useful information and constitutes initial estimates for the analysis of the use of QALYs to evaluate environmental risks to children's health. There is also a growing use of the DALYs measures in the developing countries to assess the quality of life (World Bank, 1993) but this lies above the scope of this report focused only on OECD countries.

Boyle et al. (1983) evaluate neonatal intensive care of very-low-birth-weight infants. Three different health outcomes are measured: cost per additional survivor, cost per life-year gained and cost per QALY gained.

	Cost per additional survivor	Cost per life-year gained	Cost per QALY gained
Weight: 1000 to 1499 g	$59,500	$2,900	$3,200
Weight: 500 to 999 g	$102,500	$9,300	$22,400

The impact of neonatal intensive care is more beneficial among infants weighting 1000 to 1499 g than among those of lower weight.

Hatziandreu et al. (1995) provide a comparison for three different programmes aimed at increasing the use of bicycle helmets among children ages 5 to 16. They apply a similar strategy, over a 4-year period, to different approaches: legislative, community and school-based. Three different health outcomes are evaluated: head injuries prevented, deaths averted and years of life saved. The following figures are $ 1992.

	Legislative programme	Communitywide programme	School-based programme
Cost per injury avoided	$36,643	$37,732	$144,498
Cost per death averted	$17,935,341	$18,468,909	$65,549,315
Cost per year of life saved	$934,904	$961,958	$3,417,551

Overall, they find that the legislative approach is always more cost-effective, the school-based programme being the less cost-effective. In perspective, childhood use of bicycle helmets is less cost-effective than the use of motorcycle helmets ($3,675 per year of life saved) but more cost-effective than rear-seat shoulder belts in passenger cars ($4.4 million per year of life saved) (Tengs et al., 1995).

Graham et al. (1997) evaluate the cost-effectiveness of the driver-side and the passenger-side air bag systems using a common methodology and obtain QALYs measures. The costs include all the resources involved in producing, maintaining and replacing air bags. Benefits take account for the fatalities and injuries prevented by airbags as well as the fatalities and injuries caused by air bags. For the driver-side airbag, the net cost was about $70,000 per QALY gained compared to manual safety belts. For dual-front airbags, the net cost was $399,000 per QALY gained compared to driver-side airbags. The passenger-side airbag is less cost-effective: the effectiveness is assumed to be negative for children given that passenger airbags causes more harm to children. Children have an important weight in the analysis since they lose, on average, 75 years of life expectancy while adults lose, on average, about 35 years of life expectancy. The authors conclude that cost-effectiveness of passenger-side airbags could be greatly improved if the use of safety car seat were required for children, as it is in several countries such as Germany and France.

Sullivan et al. (2002) evaluate the cost-effectiveness of a two-year intervention aimed at reducing asthma morbidity and improving outcomes. The intervention strategy they propose is based on a social-environment model of disease management aimed at the child, the caregiver and the family; i.e. it is an educational programme for the inner-city populations. They tested this intervention on 500 children aged between 5 to 11, diagnosed as asthmatics (referred to as “intervention group”) and then compared the results with a group of 500 other children referred to as “control group”. The outcomes are striking: over the two-year period, the intervention group suffered from asthma symptoms 26 days less than the “control group”. The mean medical costs per symptom-free days amount to $9.20. They estimate the mean cost of providing the intervention at $337 per child over two years. They also show that the intervention is much more effective and less costly in the more severely exposed cohort.

HRQOL

Apajasalo et al. (1996a) introduce a health-related quality of life (HRQOL) measure of adolescent aged 12-15. This measure consists of a 16 multiple choice questions each representing one health-related dimension, such as for example mobility, vision, hearing, breathing, etc. The sample is composed with “normal” and affected children (children waiting for organ transplantation, children with genetic

skeletal dysplasias, and children with epilepsy). The innovative approach consists in asking adolescents to perform the assessments by themselves: they are asked to fill in the questionnaire. The questionnaire was also sent to the parents of these children and the parents were asked to complete it from the point of view of their child in order to compare the results. The profiles obtained differ significantly according to the diagnosis. The measures obtained from the children and the parents differ on a certain number of points and the authors also highlight differences between boys and girls. They conclude that reliable HRQOL measures of adolescents' health should be based on data collected from the adolescents themselves.

Apajasalo et al. (1996b) then introduce a similar HRQOL measure for children aged 8-11 years. Based on the 16D measure developed previously, they construct a measure consisting of 17 dimensions. The children completed the questionnaire with the help of an interviewer. The results obtained are quite similar to those from the 16D study: the profiles vary according to the diagnosis. The authors conclude on the necessity to make children fill in the questionnaire by themselves in order to obtain reliable estimates of the HRQOL of children.

Chapter 3

Valuing Children's Health: Parental Perspectives

by

Mark Dickie and Shelby Gerking[12]

Strategies for reducing environmental risks faced by children operate through parents and other adult caregivers who are responsible for children's behaviour. Thus, effectiveness of policies will depend on choices parents make between their children's health, their own health and consumption of other goods. This chapter surveys the literature on parents' willingness to pay for protection of their children's health and provides new empirical estimates from a study of skin cancer. The literature review describes two types of theoretical models that have been used as the foundation for willingness to pay estimates: unitary and pluralistic models. Previous empirical estimates of willingness to pay for improved children's health are also discussed and several implications for future research are drawn.

The chapter concludes by presenting new empirical results from a study of skin cancer risks to parents and children. The unitary parental perspective is adopted to develop an expected utility model that focuses on valuation of morbidity and mortality risks to a parent and one child.

Introduction

Protection of children's health is an important priority of U.S. environmental policy because children are at greater risk than adults from hazards such as pesticides, drinking water contaminants, and exposure to solar radiation (USEPA 1996). These added risks arise because children's immunological, neurological, and digestive systems still are developing and because children spend more time outdoors than adults and eat more food and drink more fluids relative to their body weight than adults. For example, studies of pesticide exposure indicate increased risks of leukemia, the most common form of childhood cancer, for children whose parents used pesticides at home or at work as well as for children exposed to pesticides in the home (Zahm and Ward 1998, Buckley, et al. 1989). Also, Needleman et al. (1979) demonstrate that environmental lead exposure can lead to neurofunctional deficits in young children. Moreover, links between environmental exposure to ultraviolet radiation and skin cancer are well established (Finkel 1998, MacKie, Freudenberger, and Aitchison 1989, Rhodes et al. 1987, Scotto, Fears, and Fraumeni 1982) and exposure during childhood is an important determinant of lifetime skin cancer risk (Reynolds, et al.1996, Robinson, Rigel, and Amonette 1997, Creech and Mayer 1998). In fact, the American Academy of Dermatology (1997) estimates that up to 80% of a person's lifetime exposure to ultraviolet light occurs before the age of 18 and even a few severe sunburns between the ages of 10 and 15 can triple the chances of developing malignant melanoma later in life.

President Clinton's Executive Order #13045 (Federal Register 1997) directed federal agencies to identify and assess environmental health and safety risks that may disproportionately affect children and the Bush administration has continued to emphasize protection of children's health in federal environmental policy. Appropriate strategies for reducing environmental risks to children, however, operate at least partly through parents and other adult caregivers who are responsible for children's behavior. For example, a key aspect of reducing children's environmental health risks is to encourage parents to take protective actions that will reduce exposure. Effectiveness of this approach, however, will depend on parents' beliefs about risks to their children's health, as well as how they make choices between their children's health, their own health and other goods.

This report critically surveys the economics literature on what parents are willing to pay for greater protection of their children's health and provides new empirical estimates from a study of skin cancer. The next three sections provide an overview of the parental perspective for valuing children's health. Section 2 outlines the theoretical foundations of the parental perspective approach to valuation. Section 3 focuses on difficulties in using this approach to estimate social benefits. Section 4 summarizes prior empirical results. The subsequent three sections present a detailed illustration of the parental perspective to valuing children's health using results from the skin cancer study. Section 5 presents a specific theoretical model. Section 6 discusses the experimental design and survey used to collect the data. Section 7 presents empirical analysis that looks at tradeoffs between parents' health and children' health. The final section of the report provides concluding comments.

Theoretical Foundations of the Parental Perspective

Theoretical foundations for estimating parents' willingness to pay (WTP) for children's health are drawn from the literature on the economics of the family. This literature addresses a variety of issues including household formation and dissolution through marriage and divorce, labor supply and consumption decisions of husbands and wives, and allocation of resources to and among children. Behrman, Pollack and Taubman (1995) classify models of family decision-making according to two criteria: (1) whether children are treated as independent decision-makers, and (2) whether the family is assumed to maximize a single or "unitary" family utility function. This report considers both unitary (assuming the family maximizes a single utility function) and "pluralistic" (recognizing conflicting as well as common interests among family members) models, but follows the lead of most theoretical and empirical work in family economics and assumes that children are not active participants in family decision-making.

A simple way to illustrate models of family decision-making is to compare the utility functions used in each approach. Consider a three-member family where each person consumes a composite good (X_i) and where a measure of each person's health is denoted H_i, i = m (mother), f (father), and c (child). Total consumption of the composite good is $X = X_m + X_f + X_c$.

In the unitary model, family members seek to maximize a common utility function such as $F(X, H_m, H_f, H_c)$. Of course, the list of arguments in the utility function could be changed to consider more or fewer family members, more goods, separated consumption of goods by family members or other features of a specific valuation problem. The existence of a common preference function for the household usually is taken as given, although Becker (1993) and Samuelson (1956) provide alternative ways of deriving such a function from the individual preferences of family members.

A "pluralistic" (Bergstrom 1997) model, in contrast, accounts directly for individual preferences of household members, or at least of adult household members. The two spouses are allowed to have distinct preferences represented by individual utility functions such as $U_m(X_m, X_c, H_m, H_c)$ for the mother and $U_f(X_f, X_c, H_f, H_c)$ for the father. In this specification, each parent cares about his or her own consumption and health, as well as about the consumption and health of the child. In other words, the parents' consumption and health are private goods, while the child's consumption and health are public or non-rival goods within the household. Alternative specifications of the parents' utility functions could be used to allow for other features pertinent to a particular application. Various pluralistic models have been proposed that differ in how the family is assumed to coordinate resource allocation in the presence of the competing interests of the spouses.

The distinction between unitary and pluralistic approaches is important to consider in two-parent families, because estimation and interpretation of WTP occurs within the context of a model of family decision-making. Welfare measures derived from unitary and pluralistic models are not in general identical, although there are specific cases where the two approaches give the same WTP expressions (Mount et al. 2001). The mathematical form of the WTP expression, its interpretation, and the question of whether WTP for children's health may be estimated based on the behavior or survey

responses of only one of two parents all depend on the choice between unitary and pluralistic approaches. Welfare measurement is simpler in the unitary framework because benefit estimation methods developed for individuals easily extend to the family setting, but some empirical evidence discussed below casts doubt on the validity of the unitary approach.

In addition to the specification of preferences, theoretical models can be distinguished in two other ways when considering children's health. First, it is useful if the model accommodates household production relatively easily. Household production functions often are used to analyze individual household resource allocations affecting health and to account for protective or defensive behavior. "Protective behavior" refers to actions taken to defend against some health risk, for example by reducing exposure to pollution or by mitigating the effects of exposure. Examples of protective behavior include asthmatic children's greater reliance on medication when air pollution levels are high (Roemer, Hoek and Brunekreef 1993) and a family's use of bottled water or a water filtration system at home to reduce exposure to contaminated drinking water. Sections 4 and 6 of this report provide additional examples of defensive behavior in the context of studies estimating parental WTP to protect children's health.

A second point to consider is how easily the model accommodates non-rival goods and intra-family externalities. A good is non-rival if one family member's use of it does not reduce the amount available to other family members. Thus, a family that installs a water filtration system at home, or that changes residential location to avoid pollution, is employing a non-rival protective action in that all family members benefit. Conversely, increased use of asthma medication when air pollution levels are high would be a rival protective action. Intra-family externalities arise when the health of one family member affects the resources available to others. A common example occurs when a parent misses work or diverts time from other activities to care for a sick child.

Unitary Models

The unitary approach has been adopted in most economic studies of children's health, including those focused on estimating parental WTP for children's health. The existence of a single utility function means that household WTP (as opposed to individual WTP) is a relevant welfare measure, and existing benefit estimation methods are applicable. The approach readily accounts for household production functions, non-rival consumption, and intra-family externalities, as shown by Jacobson's (2000), extension of Grossman's (1972) model of health investment to a family setting.

Empirical applications of unitary models to children's health issues provide two results that are of particular interest. First, family structure and composition affect resource allocations and health outcomes experienced (Case and Paxson 2001, Rosenzweig and Schultz 1982). The "quantity-quality tradeoff" represents one example in which fewer resources are invested per child when more children are present (Hanushek 1992, Haveman and Wolfe 1995). Researchers previously have not emphasized factors like family size or marital status when estimating an adult's WTP to protect his or her own health, but these factors may be important determinants of parental WTP for children's health in a family setting. Second, parents do not necessarily treat the health of all family members equally, but instead may allocate resources differently depending on health status, gender or age (Pitt, Rosenzweig and

Hassan 1990, Pitt and Rosenzweig 1990). These results suggest that parental WTP also may vary between family members, and in particular that WTP for adults' and children's health need not be identical.

Despite successful empirical applications of the unitary approach, a key implication of the model often is been rejected when tested. The model implies that household decisions depend on the pooled income of family members, not on the individual amounts accruing to individuals. The hypothesis of pooling has been rejected in tests involving demands for private goods (Browning et al. 1992, Lundberg, Pollack and Wales, 1997), as well as in tests focused on decisions involving children. Schultz (1990) found that an increase in unearned income accruing to husbands and wives in Thailand had opposite effects on fertility; in turn, fertility is a key determinant of allocations of resources to children according to the quantity-quality tradeoff. Thomas (1990) found that positive impacts of unearned income on child health were greater when the income accrued to mothers than to fathers in Brazil. Haddad and Hoddinott (1991) report that an important indicator of child health in Cote d'Ivoire was positively related to the share of family resources controlled by the mother. Furthermore, men and women tend to perceive risk differently (Davidson and Freudenburg 1996). These results, which contradict the income pooling implication of the unitary model, as well as the inability to make inferences about individual welfare in the unitary approach, have stimulated additional interest in pluralistic models.

Pluralistic Models

Several models have been developed that view household decisions in terms of adults with individual preferences making collective decisions. Two of the more prominent models, the Nash cooperative bargaining model of Manser and Brown (1980) and McElroy and Horney (1981) and the collective approach of Chiappori (1988) have been used or proposed for nonmarket valuation.

In the cooperative bargaining model, a couple divides the potential gains from marriage by acting as if they maximize the Nash product $[U_m(\square) - T_m][U_f(\square) - T_f]$, where T_i, $i = m$ (mother), f (father) denotes the threat points. Somewhat different implications are obtained depending on how the threat point is specified (Bergstrom 1995), but the most common approach is to view each spouse's threat point as the maximum utility he or she could obtain outside of the marriage. Bolin, Jacobson and Lindgren (2001) have extended the Grossman (1972) model to a family setting using the cooperative bargaining framework.

Mount et al. (2001) develop a model of the value of reduced fatality risk for adults and children in a family using a Nash cooperative bargaining model. They show that the value of statistical life (VSL) in their model has the same form as the VSL from a unitary model. However, this result hinges on the assumption that the threat points are independent of risk and exogenous factors in the model. Bergstrom (1997) discusses how independence of the threat points implies that household decisions are consistent with maximization of a unitary utility function. While the assumption that threat points are independent of exogenous factors may or may not be reasonable in the Mount et al. model, the assumption is unlikely to hold in general. For example, an environmental change that improved a child's health or safety could easily increase the utility of the custodial parent following a divorce. The resulting impact on the threat point would be reflected in the spouse's WTP for the environmental change. In general, WTP

expressions obtained from cooperative bargaining models will differ from, and be more complex than, WTP expressions obtained from the unitary approach.

An alternative and more general pluralistic model of family decision-making is the collective approach of Chiappori (1988, 1992). Rather than assume a specific bargaining solution for the household allocation problem, the collective approach assumes that the household reaches a Pareto efficient allocation of resources by some unspecified decision process.[3] Pareto efficiency implies that the household acts as if to maximize the utility of one spouse, subject to a constraint on the other spouse's utility. The model envisions this equilibrium occurring through a two-step process in which the spouses allocate resources after first agreeing on a sharing rule that divides income between them.

Although empirical applications of the collective approach generally have focused on estimating labor supply or consumption demand, Smith and van Houtven (2002) extend the collective model to consider measurement of Hicksian consumer surplus. They show how two measures of compensating variation can be derived from the model, depending on whether the spouses' shares of income are held constant. However, they do not specifically consider WTP for children's health or safety.

In the collective approach, each spouse's WTP depends on his or her share of family income. But the sharing rule is an analytical device that is not observed. Consequently, identification of the model and recovery of individual preferences requires some way of distinguishing the individual utility functions and sharing rule from one another. This is accomplished by assuming that some variables affect the sharing rule but not preferences and by assuming that a good is "assignable," so that each spouse's separate consumption can be observed. Thus household production, non-rival goods or intra-family externalities complicate the approach by reducing the separability of decisions between spouses. For example, the assumptions proposed for identification in the presence of household production may not be plausible (Apps and Rees, 1996, 1997; Chiappori, 1997). In view of the potential importance of household production and intra-family externalities in models of children's health, the difficulties these factors pose for the collective approach may partly explain why most attempts to estimate parental WTP for child health have used unitary models.

Difficulties Hindering the Use of Parental Preferences to Estimate Social Benefits

In the presence of competing models of parental preferences, there is some uncertainty concerning the appropriate framework to use when estimating parents' WTP to protect children's health. More broadly, at least two other difficulties complicate the use of any model of parents' preferences to estimate social benefits of children's health. These difficulties reflect concern about whether application of the parental perspective would promote sound social decisions.

One concern is that parental WTP may be based on inaccurate perceptions of the health risks faced by children. Misperception of risk raises questions about whether social decisions should be based on individual WTP (Portney 1992). This problem potentially arises whenever environmental health risks are valued, but it may be compounded when risks to children are considered. Jacobson (2000) argues that it is easier to judge whether the benefit of an incremental health investment justifies the cost when considering one's own health as opposed to the health of another person. While individuals have difficulty accurately assessing their own risks, parents may find it even more difficult to assess risks facing their children. Similarly, parents may be

less certain about future health status or medical technology when considering children's lives than when considering their own, relatively shorter, remaining lifetimes.

A second concern is that society may be more willing to respect an adult's preferences concerning her own health than to respect a parent's preferences concerning her child's health. For example, respect for individual preferences would imply accepting an adult's decision to smoke cigarettes so long as the adult believed the satisfaction of smoking justified the risk to health. Respect for parental preferences would imply accepting a parent's smoking, so long as she believed her satisfaction justified her own health risk as well as the risk imposed on her child. Society may not be willing to respect parental preferences if it seems that at least some parents are inadequately attentive to the health of their children. Additionally, empirical evidence mentioned in the previous section suggests that parents do not treat the health of all children equally. But any differences in parental WTP between children of different age, gender or health status may be inconsistent with social standards. In these cases, parental WTP for children's health may not reflect social preferences.

A related way in which social values may diverge from parental WTP would occur if members of society feel paternalistic altruism toward children outside their own households. As discussed by Jones-Lee (1991, 1992), social WTP coincides with aggregate private WTP under pure altruism (caring for the general well-being of others while respecting their preferences), but not under paternalistic altruism (caring for a specific component of others' well-being, such as their health). If society were less willing to respect parental preferences for children than to respect individual preferences, then paternalistic rather than pure altruism would be more likely to occur for children than for adults.

Empirical evidence can shed some light on the nature of these difficulties. Tests between competing models of parental preferences, evidence on parents' perceptions of children's health risks, measures of altruistic WTP toward children in other households, and comparisons parents' WTP for their own and their children's health would be particularly useful in evaluating the difficulties considered here. But there have been relatively few studies of parents' WTP for children's health and some of these issues have not been addressed fully in the existing literature. The next section examines selected empirical applications of the parental perspective.

Empirical Applications of the Parental Perspective

The parental perspective has been used to estimate the value of statistical life (VSL) for children as well as to estimate values of reduced pollution and reduced morbidity using health production and stated preference approaches. These studies are reviewed briefly below, and implications of the existing research are drawn out at the end of this section.

Protective Behavior and the Value of Statistical Life for Children

Carlin and Sandy (1991) used a defensive behavior approach in a unitary model to estimate the value of a statistical life of a child under five years old. In the model, a mother makes tradeoffs between the benefits of reduced risk and the money and time costs of using automobile child-safety seats. The authors estimate a VSL for a child under age five of approximately $420,000 ($1985), net of costs of child raising. This

value is substantially below the estimate obtained by Blomquist (1979) in his study of adult seat belt usage.

Blomquist, Miller and Levy (1996) also examine motorists' use of child safety seats to estimate a VSL for children. Adjusting for misperception of risk and addressing the impact on utility of restraining children in car seats, they obtain a VSL for children under age five of $3.7 million ($2000). They also estimate a VSL for adults, based on seat-belt use, of $2.8 million.

Jenkins, Owens and Wiggins (2001) estimate a VSL for children and adults based on purchases of bicycle helmets. They compute the ratio of the annualized cost of a bicycle helmet to the reduction in fatality risk using aggregate data. When accounting for the fact that helmets are not always worn, the authors estimate a VSL that is approximately equal across two age groups of children (five to nine years and 10 to 14 years), but larger for adults (20 to 59 years). The methods used preclude testing whether these differences are statistically significant. The estimates for adults and the older children exceed the median, however, while the estimate for the youngest age group is less than the median, making it difficult to assess how median VSL might vary across age groups.

Safety seats and bicycle helmets are rival protective actions, in that only one person may use the good at any given time. In contrast, Mount et al. (2001) treat automobile safety as a non-rival good within the family. They use a modified hedonic approach to estimate a VSL for children, adults (younger than 65 years), and seniors (older than 65 years) in the context of a Nash cooperative bargaining model. According to this model, the family acts to equate the marginal benefit of safety to the marginal cost of purchasing and operating a safer car. The marginal benefit equals the sum of the automobile-usage-weighted VSL of each family member. Data limitations force the authors to restrict their analysis to single-car families, to assume how many occupants ride in a vehicle and where they sit, and to assume an income elasticity of the VSL in order to adjust for income differences between types of families. Relative valuations obtained are quite sensitive to the two values of income elasticity used. The VSL for children is 32 percent less than the adult value if the income elasticity is 0.33, but 38 percent more than the adult value if the income elasticity is unity.

Health Production Function Estimates of the Value of Reduced Pollution or Reduced Morbidity

Joyce, Grossman and Goldman (1989) apply a health production function approach in a unitary model to estimate economic benefits of reductions in infant mortality associated with ambient air quality. Parents are assumed to choose inputs such as smoking and prenatal care to influence the child's birth weight and probability of survival. The model is estimated separately by race using county-level data. Although qualitatively similar results were obtained in white and black subsamples, the estimated WTP for reduced sulfur dioxide pollution was four to seven times larger for blacks than for whites.

Agee and Crocker (1996) estimate parents' WTP for reduced lead body burdens in a child, using a health production function approach in the context of a unitary model. Data were obtained from an earlier study by Needleman et al. (1979). Agee and Crocker employ a methodology similar to the prior work of Dickie and Gerking (1991) on adults' health benefits from ozone control. This method requires that the change to be valued causes an exogenous shift in the demand for an input that is necessary to

produce better health. In the Agee and Crocker (1996) study, changes in a child's body lead burden shift the demand for chelation. Mean WTP for a one percent reduction in body lead burden ranged from $11 among parents who do not chelate to $104 among parents who do, with an overall mean of $16 per child for a one percent reduction in body lead burden. Implied aggregate benefits were two to 20 times larger than previous estimates of illness costs.

Agee and Crocker (2001) use data from the 1991 National Maternal and Infant Health Survey to estimate smoking mothers' valuations of their own and their children's health in the context of a unitary model. By computing ratios of the child and own valuations, the authors estimate the marginal rate of substitution (MRS). Health is measured on the "EVGFP" scale (excellent, very good, good, fair or poor) for the current state of health. The impact of maternal smoking on own and child future health is not considered directly. The estimated MRS implies that the average mother values her child's health about twice as highly as her own.

Dickie (2000) estimated parents' WTP to avoid acute illness in their children using a health production approach with a unitary model. Data were taken from the Panel Study of Income Dynamics, Child Development Supplement, and acute illness was measured by the annual number of days of school absence due to illness. He found that children with greater stocks of health capital, whose parents limit family size and invest in preventive and remedial pediatric care, experience fewer days of school loss. Estimated WTP to avoid one school loss day of about $500 is comparable to previously estimated valuations of workplace and household injuries.

Stated Preference Studies of Reduced Acute Morbidity

Viscusi, Magat and Huber (1987) and Viscusi, Magat and Forrest (1988) presented evidence on the value of reducing health risks to children from misuse of household chemicals. These studies did not have as their primary objective the estimation of WTP to reduce children's health risks, but rather were designed to test more general hypotheses about risk valuations. Adult subjects familiar with the type of household chemical considered were recruited by mall intercept and were asked their maximum willingness to pay, in the form of higher product prices, for reductions in risks of relatively minor injuries including child poisonings. In Viscusi, Magat and Huber (1987), reduced risks of child poisonings were valued more highly than other risks. But child poisonings were the most severe injuries considered, and therefore no inference can be drawn about the relative magnitudes of willingness to pay for equally severe injuries to adults and children.

Viscusi, Magat and Forrest (1988) used data from the same survey to estimate private and altruistic valuations of health risks. Respondents were asked their willingness to pay for an advertising campaign that would reduce risks to persons in other households in their home state and in the rest of the U.S. The majority of respondents indicated that they would pay something for the program in their home state, but less than one-quarter would pay any additional amount for a nationwide program. As discussed by Viscusi, Magat and Forrest, the resulting reduction in contributions probably reflects both a declining marginal valuation of altruism and a more remote relationship to persons outside of the state. Individuals' mean altruistic valuations were on the order of one cent per statistical injury to persons outside the individual's households. But implied aggregate altruistic valuations are quite large, because the individual values would be summed over a large population.

Liu et al. (2000) estimate Taiwanese mothers' WTP to prevent a cold for themselves and for their children using a stated preference survey. Respondents were asked to describe the symptoms and duration of the colds most recently experienced by themselves and their children, and were asked their willingness to pay for preventive medicine that would prevent recurrence of an identical illness. After accounting for the greater severity and duration of the mother's cold, WTP for the child was about 1.9 to 2.5 times greater than for the mother. Mothers were willing to pay more for their sons than for their daughters to avoid a cold.

Dickie and Ulery (2003) estimate parents' WTP to relieve acute illness affecting themselves or their children in a unitary model. Data are obtained from a stated preference survey conducted in Mississippi. Dickie and Ulery estimate marginal rates of substitution between child and parent illness of about two, indicating that parents' value avoiding an illness affecting their children about twice as highly as an equivalent illness affecting them. The estimated MRS is larger for younger children and falls toward unity as the child approaches adulthood. Parents' WTP to avoid own or child illness declines with fertility, increases with presence of asthma, and is higher in African-American than in white families.

Implications for Further Research

Previous research estimating parents' WTP for children's health highlights eight key issues that should be addressed in future empirical work. First, it would be useful to estimate jointly the value of reduced risk of morbidity and mortality in a consistent framework. Many environmental hazards increase risks of both illness and premature death, yet these two risks usually are treated separately in valuation studies. Similarly, the safety goods considered in each of the four studies reviewed here would reduce risk of both nonfatal and fatal injuries. But researchers often ignore the morbidity risk reduction (Carlin and Sandy, 1991) or else adjust for it by assuming some arbitrary division of the value of a safety good between risks of fatal and nonfatal injuries (Jenkins, Owens and Wiggins, 2001).

Second, when valuing an outcome that may be experienced by both adults and children, it is useful if a study estimates values for both adults and children in a consistent way. Comparing values for adults and children is helpful in understanding parents' preferences for children's health and in shedding light on issues of benefits transfer. For example, if parental valuations of children's health are approximately equal to adults' valuations of their own health, then existing benefit estimates based on transferring adult values to children may be reasonably accurate. Conversely, if values for children's health outcomes generally exceed values for comparable outcomes experienced by adults, as suggested by the three morbidity studies that estimate values for parents and children, then benefit estimates computed by applying adult valuations to children substantially understate benefits. Of course, this implication would apply only to health risks affecting children and adults.

Third, additional research is needed to estimate parental WTP for children's morbidity endpoints that have not been valued in the existing literature, as well as to provide additional evidence in situations where the relative magnitude of adult and child valuations is uncertain. For example, little evidence is available on parents' WTP to reduce risks of chronic or latent morbidity outcomes for their children. Likewise, three of the four mortality valuation studies discussed above estimate a VSL for adults and children, but they do not point to a consistent conclusion about the relative

magnitudes of these values. Further research is needed to assess the relative magnitude of VSLs for adults and children.

Fourth, it is important to account for parents' individual perceptions of risks faced by their children. Each of the studies estimating a VSL for children acknowledges that subjective risk perceptions often diverge substantially from objective risk estimates. Using objective risks to estimate WTP may bias results. But the studies either assume that parents perceive small changes in objective risks (on the order of 10^{-4} in Carlin and Sandy (1990) and 10^{-6} in Jenkins, Owens and Wiggins (2001) or adjust for risk misperception using a constant multiplicative scaling factor (Mount et al., Blomquist, Miller and Levi, 1996).

Fifth, as emphasized by the health production approach, the health outcomes an individual experiences partly reflect personal or familial choices. Some valuation efforts ignore the potential endogeneity of health outcomes, potentially leading to biased statistical estimation. In contrast, health production studies usually correct for endogeneity using instrumental variable methods. This approach hinges on the use of instruments that are truly exogenous variables correlated with an endogenous explanatory variable but uncorrelated with unobserved influences on the outcome of interest. In practice the selection of appropriate instruments usually is subject to considerable uncertainty, and results obtained can be quite sensitive to the choice of instruments. However, the method applied by Dickie and Gerking (1991) and Agee and Crocker (1996) does not require instrumental variables, provided that the change to be valued causes an exogenous shift in the demand for a necessary input. The empirical work presented in Section 7 presents an alternative approach to control for endogeneity through experimental design.

Sixth, some of the existing empirical evidence points to possible racial differences in WTP for children's health and illustrates the potential importance of family structure and composition. Further research should investigate how parental WTP varies with age, race, gender or health status, even though policy makers may prefer to use the same WTP value for all children.

Seventh, in many cases parents' investments in the health or safety of their children jointly affect other family members or parental utility. Although these problems do not arise in every case, they are common. Existing research reveals uneven handling of these issues. Mount et al. explicitly account for the non-rival consumption of automobile safety, while Blomquist, Miller and Levy attempt to assess the utility impact of using safety seats. However, Agee and Crocker (1996) assume that chelation has no joint costs or benefits, when in fact it is a painful treatment with potentially dangerous side effects, and Dickie (2000) assumes that pediatric care is used exclusively to reduce acute illness.

Eighth, previous research illustrates how difficult it is to estimate WTP from secondary data. The inability to account for morbidity risks, subjective risk perceptions and joint production problems in the VSL studies often can be traced to the use of secondary data. Secondary data used to value morbidity often do not include measures of the occurrence or severity of specific morbidity endpoints, forcing researchers to focus instead on behavioral reactions to morbidity changes like school loss days, or on coarse summary measures like the EVGFP scale for overall health. The data often lack other key variables as well, such as the money price of medical care, or the time required to consume it. Additionally, secondary data often force researchers to make untested assumptions about key parameters, such as the size of the income elasticity of

VSL, the length of useful life of a bicycle helmet, or the seating patterns in a family automobile. Collection of primary data allows many factors such as these to be measured and possibly controlled in an experimental design.

While stated preference studies avoid the problems associated with use of secondary data, the hypothetical nature of the valuation introduces potential for several well-known problems including insensitivity to scope and hypothetical bias. These problems may be mitigated in studies that focus on estimating ratios of values. For example, hypothetical bias would influence estimates of the MRS only to the extent that valuations of parent and child health were differentially contaminated by the bias. Variation in the extent of hypothetical bias between parent and child certainly is possible, particularly in designs like those used by Liu et al. (2000) and Dickie and Ulery (2003) where parents answer separate valuation questions for themselves and their children. This possibility would be mitigated in an approach that inferred both parent and child values from the same questions.

Remaining sections of this report discuss a new empirical study designed in light of the implications just discussed. The study estimates values of avoided morbidity and mortality for both adults and children in a consistent framework, while accounting for parents' subjective perceptions of risks that they and their children face. Primary data are collected according to an experimental design that randomly assigns exogenous changes in risk to survey respondents.

A Model of Perceived Morbidity and Mortality Risks in the Family

This section develops a specific parental perspective model that is subsequently used to value reductions in the risk of skin cancer to both parents and their children. From an environmental policy viewpoint, skin cancer is particularly interesting and important to consider for several reasons. Skin cancers are the most common cancers in the U.S., accounting for about half of all incidences (American Cancer Society, 1998). Also, links between environmental exposure to ultraviolet radiation and skin cancer are well established and chances of getting skin cancer, for a given amount of solar radiation exposure, depend partly on observable genetic characteristics such as skin type and complexion. Solar radiation exposure has been increasing in recent years due to stratospheric ozone depletion, and exposure during childhood is an important determinant of lifetime skin cancer risk (e.g., Reynolds, et al. 1996; Robinson, Rigel and Amonette, 1997; and Creech and Mayer, 1998). In fact, as stated in Section 1, the American Academy of Dermatology (1997) estimates that up to 80% of a person's lifetime exposure to ultraviolet light occurs before the age of 18 and even a few severe sunburns experienced by children between the ages of 10 and 15 years can triple the chances of developing malignant melanoma later in life.

The model adopts the unitary approach in which parental decisions are guided by one expected utility function and one set of perceived risks. This assumption is justified if expenditures on goods related to skin cancer risks represent a small fraction of family budgets. Protective actions considered in the model may be rival or non-rival. Intra-family externalities are ignored because skin cancer typically occurs later in life, so that the resources available to the parent or child are unlikely to be affected significantly by whether the other party contracts skin cancer. By the time a parent or child develops skin cancer, the other party, if surviving, is likely to live in a separate household.

The theoretical approach supports empirical estimation of morbidity and mortality risk reduction in a consistent framework. As mentioned in Section 4, prior empirical studies have valued either morbidity or mortality risk reduction, yet these two health endpoints are closely related. The model also has the advantage of considering a risk faced by both parents and children. This means that parents' values of reducing the risk to their children and to themselves can be compared. In fact, the model is useful in showing how to compute the marginal rate of substitution between risk reduction to the parent and risk reduction to the child. Estimates of marginal rates of substitution may assist in benefits transfer in cases where willingness to pay to reduce a risk has been established for adults but not for children.

The model to be applied has at least broad similarities to other prominent approaches taken in the literature on environmental risks to health. In their analysis of health consequences of exposure to hazardous wastes, Smith and Desvousges (1986, 1987) split the unconditional risk of death from exposure into the probability of exposure and the conditional probability of premature death given exposure. Their model, however, envisions only two health states (alive and dead), so morbidity is not explicitly treated. Eeckhoudt and Hammitt (2001) look at a model with two health states (alive and dead) and demonstrate how a specific risk to an individual's health (such as a possible fatal job accident) should be valued when that individual faces a set of independent life-threatening background risks. The model developed here generalizes this framework in that background risks incorporated may pertain to another family member. The value of reduced child morbidity, for example, is computed with parents' morbidity and mortality risks in the background. Shogren and Crocker (1991, 1999) consider a model with endogenous risk and examine conditions under which willingness to pay to avoid risk can be expressed without terms from the utility function. Risk also is treated as endogenous in the model developed here; in fact, it is measured as risk perceived by survey respondents. The method for estimating willingness to pay, however, rests on directly estimating an indifference relation showing utility-constant trade-offs between morbidity risks, mortality risks, and consumption goods. It does not rest on a particular model specification that happens to result in elimination of utility terms.

In the one-period version of the model presented here, a parent's expected utility E(U) is a probability weighted sum of utilities in 3^2=9 possible states of the world that depend on whether a parent and one child are healthy, sick, or dead. Extension to the case of a larger "family" (more than one child, for example) is not conceptually difficult, but would geometrically expand the number of health states and may be unmanageable when applied in a survey context.

The model focuses on four probabilities: (1) the probability that the parent will get skin cancer (S_p), (2) the conditional probability that the parent will die from skin cancer given that the disease is contracted (D_p), (3) the probability that the child will get skin cancer (S_c), and (4) the conditional probability that the child will die from skin cancer given that the disease is contracted (D_c). Probabilities are influenced by predetermined factors such as genetic endowments ($\mathtt{W}_j$, $j = p,c$), but nevertheless are treated as endogenously determined because parents may choose to engage in self- and child-protection behavior (Z_j, $j = p,c$). For example, parents may use sun protection products to reduce the chance that they or their children will get skin cancer

and may seek regular medical examinations to detect skin cancer at an early stage so that treatment might lower conditional death risk if this disease is contracted. Additionally, probabilities can be viewed as certain (known) or uncertain (stochastic). The assumption of uncertainty is attractive because parents may not form risk perceptions with complete precision, but the discussion below sticks to the easier case of certainty of probabilities. In any case, morbidity and conditional mortality probabilities are determined according to

$$S_j = S_j(Z_j, \mathrm{W}_j, \mathit{1}_j) \qquad D_j = D_j(Z_j, \mathrm{W}_j, \mathit{\alpha}_j), \qquad j = p, c, \quad (1)$$

where $\mathit{1}_j$ and $\mathit{\alpha}_j$ are experimental design parameters representing (hypothetical) treatments that reduce risk.

Perceived skin cancer risks are incorporated into the expected utility model as shown in equation (2).

$$\begin{aligned} E(U) &= (1 - S_p)(1 - S_c)U_0(Y) \\ &+ (1 - S_c)S_p[U_p(Y) + D_pV_p(Y)] + (1 - S_p)S_c[U_c(Y) + D_cV_c(Y)] \\ &+ S_pS_c[(1 - D_p)(1 - D_c)U_{pc}(Y) + (1 - D_c)D_pW_p(Y) + (1 - D_p)D_cW_c(Y) + D_pD_cW_{pc}(Y)], \end{aligned} \quad (2)$$

where U_0 denotes utility in the state where both parent and child are healthy, U_j denotes utility in a state in which either the parent or child ($j = p, c$) contracts skin cancer and the other does not and neither dies, V_j denotes utility in a state in which either the parent or child ($j = p, c$) dies from skin cancer but the other does not get it, U_{pc} denotes utility in the state where both parent and child get skin cancer but neither dies, W_j denotes utility in the state in which both parent and child contract skin cancer and one of the two dies ($j = p, c$) but the other does not, and W_{pc} denotes utility in the state in which both parent and child die from skin cancer. In states in which the parent and/or child die, parents' utility is taken to be positive; for example, if the child dies, the parent's life may still go on and if the parent dies utility may be obtained from a bequest. Also, Y denotes the parent's wealth net of: (1) expenditures for self- and child-protection goods (Z_j) and (2) bids for treatments presented in the experimental design ($\mathit{1}_j$ and $\mathit{\alpha}_j$). The parent's gross wealth is denoted as y and for simplicity here is assumed to be the same in all health states. Of course, parents may have different amounts of net wealth available because self- and child-protection expenditures may vary by health status. These differences are recognized, but are not made explicit here in order to economize on notation (see Shogren and Crocker (1991) for discussion of a model reflecting these aspects.)

The model can be manipulated to obtain values of reduced risk of morbidity and mortality. The starting point is equation (2), assuming that: (1) the parent already has chosen expected utility maximizing values of self- and child-protection expenditures in each health state, and (2) $\mathit{1}_j$ and $\mathit{\alpha}_j$ are initially zero. Morbidity and mortality values are obtained by calculating the sacrifice in y needed to hold $E(U)$ constant in the face of changes in treatment effects that increase safety. Prices of treatments and

magnitudes of risk reduction are randomized across sample members; thus parents are asked to value parametric risk changes. Assume that $\partial S_j / \partial \lambda_j = \partial D_j / \partial \alpha_j = -1$. Then, willingness to pay for a reduction in the probability of the child getting skin cancer (morbidity risk) can be obtained from equation (2) by setting $dE(U) = 0 = d\lambda_p = d\alpha_p = d\alpha_c$, assuming that re-optimization leads to negligible changes in expenditures for other self-and child-protective goods, and computing

$$\partial y / \partial \lambda_c = -[(1-S_p)(U_0 - U_c) + (1-S_p)D_c(U_c - V_c) + S_p(1-D_p)(U_p - U_{pc}) + S_pD_c(1-D_p)(U_{pc} - W_c) + S_pD_p(V_p - W_p) + S_pD_cD_p(W_p - W_{pc})]/\Delta \quad (3)$$

where Δ denotes the expected marginal utility of income, which is positive if the marginal utility of income is positive in each state. Also, the numerator of the right hand side of equation (3) is negative using the fact that $\partial S_j / \partial \lambda_j = -1$ together with the plausible assumptions that utility is positive in all states and that the utility differences in each term of the sum are positive (i.e., healthy is preferred to sick, sick is preferred to dead, one person sick is preferred to two people sick, etc.). Thus, $\partial y / \partial \lambda_c < 0$, indicating that wealth must fall to hold expected utility constant when the child's morbidity risk is reduced.

Willingness to pay for a small reduction in perceived conditional death risk faced by the child, holding all other perceived health risks constant, is

$$\partial y / \partial \alpha_c = -\{(1-S_p)S_c(U_c - V_c) + S_pS_c[(1-D_p)(U_{pc} - W_c) + D_p(W_c - W_{pc})]\}/\Delta \quad (4)$$

Thus $\partial y / \partial \alpha_c < 0$, if $\partial y / \partial \lambda_c < 0$.

Equations (3) and (4), together with corresponding results for parents ($\partial y / \partial \lambda_p < 0$, $\partial y / \partial \alpha_p < 0$), support three types of empirical estimates that are of direct interest. First, parents' marginal rate of substitution between reduced skin cancer risk to their children and reduced skin cancer risk to themselves is $(\partial y / \partial \lambda_c)/(\partial y / \partial \lambda_p)$. This ratio shows the extent to which parents value morbidity risks to their children differently than morbidity risks to themselves, holding conditional mortality risks (α_c and α_p) constant. It would be of interest to test whether $(\partial y / \partial \lambda_c)/(\partial y / \partial \lambda_p) = 1$. Second, because perceived unconditional risk of death from skin cancer is $R_j = S_jD_j$, $j = p, c$, parent's willingness to pay for a reduction in unconditional death risk for a child seen by parents, is

$$\begin{aligned} -\partial y / \partial R_c = {} & \{(1-P_c)(1-P_p)(1-R_p)U_0 + (1-P_c)[P_p(1-R_p)U_p - R_pV_p] \\ & + P_p(1-R_p)[P_cU_{pc} - W_c] + R_p[P_cW_p - W_{pc}]\}/\Delta \\ & \left(\frac{1-S_c}{1-R_c}\right)(-\partial y / \partial \lambda_c) + \left(\frac{1-D_c}{1-R_c}\right)(1/S_c)(-\partial y / \partial \alpha_c), \end{aligned} \quad (5)$$

where $P_j = (S_j - R_j)/(1 - R_j), \quad j = p, c$ denotes the conditional risk of a nonfatal case of skin cancer. This expression is positive as long as the marginal utility of wealth is positive and expected utility is higher when the child is alive than dead. Third, notice that the model permits a corresponding calculation of willingness to pay for a reduction in unconditional death risk for parents. This estimate is useful in its own right and as a benchmark in assessing the magnitude of $-\partial y / \partial R_c$ as might be done by looking at parents' marginal rate of substitution between their children's unconditional risk of death and their own unconditional risk of death $(\partial y / \partial R_c)/(\partial y / \partial R_p)$. It would be of interest to test whether $(\partial y / \partial R_c)/(\partial y / \partial R_p) = 1$. However, equation (5) cannot be used to estimate the value of a statistical life, if the risks considered occur in the future, because the value of a statistical life refers to willingness to pay today to save a life today (or in the very near future). The next section discusses survey data to be used to estimate the model, and estimation results are presented in Section 7.

Sampling, Survey Methods and Data

Sample Selection

Data were collected during summer of 2002 in a survey of 610 parents of children aged 3-12. All survey respondents were residents of the Hattiesburg, MS metropolitan statistical area. Hattiesburg is located in the southern part of Mississippi, has a mean annual high temperature reading of 77.5 degrees Fahrenheit, a subtropical climate, and a large number of sunshine days each year. Thus, residents have experience with exposure to ultraviolet radiation from sunlight, which has been linked to development of both melanoma and non-melanoma skin cancer. The Hattiesburg population of approximately 112,000 persons is comprised of 71.7% whites and 26.3% African-Americans. Melanoma incidence among whites is about 16 times the incidence of melanoma among African-Americans (Ries et al. 1999). In consequence, the Hattiesburg survey provides an opportunity to compare risk beliefs and willingness to pay for groups with quite different skin cancer incidence rates.

The sample was drawn by first generating all possible telephone numbers in the Hattiesburg area. This list was screened to remove business, government, and cellular numbers. Interviewers then began dialing the remaining telephone numbers at random. If the call reached a non-working telephone line, the number was removed from the list. If the call reached a working line, but no one answered or an adult was unavailable, the number was redialed up to two more times over the next 7 days. Dialing was scheduled so that if a number was dialed 3 times, contact attempts fell on a weekday, a weekday evening, and a Saturday. When a call reached an adult, interviewers described the general purpose of the survey (federally funded research on health risks to parents and their children) and asked whether the prospective sample member had at least one biological child between the ages of 3-12 living at the same address. If the adult did not meet this eligibility requirement, the interviewer ended the call and the number was not tried again. Otherwise, interviewers asked whether the person was willing come to the University of Southern Mississippi to participate in the survey, and stated that respondents would be paid $25 for completing the 30-minute questionnaire. Interviewers reached agreements with people to participate in the survey in about 1% of the total number of calls placed.

Survey Instrument

The survey, which was administered by computer using interactive software, began by ascertaining the race, age and gender of the respondent and the number of children living at home. Table 3.1 (see Annex) shows that of the 610 sample members, 75.4% were white, 20.0% were African-American, 23.4% were male, and 76.9% were under the age of 40. The average household size was 4.01 persons and an average of 2.08 children lived in each household. The responding parent had an average of 1.54 biological children between the ages of 3-12 living in their household. Biological children are considered in this study in order to look at characteristics governing skin cancer risk (e.g., fairness of skin and sensitivity of skin to sunlight) that are inherited from parents. The upper age limit of 12 years was chosen because parents have more knowledge and control of younger children than teenagers.

From among the biological children aged 3-12, one child was randomly selected (if there was more than one) and designated as the sample child. Because of random selection, about half (50.5%) of the sample children were male. The average age of sample children was 7.07 years. The remainder of the survey obtained information about the parent/respondent and the sample child. Information was not obtained about other children in the household to limit the length of the interview, to avoid repetitive questioning, and because the model presented in Section 3 assumes that parents treat each child equally.

The survey then asked preliminary questions about respondents' knowledge about skin cancer. As shown in Table 3.2 (see Annex), 95.4% or respondents had heard of skin cancer, 83.8% knew of someone (public figures, friends, or relatives) who had been diagnosed with this disease, 22.1% knew of someone who had died from skin cancer, 3.4% had been diagnosed with this disease themselves, and 71.1% had considered the possibility that one of their children might get skin cancer. Additionally, 80.3% of respondents had thought about the possibility that they might get skin cancer and 71.1% had considered the possibility that their children might get this disease. Thus, respondents appear to be generally aware of skin cancer, that their children could get it, and the possibility that this disease can be fatal.

After these preliminary questions, respondents' attention was directed to the chances that they or their sample children might get skin cancer in the future. Chances of getting skin cancer were assessed using an interactive risk scale that closely resembled the grid squares used by Krupnick et al. (2002). This approach was used because risk information appears to be better understood using this type of visual aid (Corso, Hammitt, and Graham 2001). The scale depicted a large square divided into 20 rows and 20 columns showing 400 equal-sized smaller squares. Initially, all 400 of these squares were green. Respondents changed green squares into red ones to represent the chance that an event might occur. By pressing a button at the bottom of each column of squares, they could recolor a column of 20 squares from green to red (or from red back to green). Additionally, they could change the color of any individual square by clicking on it with their mouse. A box beneath the scale showed the percentage of squares out of 400 that had been colored red. This calculation was updated each time the respondent made an alteration in risk scale.

Before using the scale to represent skin cancer risk, respondents were told about the meaning of "chances in 400" and given an opportunity to practice using the risk scale in the context of an unrelated event (a possible auto accident). Respondents then used the risk scale to represent their own chance of getting skin cancer in the future (or

of getting it again if they had already had it). Before using the scale, they were told not to consider how serious the case of skin cancer might be; rather they were to consider only the chances that they would get this disease. Then, they were given an opportunity to answer using the risk scale and were allowed to make as many changes as desired before moving on. After completing this task, respondents were shown a new risk scale and asked to estimate the sample child's lifetime chance of getting skin cancer, again disregarding the issue of severity. Table 3.3 (see Annex) presents frequency distributions for these responses. Risk estimates tended to pile up at the 5, 10, 15, etc. percent marks perhaps because respondents had the ability to recolor 20 squares at a time. In any case, risk estimates for both the parent/respondent and the sample child exhibit considerable variation, with some respondents believing that skin cancer is unlikely to occur (e.g., 25.3% of respondents believed that their sample child had less than a 10% chance of getting it) to occur, while others believed that skin cancer is inevitable (e.g., 8 of the 610 respondents thought that their child's chances of getting skin cancer exceeded 90%).

Table 3.4 (see Annex) shows mean risk estimates for white and African-American parents and children. White parents, on average, estimated that their own lifetime risk of getting skin cancer exceeded that for their sample child (27.6% vs. 22.8%), whereas the opposite was true among African-Americans (11.8% vs. 12.9%). Estimates of both white and African-American parents appear to exceed corresponding actual lifetime risk estimates reported in epidemiological studies. Ries et al. (1999) found that whites have about a 21% chance of getting either melanoma or non-melanoma skin cancer at some point in their life, while African-Americans have less than a 1% lifetime chance of contracting this disease. Thus, African-Americans appear to have overestimated risk by the greatest amount, an outcome consistent with literature suggesting that people tend to overestimate small risks. Additionally, the fact that the survey introduced the possibility of getting skin cancer again if the respondent had already had it does not appear to be an important complicating factor because sample members are relatively young and only 3.4% reported having been previously diagnosed with this disease.

The null hypothesis that perceived lifetime skin cancer risks are equal for parents and children can be efficiently tested by noting that respondents made pairs of risk estimates for themselves and for the sample children. Thus, an appropriate test statistic, asymptotically distributed as a unit normal variate, is the average of the individual parent/child risk differences divided by its standard error. For whites, this statistic is 4.85/0.65=7.46 so the null hypothesis is rejected. For African-Americans, on the other hand, the statistic is –1.08/0.76=-1.43, so the null hypothesis is not rejected. The outcome for whites may reflect parents' beliefs that they take greater precautions to protect their children from skin cancer risk with their own children than their parents did in an earlier period when less was known about the hazards of solar radiation exposure. Also, it may reflect a belief that skin cancer will take longer to develop in children than in parents together with the idea that delayed risks are perceived as smaller. African-Americans, on the other hand, perceive lower risk levels, and therefore may have fewer incentives to think about precautions against solar radiation exposure and how their own risk might differ from that of their children.

After estimating skin cancer risks, respondents were told that, according to the National Cancer Institute, the average person in the United States has a lifetime risk of getting skin cancer of 18%. Additionally, they were asked a series of questions about themselves and the sample child that drew attention to reasons why an individual's risk may differ from this average. These questions gathered information about: (1) skin

color and sensitivity to sunlight, (2) family history of skin cancer, (3) amount of time spent in direct sunlight, (4) experience with sunburns, and (5) use of sun protection products. Brief narratives provided information about how these aspects have been related to skin cancer risks in epidemiological studies. Table 3.5 (see Annex) shows skin characteristics by race with blacks, of course, reporting darker skin with less sensitivity to sunlight than whites. Table 3.6 (see Annex) presents information about sunlight exposure parents and children together retrospective information on sunburns experienced and use of sun protection products. Respondents reported greater levels of solar radiation exposure and more skin damage for themselves than for their children. Parents also tended to apply sun lotions with higher SPF levels to their children than they applied to themselves.

Then, respondents again were shown the risk scales with the initial risk estimates for themselves and for their sample children and asked whether they wished to change their estimate in light of the information that just had been presented. Surprisingly, respondents made virtually no revisions in their original risk estimates for themselves, but instead made significant downward revisions in risk estimates for their children. For parents, the average difference between original and revised risk estimates divided by its standard error is 0.0057/0.388=0.015 and for children, this statistic is 1.57/0.402=3.913. Thus, the null hypothesis of no revision is rejected for children, but it is not rejected for parents. In fact, the mean of revised risk estimates for parents differed from the mean of the original risk estimates by about one-hundredth of a percentage point, whereas the mean of revised risk estimates for children was about 1.5 percentage points lower than the mean of the original risk estimates.

Once respondents had revised their lifetime skin cancer risk estimates, they were asked for their beliefs about age at onset and severity of this disease both for themselves and for their sample children. Regarding age at onset, respondents were asked, "If you do get skin cancer…at what age do you think that you would get it for the first time (or get it again)?" A parallel question asked for an estimate of age at onset of skin cancer for the sample child. Responses, tabulated in Table 3.7 (see Annex), were obtained for five-year age intervals between the ages of 40-79 with the oldest age category top-coded at age 80 or later. These responses were used to test the null hypothesis that parents believed they would get skin cancer at the same age as their sample children. Averaging the respondent-specific differences in age at onset estimates for parents and children shows that parents believe that their children would be 5.70 years older than they would be if skin cancer develops. This age difference, which has a standard error of 2.07, is statistically significant at the 1% level indicating that the null hypothesis of equal parent/child age at onset is rejected.

To assess perceived severity of skin cancer, respondents were asked, "Suppose that a doctor tells you that you have skin cancer and you begin treatment. What do you think is the chance that you would die within five years of this diagnosis?" In this way the perceived risk of contracting skin cancer was fixed before respondents considered the conditional risk of dying from the disease. Respondents answered using the previously described risk scale by estimating the chance of death in 400 (given the diagnosis of skin cancer) for both themselves and their sample child. Table 3.8 (see Annex) presents the frequency distribution of these responses. On average, respondents perceived higher conditional death risks for themselves (12.2%) than for their sample children (9.4%), a difference of 2.8 percentage points. Dividing this difference by its standard error yields 2.8/0.291=9.62. Thus, the null hypothesis of equal perceived conditional death risks for parents and children is rejected at the 1% level. Also, about

two-thirds of respondents believed that their conditional risk of death given a diagnosis of skin cancer is 10% or less and about three-fourths of respondents believed that if similarly diagnosed, their sample child's conditional risk of death is 10% or less. Many respondents felt that the conditional risk of death is virtually zero both for themselves and for their children. This outcome suggests that respondents were aware that skin cancer, particularly non-melanoma skin cancer, is seldom fatal.

The next section of the survey assessed willingness to pay for a hypothetical sun protection product that would reduce skin cancer risk if the product were used as directed. The survey employed a private good rather than a public policy to reduce risk, because as shown in Table 3.6 (see Annex), over 5/6 of respondents had at least some experience purchasing sunscreen lotion. As a consequence, however, willingness-to-pay estimates do not account for any potential altruism for the children of others, an important issue to address in future research. Respondents became familiar with the hypothetical sunscreen lotion product by reading a label that was designed to look like those used on bottles of over-the-counter sun lotions (see Figure 1). The label indicated that the hypothetical sunscreen would be similar in most respects to currently marketed products (available in a variety of SPFs, non-comedogeneic, oil-free, and unscented), but that it would be more water-resistant and offer greater levels of skin cancer protection. Similarity of the new sunscreen to current products in all respects other than risk reduction and water resistance implies that joint benefits of sunscreen use (such as protection against sunburn or against premature aging of skin) do not affect willingness to pay for the new sunscreen[4].

Eight labels were used in the study. Labels were identical in every respect, except for differences in the amount of skin cancer protection they afforded. Four labels varied reductions in risk of getting skin cancer, while four other labels varied reductions in conditional death risk of this disease. Table 3.9 (see Annex) shows the reductions in risk stated on each of label. Labels A, D, E, and H offered equal percentage reductions in skin cancer risk (either 10% or 50%) for both adults and children. Labels B and F offered relatively greater skin cancer protection for children, while Labels C and G offered protection for adults. Each respondent was shown two randomly assigned labels. One of these offered reduced risk of getting skin cancer and the other offered reduced conditional death risk from skin cancer. The order in which these labels were presented was randomized.

After respondents were given time to read the label presented as if they were buying a product for the first time, they were referred back to the risk scale and shown the amount by which use of the hypothetical sunscreen would alter skin cancer risks for themselves and their children. Then, they were asked, "Now please think about whether you would buy the new sun protection lotion for yourself or your child. Please do not consider buying it for anyone else. Suppose that buying enough of the lotion to last you and your child for one year would cost $X. Of course, if you did buy it, you would have less money for all of the other things that your family needs. Would you be willing to pay $X for enough of the sunscreen to last you and your child for one year?" The value of X was varied between $20 and $125. When responses were affirmative, respondents were asked if they would pay a higher price; when responses were negative, they were asked whether a lower price would be paid. Initial and follow-up prices are shown in Tables 3.10 and 3.11 (see Annex) along with a frequency distribution of responses. As expected, more respondents expressed an intention to buy the new sunscreen at lower prices than at higher prices.

The survey concluded by ascertaining marital status, schooling completed, household income, and occupation for each respondent. Means of these variables are presented in Table 3.12 (see Annex). Mean household income was $53,000 per year. Only 16.5% of respondents had not attended college. Also, 75.9% of respondents were married and 59.0% worker full-time. The disproportionate number of college graduates may reflect that many respondents were graduates of University of Southern Mississippi and were willing to return to a familiar location to participate in the survey. The relatively small percentage of respondents that were employed full-time may reflect that most respondents were women with child-care responsibilities.

Empirical Results

Data described in Section 6 are used to estimate parents' marginal rates of substitution between their own risk of skin cancer risk and their children's risk of skin cancer. They also are used to estimate parents' marginal rates of substitution between the risk of getting skin cancer and the risk of dying from this disease given that it occurs both for themselves and their children. These estimates are obtained by regressing the bids for the hypothetical sunscreen on the risk changes shown on the labels. The equation estimated was obtained from the model presented in Section 5 by totally differentiating equation (2), setting $dE(U) = 0,$ and interpreting the bid for the sunscreen as the change in wealth, dy.

Estimates make use of a double-bound maximum likelihood procedure in which the latent dependent variable, willingness to pay for a year's supply of sun protection lotion, is assumed log-normally distributed. Estimates are obtained in a random effects framework by incorporating a respondent-specific error term to reflect that each parent expressed purchase intentions for two types of the hypothetical sun protection lotion. Also, estimation uses the fact that risk changes presented by the sun protection product labels were randomized across respondents. Thus, variables measuring risk change can be treated as exogenous in the regression and are orthogonal to other variables (e.g., family income and number of children in the household) that may be used as controls. This feature is an advantage over related studies reviewed in Section 4 because in econometrically estimating the desired marginal rates of substitution, it is not necessary to instrument for risk change and estimates are unaffected by the choice of controls.

Table 3.1 (see Annex) presents covariate definitions in column 1 and regression results in columns 2 and 3. Five covariates are dummy variables and interactions of dummy variables that reflect skin cancer risk reductions shown on the labels. GET shows whether the label presented a reduction in the chance of getting skin cancer or a reduction in the conditional risk of dying from it. Thus, GET=1 for Labels A-D and GET=0 for Labels E-H. Also, PCHG=1 if the label offered parents a 50% reduction in risk for themselves and KCHG=1 if the label offered a 50% risk reduction for their children. This setup means that willingness to pay for Label E, offering a 10% reduction in the conditional risk of dying from skin cancer for both parents and children, is estimated by the constant term in the regression. The willingness to pay for Label A, offering a 10% reduction in the risk of getting skin cancer for both parents and children is estimated by the constant term plus the coefficient of GET. The willingness to pay for Label B, then, would be estimated by the willingness to pay for Label A plus the coefficient of KCHG*GET. Willingness to pay for the risk reductions indicated by the other labels can be estimated in a corresponding manner. Remaining covariates measure household income and number of children per household.

For the estimates presented, likelihood ratio tests at the 1% level reject the null hypotheses that: (1) the variance of the parent-specific error is zero and (2) all slope parameters are jointly or individually zero. The positive coefficients of GET*PCHG, GET*KCHG, (1-GET)*PCHG, and (1-GET)*KCHG indicate that parents are willing to pay more for larger risk reductions than for smaller risk reductions (see Hammitt and Graham 1999 for further discussion of this issue). Also, because risk changes were randomly assigned to sample members, variables used to distinguish between the eight labels are orthogonal to respondent characteristics. Thus, when additional covariates are included in the column 3 regression, coefficients of the label variables are almost identical to those presented in the column 2 regression. Moreover, in column 3, the coefficient of household income is positive and significant indicating that respondents with higher incomes are willing to pay more for the new sunscreen. The coefficient of the number of children, on the other hand, is negative suggesting that respondents with more children are less inclined to pay as much for protection for themselves and just one of their children. This outcome is consistent with the idea discussed in Section 2 that fewer resources are invested per child when more children are present.

Additionally, coefficient estimates of the label variables can be used to estimate values of willingness to pay and marginal rates of substitution discussed in connection with the model in Section 5. Estimates from the column 3 regression are used for this purpose, although the choice of which regression to use matters little because coefficients of the label variables are virtually identical in each. Estimates of WTP in Table 3.2 (see Annex) are interpreted as values of a statistical case of skin cancer or a statistical life in the future and are computed by first calculating marginal WTP using equations (3) and (5), and then inflating to the value of a statistical case. Marginal WTP was estimated using the regression to compute willingness to pay for 1% risk changes (recall that the dependent variable is in natural logarithms) and then using the sample mean of the baseline risk to translate the value of a percentage risk reduction to the value of an absolute risk reduction. The resulting values reflect parents' WTP in the first year only and cannot be used to estimate the value of statistical life. The value of a statistical life refers to willingness to pay today to save a life today (or in the very near future), whereas the willingness to pay values that can be computed from the Table 3.1 (see Annex) regressions refer to reducing risk of events in the distant future, as is clear from the discussion of perceived skin cancer latency in Section 6. Also, marginal rates of substitution shown in Table 3.3 (see Annex) can be computed as ratios of WTP values given in Table 3.2 (see Annex). The child-to-parent WTP ratios reflect parents' relative valuation today of future risks to themselves and their children, given the longer latency period associated with the children's risk, and thus represent one type of tradeoff relevant for policy purposes.

As shown in Table 3.3 (see Annex), parents' marginal rate of substitution between their children's risk of getting skin cancer (S_c) and their own risk of getting skin cancer (S_p) is 2.05. This value, which is a tradeoff between unconditional morbidity risks, is significantly different from unity at the 1% level and suggests that parents are willing to pay about twice as much to reduce lifetime skin cancer risk for their children as for themselves. Correspondingly, parents' marginal rate of substitution between their children's unconditional risk of dying from skin cancer ($R_c=S_cD_c$) and their own unconditional risk of dying from skin cancer ($R_p=S_pD_p$) is 2.33. Again, this value is significantly greater than unity at the 1% level and indicates that parents are willing to pay more than twice as much to reduce the unconditional chance of dying from skin cancer for their children as for themselves. That parents are willing to pay more to reduce risks to their children's health than they are willing to pay to reduce risks to

their own health is of particular interest because age at onset of skin cancer is in the more distant future for children than for parents. Obviously, parents are older than their children and parents' estimates of age at onset (see Section 6) are about 6 years higher for their children than for themselves. If the time to onset of illness were the same both for parents and children, the marginal rate of substitution values may well be larger.

Table 3.3 (see Annex) also reports calculations of parents' marginal rates of substitution between the unconditional risk of dying from skin cancer and the unconditional risk of getting skin cancer for themselves and for their children. Whereas the marginal rates of substitution discussed above reflect tradeoffs between the same risk faced by different people, these calculations reflect tradeoffs between different types of risk faced by the same person. As shown in Table 3.3 (see Annex), parents' marginal rate of substitution between unconditional death risk and unconditional morbidity risk for themselves is 19.16 and the corresponding value for their children is 21.78. These estimates indicate that parents are willing to pay approximately 20 times more to reduce unconditional death risk by one unit than to reduce unconditional morbidity by one unit. This outcome supports the idea that public policies aimed at reducing death are much more important to people than policies aimed at reducing morbidity.

Conclusions

This report has critically reviewed the economics literature on what parents are willing to pay (WTP) for greater protection of their children's health and provided new empirical estimates from a study of skin cancer. Theoretical foundations of the parental perspective approach to valuation, including both unitary and pluralistic models of family decision-making were reviewed. The report discussed difficulties arising when the parental perspective is used to estimate social benefits, and examined prior empirical research to assess issues that should be considered in future research.

A detailed illustration of application of the parental perspective to value morbidity and mortality risks affecting children was presented. The application focused on skin cancer, the most common form of cancer in the U.S. Links between environmental exposure to ultraviolet radiation and skin cancer are well established, and chances of getting skin cancer, for a given amount of exposure to solar radiation, depend partly on observable genetic characteristics such as skin type and complexion. The theoretical model adopts the unitary approach and supports empirical valuation of morbidity and mortality risks faced by both parents and children in a consistent framework. Risk is treated as endogenous and is measured as the risk perceived by survey respondents. The method for estimating WTP rests on directly estimating an indifference relation showing utility-constant trade-offs between morbidity risks, mortality risks, and consumption goods.

The model provides a basis for computing parents' marginal rates of substitution between risk of death from skin cancer faced by both themselves and their children. This calculation shows how parents value children's health relative to their own and may be useful benefits transfer in situations where willingness to pay for reduced risk to adults have been established but corresponding values for children are not available. The model is estimated using data collected by an interactive computerized questionnaire administered on the University of Southern Mississippi campus during summer of 2002. Key aspects of the experimental design were to: (1) determine parents' perceptions of skin cancer risk to themselves and their children, and (2) obtain

willingness to pay for skin cancer risk reductions. Risk reductions were presented to parents using randomly assigned labels of a hypothetical sun lotion that offered different amounts of protection to adults and children. Random assignments of risk reductions facilitate estimation of marginal rates of substitution between parent's health and children's health. For example, parents' marginal rate of substitution between their own lifetime chances of getting skin cancer and their children's lifetime chances of getting skin cancer is about two. This indicates that parents value reductions in risk to their children's health more than reductions in risk to their own health. Additionally, parents' marginal rates of substitution between risk of getting skin cancer and risk of dying from it are about for 20. This indicates that parents value reductions in mortality risk much more than reductions in morbidity risk, for both themselves and their children. Of course, the rate of substitution between morbidity and mortality risk may differ for other health effects and might even be less than unity for illnesses or injuries resulting in permanent disability.

Empirical results obtained suggest that the recent policy emphasis on protecting children's health may be justified from an efficiency standpoint when a parental perspective is adopted. Estimating willingness to pay for children's health by transferring estimates computed for adults on a one-to-one basis would appear likely to substantially understate children's health benefits. Although results in this and other recent research suggest that parents are willing to pay about twice as much to protect their children's health as to protect their own, it is important to note that little evidence yet exists on how the marginal rate of substitution may vary across different health risks or between different demographic groups. If the value of child health relative to parental health varies significantly, for example with the age, gender or health status of the parent or child, the estimating children's health benefits as any constant multiple of adult benefits may be misleading. Primary research directed at valuing children's health protection is likely to yield more reliable benefit estimates for policy purposes.

Notes

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[3] The cooperative bargaining model implies a Pareto efficient solution and so could be viewed as one example of a decision process underlying the collective approach.

[4] See Dickie and Gerking (1996) for analysis of how joint products affect demand for sunscreen.

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Annex 3.A
Supporting Tables

Table 3.1 Respondent and Household Characteristics

n=610	
Gender	
Male	23.4%
Female	76.6%
Age	
Less than 25	6.9%
25 to 29	18.0%
30 to 34	26.9%
35 to 39	25.1%
40 to 44	17.0%
45 to 49	3.3%
50 and up	2.8%
Race / Ethnicity	
White, not Hispanic	75.4%
Black, African American	20.0%
Hispanic	2.0%
Asian / Pacific Islander	0.7%
Native American / Alaskan Native	0.5%
Other	1.5%
Household Information	
Household Size	4.01
Children	2.08
Biological Children Aged 3-12	1.54

Table 3.2 Respondents' Familiarity with Skin Cancer

n=610	
Have heard of Skin Cancer	95.4%
Know of Someone Diagnosed	83.8%
Known of Someone Who Died	22.1%
Have Been Diagnosed	3.4%
Relative Diagnosed	20.3%
Thought about Chance of Skin Cancer	80.3%
Thought about Child's Chance Skin Cancer	71.1%

Table 3.3 Frequency Distribution of Initial Risk Responses: Parents and Children

n=610		
Risk Range (%)	Parents	Children
0 - 4.75	85	75
5 - 9.75	57	79
10 - 14.75	70	94
15 - 19.75	65	69
20 - 24.75	65	74
25 - 29.75	66	73
30 - 34.75	45	35
35 - 39.75	23	19
40 - 44.75	36	25
45 - 49.75	6	5
50 - 54.75	53	32
55 - 59.75	4	2
60 - 64.75	5	7
65 - 69.75	0	1
70 - 74.75	5	2
75 - 79.75	6	5
80 - 84.75	2	3
85 - 89.75	3	2
90 - 94.75	8	5
95 – 100	6	3

Table 3.4 Mean Initial Risks: Parents and Children by Race

White, n=460	
Parent	27.6%
Child	22.8%
African American, n=122	
Parent	11.8%
Child	12.9%

Table 3.5 Skin Characteristics by Race

Respondents		
	White, not Hispanic	Black / African American
	n=460	n=122
Natural Skin Color		
Very Fair	23.5%	3.3%
Moderately Fair	36.7%	5.7%
Medium	37.6%	58.2%
Dark	2.2%	32.8%
Skin Type		
Always Burns	30.9%	2.5%
Burns then Tans	49.6%	12.3%
Tans	9.6%	36.1%
Tans Easily	8.9%	14.8%
Neither Tans nor Burns	1.1%	34.4%

Table 3.6 Exposure History and Protective Actions: Parents and Children

	Respondent	Child
Exposure		
Direct Sunlight as Child/Teenager		
More than Others	33.3%	12.0%
Same as Others	53.3%	61.4%
Less than Others	13.4%	26.6%
Lifetime Exposure		
Greater than Others	28.5%	11.3%
Same as Others	53.5%	66.4%
Less than Others	18.0%	22.3%
Sun Protection Product Use – Total	486	530
Use During Summer Outdoors		
Less than half the time	28.0%	19.0%
About half the time	24.7%	24.7%
More than half the time	19.1%	20.6%
Always or almost always	28.2%	35.7%
SPF Normally Used		
Less than 15	16.0%	6.4%
15 to less than 30	41.8%	23.4%
30 or higher	42.2%	70.2%
Skin Damage		
Sunburn	85.6%	59.8%
Bad Sunburn	76.4%	23.1%
3 or more Bad Sunburns	54.9%	5.1%
Bad Sunburn as a Child / Teenager	70.0%	--

Table 3.7 Distribution of Age at Skin Cancer Diagnosis: Parents and Children

n=610		
Age at Diagnosis	Parents	Children
Before Age 40	61	99
Between Ages 40 and 44	81	61
Between Ages 45 and 49	79	66
Between Ages 50 and 54	127	97
Between Ages 55 and 59	72	70
Between Ages 60 and 64	99	65
Between Ages 65 and 69	49	54
Between Ages 70 and 74	24	59
Between Ages 75 and 79	6	16
Age 80 or later	12	23

Table 3.8 Frequency Distribution of Conditional Death Risk Estimates: Parents and Children

n=610		
Risk Range (%)	Parents	Children
0 - 4.75	103	142
5 - 9.75	163	194
10 - 14.75	122	111
15 - 19.75	67	44
20 - 24.75	42	31
25 - 29.75	26	23
30 - 34.75	13	8
35 - 39.75	8	8
40 - 44.75	7	7
45 - 49.75	5	2
50 - 54.75	19	11
55 - 59.75	2	1
60 - 64.75	3	0
65 - 69.75	0	0
70 - 74.75	2	0
75 - 79.75	0	0
80 – 100	0	0

Table 3.9 Hypothetical Sun Protection Product Labels

Label	Percent Change in Morbidity Risk			Percent Change in Mortality Risk	
	Parent	Child		Parent	Child
A	10	10		0	0
B	10	50		0	0
C	50	10		0	0
D	50	50		0	0
E	0	0		10	10
F	0	0		10	50
G	0	0		50	10
H	0	0		50	50

Table 3.10 WTP Responses for Hypothetical Sun Protection Product with Reduced Skin Cancer Risk Labels

n=610							
				WTP Responses (Initial / Follow-Up)			
Initial Price	If "YES" to Initial, Higher Follow-Up Prices	If "NO" to Initial, Lower Follow-Up Prices		Yes / No	Yes / Yes	No / Yes	No / No
20	40	15		10	26	1	6
25	45	10		24	48	6	7
30	50	20		12	20	1	4
40	75	25		18	13	4	5
50	90	20		28	35	15	15
50	100	35		13	11	6	9
60	120	45		12	8	2	14
75	120	35		24	23	15	15
100	150	45		21	22	12	28
125	200	60		14	29	6	28

Table 3.11 WTP Responses for Hypothetical Sun Protection Product with Reduced Conditional Death Risk from Skin Cancer Labels

n=610							
				WTP Responses (Initial / Follow-Up)			
Initial Price	If "YES" to Initial, Higher Follow-Up Prices	If "NO" to Initial, Lower Follow-Up Prices		Yes / No	Yes / Yes	No / Yes	No / No
20	40	15		15	20	0	3
25	45	10		20	48	6	9
30	50	20		9	23	2	11
40	75	25		10	15	4	6
50	90	20		17	28	18	11
50	100	35		12	10	3	11
60	120	45		13	13	4	11
75	120	35		30	33	21	12
100	150	45		16	33	17	16
125	200	60		14	18	16	32

Table 3.12 Demographic and Socioeconomic Characteristics

n=610	
Household Income	
Less than $20,000	18.0%
$20,000 to less than $50,000	38.0%
$50,000 to less than $75,000	20.7%
$75,000 to less than $100,000	14.4%
$100,000 and up	8.9%
Mean Household Income	$53,000
Educational Attainment	
< High School	1.8%
High School, including Equiv	14.7%
Some College (incl. 2-yr degree)	32.3%
4-yr Degree	28.7%
Graduate / Professional Degree	22.5%
Marital Status	
Married	75.9%
Divorced	9.3%
Separated	3.4%
Widowed	0.5%
Never Married	9.3%
Living with a Partner	1.5%
Employment Status	
Full-time	59.0%
Part-time	16.3%
Not employed	24.7%

Table 3.13 Willingness to Pay for Reduced Risk of Skin Cancer

Variable	Coefficient (t-statistic)	Coefficient (t-statistic)
Constant	4.028 (130.32)	4.023 (86.63)
GET=1 if label changes risk of getting skin cancer; 0 if label changes conditional risk of dying from skin cancer	-0.089 (-1.992)	-0.092 (-2.079)
PCHG=1 if parent risk change = 50%; 0 if risk change = 10%	---[a]	---[a]
KCHG=1 if child risk change = 50%; 0 if parent risk change = 10%.	---[a]	---[a]
GET*PCHG	0.251 (6.82)	0.252 (6.86)
GET*KCHG	0.436 (11.84)	0.437 (11.85)
(1-GET)*PCHG	0.309 (8.38)	0.306 (8.30)
(1-GET)*KCHG	0.340 (9.23)	0.339 (9.22)
FAMILY INCOME ($10,000/year)	---[a]	0.031 (7.66)
NUMBER OF CHILDREN IN HOUSEHOLD	---[a]	-0.076 (-5.23)

a: Denotes omitted dummy variable.

Table 3.14 Willingness to Pay in the First Year to Prevent a Future Case of Skin Cancer or a Future Fatality

	Unconditional Morbidity	Unconditional Mortality
Parent	$526.42	$10,086
Child	$1080.79	$23,544

Table 3.15 Estimated Marginal Rates of Substitution

Marginal Rate of Substitution	Estimate (standard error)
Child vs. Parent Unconditional Morbidity	2.05 (0.35)
Child vs. Parent Unconditional Mortality	2.33 (0.32)
Unconditional Mortality vs. Unconditional Morbidity (Parent)	19.16 (3.15)
Unconditional Mortality vs. Unconditional Morbidity (Child)	21.78 (2.59)

Chapter 4

Transferring Measures of Adult Health Benefits to Children[1]

by

Mark D. Agee[2] and Thomas D. Crocker[3]

This chapter discusses issues involved in inferring the economic value of children's health from estimates of the value of adult health. A central theme is that if health benefit transfers across individuals are to be useful to policymakers, they must be founded on analytical as well as statistical commonalities. Whether the health benefits transfer issue is among adults or between adults and children, a vision that embeds the individual in a collective entity, such as a family with limited time and resources, can provide a common analytical structure having substantive economic content and able to accommodate varying measures of health. Adult values of own health relative to children's health are discernable by studying intra-family allocations of time and resources. The chapter concludes with an example of how the adult-child health benefits transfer problem can be dealt with empirically using a single analytical structure applying to both adults and children.

Introduction

Protection of one's health is expensive. The reasons are simple. Opportunities for a person to borrow to invest in his health are limited because human capital, a component of which is health, makes poor collateral. Also, free and functioning public health facilities to which a person has access do not exist or are free in name only. The individual must therefore draw upon his own resources or upon those of his kin to support his health.

This paper discusses issues involved in inferring the economic value of children's health from estimates of the value of adult health. Such inferences are an important dimension of the general economic benefits transfer problem in which policymakers, when confronted with yet another policy problem, must decide whether to extrapolate to a new setting the results of benefits studies performed in other contexts or to commission a new benefits assessment unique to the current setting. But the transfer of adult health benefit measures to children has a feature making it analytically and empirically quite different from benefits transfers involving, say, outdoor recreation or residential properties.[4] In particular, because market and public institutions usually do not fulfill the individual's demand for own health, he seeks help from another social institution—his family (we use family and household, and adult and parent, interchangeably throughout this essay).

Most adults and nearly all children live in family groups. But children have little if any economic standing in the society or in the family, though they have legal standing. They lack economic standing because modern industrialized societies believe children's mental and physical capacities are too limited for them to be independent decision-makers. Children are viewed as becomings rather than beings. They are not yet able to act and to speak knowledgeably for themselves. Family adults thus decide how much to invest in their children's health, physical, intellectual, and emotional. Society deems them to be their children's trustees. Whether genetics or the immediate cultural environments ultimately drive this investment, its proximate source is a family adult's decision and, for these adults, it must contest with the demands that own consumption and investments in own health make upon scarce family resources.[5] Scarce family resources cause the health of adult and child members to be economically linked.

Numerous studies have appeared in the last 15 years which summarize, with an eye to benefits transfer, the economic valuation literature on various facets of the natural environment or human health.[6] These summaries are statistical syntheses rather than qualitative literary overviews. They presume an unspecified grand analytical valuation model for the facet exists that has generated different random samples, each of which has been used in a distinct study. Each study is said to represent an imperfect replication of the undefined common analytical structure. One or another of a variety of statistical estimators is then used to explain the study procedure sources (sample characteristics, measurement technique, baseline conditions, functional form, etc.) of these imperfections or to build a grand valuation model based on the statistical similarities among studies.

This paper suggests that if transfers of health benefit estimates across individuals are to be useful to policymakers, they must be founded on analytical as well as statistical commonalities. Synthesis requires more than the application of statistical minutiae. A common vision across studies of what health is and of the economic

structure underlying investment behaviors which influence health must also prevail. Otherwise, statistical expositions of similarities among health benefits studies become little more than intellectually dexterous correlations rather than systematic explorations of the causes and effects of study differences. Whether the health benefits transfer issue is among adults or between adults and children, a vision that embeds the individual in a collective entity, such as a family with limited time and money resources, can provide a common analytical structure having substantive economic content which is able to accommodate varying measures of health. Adults' relative value of own health versus children's health is discernable by studying intrafamily or intracommunity allocations of time and resources. Given a common analytical structure for studying these allocation processes, statistical syntheses of such studies can be used to discover those differences in allocation outcomes that give rise to differences in adult-child relative health values. Hence, we focus in this paper on the use of collective, mainly intrafamily, allocation processes to infer the value of adult health relative to child health. A presumption that adult individuals choose to have no obligations to anyone other than themselves neglects the intrahousehold adaptation opportunities they have and thus leads to inaccurate estimates of adult values of own health. Some adult obligations are to children; thus accurate estimates of adult valuations of own *and* of children's health require careful analysis of intrahousehold allocations.

The adult-child health linkage due to intrahousehold allocation issues is easily seen with the following simple example. Let child health, H^C, be fully determined by

$$H^C = H^C(M; X), \tag{1}$$

where X is exogenous health infrastructure and M is endogenous (to household adults) health inputs such as physician use. The effect of a marginal improvement in health infrastructure on child health is

$$\frac{dH^C}{dX} = \frac{\partial H^C}{\partial X} + \frac{\partial H^C}{\partial M}\frac{dM}{dX}. \tag{2}$$

That is, a change in child health status resulting from a change in health infrastructure is due to a direct effect, $\partial H^C/\partial X$, and an indirect effect, $(\partial H^C/\partial M)(dM/dX)$. This indirect effect represents the intrahousehold response of endogenous inputs to the change in X. A similar expression applies to household adults. Inattention to this indirect effect will bias the impact of dM on health, whether for adult or for child. If adult health benefit measures are biased, their transfer to children will also bias the child health benefits measure, whatever the factor by which adult health benefits are to be divided or multiplied. Benefits transfer serves little purpose if the estimates to be transferred are inaccurate. Measures of adult or child health benefits which do not embed the individual within a household will be inaccurate. Also, if the intrahousehold response to an exogenous environmental change differs in its effects on adult and child health, inattention to intrahousehold allocation will bias estimates of the relative value of adult-to-child health, thus reducing if not eliminating usefulness of these estimates for subsequent benefits transfer exercises.

The next section speaks to issues likely to arise in any exercise involving the transfer of health benefits measures from adults to children, whatever the analytical foundation of the exercise. Because only about 20 economics studies of children's health benefits exist while a great many more adult studies are available, we presume that any transfer exercise must work from adults to children rather than vice versa.

Discussed in turn are measures of health, sources of differences between adults' and children's dose-responses and adult valuations of own and of children's exposures to environmental hazards, benefit measures, and transfer estimators. The central theme is that if transfer exercises are to avoid blunders similar to comparing apples to oranges, they must first specify a consistent accounting framework for each of these issues and then identify studies conforming to this framework. A third section presents an overview of collective, especially intrafamily, models of resource allocation, relates how these models have been used to arrive at estimates of adult values of own health relative to children's health, and briefly reviews the empirical results and properties of these results. Section four provides a synopsis of a model and associated empirical estimates of adult-child relative health values for a U.S. national sample of households who choose to participate in medical services markets. This example shows how a model of intrahousehold allocation can be used to obtain the sought-after relative valuation of general health within a single analytical structure applying to both adults and children. A conclusion summarizes the case for studying collective, especially intrafamily, allocation processes to establish factors with which to translate measures of adults' health benefits into those for children. We submit that collective allocation processes involving tradeoffs between adult consumption, adult health, and child health permit a shared analytical vision of adult and child health investments. The sharing encourages a common accounting framework across health benefits studies, thus enhancing the legitimacy for policy purposes of benefits transfer exercises.

General Issues

Health Measures

Any coherent treatment of the economic value of human health must employ measures of health consistent with biomedical knowledge which also matter to the time and resource-constrained individuals whose health is being measured. For a biomedical measure to express anything in terms of a person's preferences, the person either must be able to link the measure directly to his preferences or the researcher must reconcile the measure with a health state about which the person cares. Efforts to assess adult values of own health relative to children's health involve three added layers of complexity. First, not only must the adult measure of own health be meaningful to his preferences, the measure of child health also must have preference significance. Second, health is multidimensional. No single, all-encompassing measure of health exists although health status indices may be formed from combinations of various scalar measures. Such measures include: (i) anthropometric measures of height, weight, arm circumference, etc.; (ii) clinical measures of body functions such as blood pressure; (iii) respondent-reported general health histories, disease and illness symptoms, and subjective (good, fair, etc.) health evaluations; and (iv) respondent-reported incapacities for engaging in everyday activities. Measures of adult health either must be identical to measures of child health, or some transformation factor must be known that converts one measure into the other. Otherwise there exists no benchmark for the comparison of values.

Third, whether for adults or for children, measurement errors may differ significantly among health measures. The error for the same measure may also differ systematically between adults and children. In addition, the manner in which a common measure enters adult preferences for own or children's health may differ among measures. The effect of measurement error on estimates of adults' expressions of their relative preferences may then differ among the various measures. There is no *a*

priori reason to suppose any of these measurement errors will be uncorrelated with factors that explain the phenomenon of ultimate interest: the budget-constrained adult's preference for (value of) own health relative to children's health. For example, measurement errors associated with respondent-reported measures of health status, such as self-assessed health or incapacities, are likely correlated with adult education or employment status—variables that any value expression typically includes as explanatory variables. Since value expressions for nonmarketed goods like health are not directly observed but must be inferred from market observations and sociodemographic factors, these correlations will cause parameter estimates of value expressions to be biased when health is included as an explanatory variable and cause imprecision of estimates if it is used as a dependent variable.[7] The problem of multiple measurement errors favors a single analytical structure to adjust adult health benefit measures for children. Bockstael and Strand (1987) show how different assumptions about sources of error require different approaches to calculation of benefits for a nonmarketed good. Since there is no good reason to expect error sources to be identical for adults and children when their health benefits are estimated separately rather than jointly (within the frame of a model of intrahousehold allocation), the use of a similar measure of adult and child health in separate estimation exercises will likely necessitate different methods to calculate adult and child health benefits.[8]

Sources of Adult-Child Dose-Response and Value Differences

There are several reasons to expect adult valuations of own and children's health to be dissimilar. It is widely acknowledged that exposures to environmental hazards and health responses to these exposures often differ between adults and children. Much less acknowledged is that these differences arise from economic as well as biological sources. That is, by being vigilant and taking precautions, adults can influence the probabilities they and their children will be exposed to environmental hazards as well as the severity of their responses to any exposure. With exposures and exposure responses endogenous, adult choices can cause differences between own and children's exposures and responses. The basis by which parents make decisions about exposures and responses will differ across families and across situations with the relative marginal productivities of parents' precautionary efforts, even if the properties of the natural phenomena triggering these efforts apply equally to everyone. It follows that attempts to assess exposure and response levels solely in terms of natural science may be misleading if endogenous self-protection and child-care opportunities exist and vary systematically among families in observed exposure and response data. Sources of systematic variation include relative prices, incomes, and other economic and social parameters. The ability of adults to undertake costly actions to modify events or to reduce their family's vulnerability to loss has implications for differences in adult-child does-response functions which, along with adult preferences and time and resource constraints, determine the values adults attach to their own versus their children's health. In effect, adult-child exposure and response differences originate from differences in biological sources and economic parameters; and adult-child health value differences arise from differences in their exposures, responses, and economic parameters. Though parent-child altruism is likely an important element of the adult-child difference in health values, biological and economic parameters matter as well (Crocker and Shogren, 2003). Below we review some reasons why child-care efforts and technologies matter.

One reason is that parents control the scope of their children's choice sets. Any analysis that constructs dose-response functions using tradeoffs parents make among

already selected activities for their children will omit the dose-response implications of any activities newly engaged under whatever policy action is being contemplated. For example, a child who was forbidden to play at a polluted site might now be allowed access to the restored site. Accurate evaluation of the child's dose-response and its implication for parental valuation of child health requires focus on total rather than marginal dose-response. Focus on marginal dose-response will result in underestimation of the sacrifices adults are willing to make for the child if the likelihood of the child gaining access increases with the magnitude of the policy intervention (Conley, 1976).

Another reason stems from the intertemporal nature of many health effects of environmental hazards. Adult investments in children's health with potential long-term consequences are likely riskier than equivalent own health investments, given that children have no performance records predictive of their investment payoffs. Markets for adults to insure against this risk are incomplete. Also, adults clearly can better predict own payoffs. As in Becker and Tomes (1986), parents might invest freely (and thus efficiently) in their children's health or future prospects if all investments could be easily borrowed and made the children's future obligation. However, since few, if any, such institutions exist for parents' to debt-finance all desired investments in their children's futures, markets for these futures are incomplete (see also Grossman, 1972b; Marshall, 1976). Resource constrained parents with imperfect access to capital must therefore make present-future tradeoffs regarding their children (Graham, 1981); the less complete the market, the greater the investment cost. A greater investment cost for child health suggests adults purchase less of any particular dimension of child health relative to own health.

However, a related feature—children's longer expected life spans—may temper or even negate this cost effect. Suppose for example a parent weighs own and child health equally, and the returns to investments in each form of health are equally risky (perhaps because the adult's performance record is mediocre). Given the child's longer expected life span, the parent's investment in child health will have greater present value than the same investment in own health because child health benefits accrue over a longer time interval. Also, the adult may recognize that certain health conditions will affect the child's ability to accumulate human capital more than for the adult whose stock is already largely accumulated.

Finally, in addition to cost and present discounted value differences in adult-child health investments, the marginal productivities of these investments likely differ as well. Literature health investment models (e.g., Grossman, 1972a) generally presume concavity of health investments (such as preventive care) in producing the overall stock of health; and if investment productivities are not identical between adults and children, there is no reason to expect, for a given marginal health investment cost, equality of adult marginal values of own and children's health investments. In general, the extent of adult net benefits of own or children's health improvements is an empirical question which is influenced by the properties of the hazard-risk-reduction technologies unique to the family (Shogren and Crocker, 1991, 1999). Thus an identical exposure hazard that raises both marginal benefits and marginal costs of family health investments may reveal substantial differences in adult-child relative health values; these values depend on differences in the relative magnitudes of adult-child marginal health investment costs and benefits.

Value Measures

Four measures of health benefits appear in the biomedical and the economics literatures: cost-of-illness (COI); value of statistical life or health status (VSL); quality of life years (QALY's); and willingness-to-pay or compensation demanded (WTP). Adult value estimates of own versus children's health likely differ among the four measures because the measures differ in the extent to which they take endogeneity of health into account. Also, estimates from any single measure will differ according to the completeness of its account of the budget-constrained intrafamily allocation process.

The COI measure represents health improvement benefits as the sum of savings in medical expenditures (direct costs) and lost wages (indirect costs) from either morbidity or premature mortality. Savings are 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 presume that threats to adult and child health are exogenous, beyond the control of one's self or of caregivers.[9] By design, COI estimates are *ex post*. They thus exclude savings in precautionary expenses, values of pain and suffering avoided, and risk aversion components of health benefits. These exclusions can produce odd results. Tengs (1995), for example, uses a COI approach with these exclusions to conclude that heart transplantation is more beneficial than exercise as a means to overcome heart problems. The exclusions can also produce odd equity judgments. For example, if medical expenditures for men and women with the same illness are identical, then, if women get paid less than men, the COI measure implies that treating women will be more cost-effective than treating men. In contrast, an *ex ante* measure of health benefits includes expectations of medical expenditures saved, wages earned, precautionary expenses saved, pain and suffering avoided, and preferences satisfied due to intolerance to a risk to health. The *ex post* COI measure presumes that adults choose to treat all or a constant proportion of realized own or children's health impacts, i.e., no choice is involved in acquiring medical treatments or in foregoing work time. It further assumes that the dimensions of health benefits its *ex post* perspective forces it to disregard will not alter estimated absolute or relative values of adult-child health. This is an implausible assumption. Berger et al. (1987) show analytically that no set of simplifying assumptions exists which enables a COI measure to capture the individual behavioral dimensions it disregards. It is equally implausible that valuation impacts of these neglected dimensions would not affect adult-child relative health values.

A VSL is the value/cost of a randomly selected individual's death or personal illness weighted by a probability founded either on prevalence or incidence (see Freeman, 2003, Chapter 10 for a review). But even if people have identical risk preferences, substantial differences may exist in their opportunities for (and costs of) altering probabilities. The VSL idea fails to address differences in individual probabilities caused by differences in people's choices of self-care and child-care alternatives. Again, it is implausible that valuation impacts of these choices would not affect adult valuations of own versus children's health. Adult choices influenced by family circumstances logically differ from adult choices independent of these circumstances.

Shogren and Stamland (2002) provide a case in point. They identify a corollary of the general problem that endogeneity of choice makes for the meaningfulness of VSL

estimates. Most VSL estimates are based on compensating price differentials wherein individuals demand price adjustments to compensate for risks to health. For example, an adult may demand a wage premium to accept a job that endangers his health. Similarly, the same individual might purchase a car that is less safe for his family if he can acquire it for a lower price. With these compensating price differentials, discrimination between the average and marginal individual is relevant to calculating values of risk reductions. The reason is that people's risk preferences and self- or family-protection skills differ. Consequently, we would expect family adults who drive a less safe car to be safer drivers, or be more tolerant to risk, or both. This implies that the marginal adult—the driver in this example—is not randomly selected. He is instead that person among those who have selected a less safe car who demands the greatest price compensation for his and his family's risk while driving that car. The amount of compensation reflects his particular combination of risk tolerance and lack of safe-driving skills relative to other drivers who drive the same model of car. This implies that when the marginal driver's price differential is divided by the statistical risk (the prevalence or incidence of health-damaging car accidents for the average individual who drives that car model), the resulting VSL estimate is upward biased. The upward bias occurs because the highest required compensating price differential among the population of drivers is divided by their average risk. Shogren and Stamland (2002) further show that this result holds when people choose among activities or commodities with differing accident incidence rates. Therefore, even when intrafamily allocation processes are accounted for, all that is required for this bias to affect relative adult-child health valuations is for incidence rates to differ between adults and children.

Another measure used to assess general health as well as health benefits is quality-adjusted-life-years (QALY). The QALY measure has found considerable favor in biomedicine and, to a substantially lesser extent, in health economics. It is an *ex post* measure of the quality-weighted change in a person's life span produced by some intervention thought to affect that person's health. The quality weights lie in the [0,1] interval and characterize subjective assessments of the 'utility' of a life-year either by biomedical professionals or a sample of the population affected by the health change of interest. A positive aspect of these subjective assessments is that they are explicitly linked to individual preferences; but as Freeman (2003) explains, the form of these preferences must be quite restrictive for the linkage to make sense in a budget-constrained utility maximization frame. The restrictions are threefold. First, a person must be indifferent (risk neutral) between two sets of likelihoods of a change occurring (or not occurring) which have the same expected impact on life span. Indeed, it is hard to believe that a parent would be indifferent between her child's certain lifespan of 70 years and a gamble wherein her child lives only 40 years with 50 percent probability, or lives 100 years with 50 percent probability. Second, the rate of tradeoff between health and longevity is always the same such that if one's desired tradeoff is 1 health unit for 2 longevity years, one's tradeoff for 20 health units is 40 longevity years. Third, a parent's preferences for own health or children's health must be independent of current *and* of future income. Taken as a package, these preference restrictions imply that the values individuals attach to changes in health status are inversely related to their life expectancy. Thus, even if a parent is unwilling to sacrifice any more resources for her child's health than for her own health, the use of QALY's to measure health would be consistent with her attachment of a greater value to her child's health relative to her own health. In short, if a vision of the budget-constrained, utility

maximizing parent is the standard, use of QALYs will exaggerate adult values of children's health relative to own health.[10]

WTP is the only measure of benefits capable of capturing all facets of an individual's health that he believes contribute to his well-being. It is the measure consistent with Becker's (1976) classic definition of how the economic approach frames behavioral problems: "The combined assumptions of maximizing behavior, market equilibrium, and stable preferences, used relentlessly and unflinchingly, form the heart of the economic approach…" With this approach, the correct values of adult or child health improvements due to an environmental hazard reduction are the maximum amount of money an adult is willing to pay to secure a given hazard reduction, or the minimum amount of money the adult would accept to forego the reduction. Willingness-to-pay measures are appropriate when individuals cannot claim to own sources of the hazard; and compensation demanded fits when individuals control this source. Note that reference to ownership refers to sources of the environmental hazard and not to the individual's ability to affect hazard exposures by practicing vigilance and precaution. Given that an individual's preferences allow substitution between income (wealth) and health changes, this substitution rate reveals his monetary value of health—the rate that leaves him indifferent between either having the money or having the change in health.[11]

Because the economic approach makes the decision agent its fundamental unit of analysis, it reflexively focuses on resource-constrained households in which adults and children live when evaluating the tradeoff between adult and child health. A focus on the family as the unit of analysis changes the adult-child health benefits transfer issue to, at least in part, a behavioral question rather than (almost wholly) a statistical problem. Acquisition of an understanding of adult-child health valuations for benefits transfer purposes requires valuations from family rather than from individual settings exclusive of family obligations. Stand-alone adults do not face tradeoffs between their own and their children's health. It is therefore easier for stand-alone adults than for family adults to adapt to environmental hazards. This implies that the adult-child benefits transfer problem involves transferring adult-child health benefits estimates across families rather than stand-alone adult health benefits estimates to children who almost always live in families. Alternatively stated, the adult-child benefits transfer problem can be viewed as one of identifying adult valuations of children's health already implicit in their valuations of own health—rather than of estimating what stand-alone adults' values of own health mean in terms of their value of anonymous children's health.

Inattention to the family basis of adult decision making runs the risk in benefits transfer exercises of double counting the health benefits of an environmental improvement. Viewing the adult as standing alone when he is in fact embedded in a household means that his purportedly stand-alone value actually embodies the value he attaches to the health of other household members. To transfer this value to these other members would then constitute double counting. Accurate benefits transfer requires the decomposition of adult valuations into own and child health components rather than the addition of child health valuations to purportedly stand-alone adult health valuations. The validity of this decomposition rather than adding-up perspective is made vivid if adult health is viewed as an input into child health (Nastis and Crocker, 2003) as when their health influences the wealth and the time adults have to invest in (and to care for) their children. The value the adult attaches to own health is then in part determined by the contribution own health makes to the child's health. To attribute

this element of the value of the adult's health improvement to the adult and then again to the health improvement of the child would constitute double counting.

Of course, identification of adult-child health valuations from household-based adult valuations of own health complicates the benefits transfer problem. Adult health valuations must be separated into adult and child components and then factors influencing the relative magnitude of these components across families must be ascertained. A plausibly significant complicating factor, for example, is the impact that neighborhood conditions (crime rates, pollution, transportation alternatives, etc.) have upon the structure of internal household environments and resource allocations (Agee and Crocker, 2002c). If complications are to be added, there must be good reasons for doing so. There are. As emphasized throughout, reinforcing and compensating behaviors within the family may systematically affect adult values of own versus children's health. Given the increasing scarcity of household time in the modern world (especially for single parents and dual-career couples), and with fixed costs of household maintenance, these systematic effects likely bear increasing influence.[12] Also, because the unobserved economic value of health must be inferred from agents' decisions, such inferences are not comparable if not drawn from a common unit of analysis and vision of agents' decision problems. Thinking of the adult-child benefits transfer problem in terms of families rather than stand-alone individuals not only acknowledges the choices that budget, time, and technological constraints force; it also applies these constraints in settings where the adult-child linkage of preferences is most direct and vivid.

Transfer Estimators

The least restrictive statistical foundation upon which benefits transfer exercises can rest is the Bayesian concept of exchangeability or transferability (Lindley and Smith, 1972; de Finetti, 1974). Exchangeability asks whether coefficients reported in studies of given groups experiencing a common phenomenon drawn from numerous places and times were generated randomly as from a fixed normal continuum. The concept asks whether, and to what degree, each study represents an imperfect replication of a common structure. Given exchangeability, Bayesian estimators allow one to draw systematic and communicable inferences about health production, preference, and demand parameter values in a new group from the observations in previous studies. If exchangeability is complete the identical model would apply to each group. One could then pool the data from all studies of these groups and transfer without revision the results from one study to any other group—including a new group. At the other extreme, if exchangeability is utterly absent, then each group has its own unique structure and no transfer of results could be justified. Each group would be totally idiosyncratic. In the context of transferring health benefits measures from adults to children, Bayesian estimators for exchangeability allow tests of the extent to which studies are similar. The policymaker can assess the degree of closeness of health benefits estimates between adults and children as well as the implications of any such degree for estimating payoffs of policy alternatives. Exchangeability recognizes that a central aim of inference is to generate predictions about the values of distant observables.

Though it is sometimes used in epidemiology (e.g., Du Mouchel and Harris, 1983), Bayesian exchangeability has not been applied to assess the transferability of estimates of adult health benefits to children. Its application to any economic benefits transfer question whatsoever is rare.[13] Meta-analysis (Cooper and Hedges, 1994) is the most

inclusive of the transfer estimators used thus far in most of the economics literature. But meta-analysis implicitly treats exchangeability as a maintained rather than testable hypothesis. It presumes exchangeability exists among some arbitrarily selected set of studies and then examines how benefit estimates differ with the fixed effects of settings, restrictions, and statistical methods. It assumes all of the variance among study fixed effects, other than sampling variance, can be explained as a function of differences in known statistical characteristics (data properties, functional form, estimators, error distributions, etc.).[14] Moreover, as Smith and Pattanayak (2002) and Smith et al. (2002) point out, no meta-analytic study makes explicit any underlying utility maximization framework to drive the behaviors implicit in the benefit estimates being treated. Because meta-analysis is strictly statistical, no role is accorded preferences or budget, time, or technology constraints.[15] Thus, for example, a benefit estimate for a health intervention applicable to a wealthy person might be transferred to a person who actually cannot afford the intervention.

A yet more restrictive method of benefits transfer is the transfer of benefit functions. The procedure simply presumes that statistical characteristics of an estimated benefits function would be appropriate for transfer to another context, if this benefits function for the other context were indeed to be estimated. Key parameter estimates are transferred to the new context, and benefit responses in this context are determined by substituting values of applicable variables with values taken from the original context. In non-health-related contexts, tests of the benefits function transfer method have not been favorable (Chattopadhyay, forthcoming), although in the presence of increasing sociodemographic dissimilarities, accuracy of the function transfer method remained constant or increased while accuracy of the point transfer method deteriorated.

The most restrictive method of benefits transfer is the outright transfer of point estimates of benefits. An application of adult health benefits to children would simply presume that the benefits response of a particular health intervention for children is identical to that for adults. Any adjustments made to the adult response would be founded on such ad hoc criteria as the researcher's or policymaker's professional judgments about plausibility. To date, the criteria for plausibility and the degree of plausibility of judgments have not been formalized, thus inhibiting opportunities to assess the statistical soundness of this analytically simplistic transfer method.

Estimates of adult-child relative health benefits

Models of Intrafamily Allocation Processes

If the family or household is to be the unit of analysis in health benefits transfer between adults and children, then a framework explaining and predicting the tradeoffs resource-constrained families make between adult and child well-being must be provided. Transfers can then be built upon a grasp of the factors which influence differences among families in this tradeoff. Unfortunately, despite the plausibility of using the family as the unit of analysis for the transfer problem, economics has no single framework to explain the tradeoffs families make between the well-being of adult and child members. Probably no single economic model will ever comprehensively explain family investment decisions and resultant valuations of individual members' health states and prospects. Although derivation of propositions from first-principles will induce a satisfying feeling of logical integrity, such logic-chopping for the adult-child health benefit transfer problem will require prior

consensus on which one of several alternative frameworks of intrafamily allocation to employ.

The most frequently employed image in family economics is the 'unitary' model in which all family resources are pooled such that behaviors of individual members do not influence household demands or opportunities for goods or leaving the family (Behrman, 1996). In effect, the family acts as a unified individual wherein a single member allots resources among all members. But this does not imply the framework is unable to say anything about intrahousehold allocations. Adult preferences can be defined over own consumption, own health, and child health. These preferences are then maximized subject to an adult budget constraint and adult and child health production functions. The investments adults choose to make in a child together with the child's genetic and cultural inheritances determine that child's health production. Altruism and the implicit purchase of insurance for parents' dotage (e.g., Rangazas, 1991) motivate adult-child health investment decisions. The rate of return parents receive on investments in their children varies with children's behaviors and parents' access to capital markets (Becker and Tomes, 1986).

In the last decade or so, three types of 'collective' models of intrahousehold allocation have emerged to challenge dominance of the unitary framework. All allow the nonpooling of family resources. Two versions of these collective models assume cooperative behavior among family members. One version presumes Pareto-efficient behavior such that all possibilities for gains from trade among family members are exhausted (Chiappori, 1992); another cooperative type imposes more structure by representing intrafamily allocations as outcomes of Nash-bargaining involving threat points—efforts by one member to make another member accountable for his or her undesirable actions (McElroy 1990; Lundlberg and Pollak, 1993). In contrast, noncooperative, collective models allow some members to be losers (Udry, 1999). Children infrequently appear in any of these collective versions, cooperative or noncooperative. When they do so, they appear as public goods or investments which enter the individual production and consumption activities of family adults. Chiuri and Simmons (1997) show how collective models can account for the externality and public good features of family investments. Zeliger (1994) suggests that the methods (allowances, joint accounts, etc.) used to earmark its budget signal the appropriate model version to apply to a family's intrahousehold allocations.

Controversy reigns within economics as to the circumstances under which of the intrahousehold allocation models is appropriate. However, substantial empirical evidence indicates that the unitary framework is frequently inappropriate when applied to allocations among adult household members (e.g., Thomas, 1990; Doss, 1996; Browning and Chiappori, 1998). These results imply that intrahousehold allocations between spouses result from an exchange process based on a division of labor rather than on the family leader-determined allotments upon which the unitary framework rests. But because children either do not appear in these analyses, or appear solely as public goods or investments in empirical tests of these frameworks, it is not clear what would be gained by employing any of these more analytically and empirically complex collective frameworks rather than the straightforward unitary framework to assess adult tradeoffs between own and children's well-being. Young children undeniably receive allotments of parental time and resources. Older children may participate in exchange processes with their parents; but if they behave according to the 'rotten kid theorem' (Becker, 1981) and provide positive amounts of public goods as preferred (requested) by their parents, the allocations provided these children are equivalent to those

predicted by the unitary framework. In fact, nearly all of the existing empirical work on the value of adult health relative to child health uses the unitary framework to embed adults and children in a single family.

Estimates of Relative Benefits: A Literature Review

Empirical estimates from original research on adult values of own relative to children's health probably number less than 15.[16] Most have not yet seen the light-of-day in the refereed, published literature. All have implicitly or explicitly embedded their study subjects in models of intrahousehold allocation, though they employ a variety of health and value measures and estimators. Given the extremely small number of studies and the measure and estimator disparities among them, we do not attempt a formal statistical synthesis such as a test of Bayesian exchangeability or a meta-analysis. Instead we resort to a rough kind of point and function estimate transfer by identifying similarities in study estimates of the adult-child health tradeoff and the factors which influence this tradeoff. The reader is left to judge whether the similarities we identify are sufficiently exchangeable, i.e., close enough to each other to discriminate among relevant policy alternatives relevant to a not yet studied setting. Two key similarities in estimates of the adult-child health benefit tradeoff appear: (i) adults value children's health more than their own health; and (ii) the adult-child health benefit tradeoff is influenced by factors such as child age and family income. We discuss each similarity in turn.

With but one exception noted below, all existing studies of adult-child relative health values adopt a framework consistent with the unitary approach. Most studies estimate that adults value children's health more than own health; however, a couple of exceptions conclude the opposite. These two exceptions either start from a collective framework or employ a benefit measure such as VSL that, for reasons explained earlier, may not conform to marginal willingness-to-pay.

One of the exceptions is Mount et al. (2001). Using a Nash-bargained collective framework, they used observed purchases of car safety features to estimate the VSL for adults and children. They found that adults' VSL for children exceeds their own VSL only when the income elasticity of demand for risk reduction approaches unity. At an income elasticity of 0.65 the adult-child VSL estimates are equal. In a study using family purchases of bicycle safety helmets, Jenkins et al. (2001) estimated that parents' own VSL's are roughly twice that of their children's VSL's. Except for these two studies, all remaining studies of which we are aware conclude that adult values of children's health exceed values of own health.

Dickie and Gerking (2002) use contingent valuation to arrive at an estimate of parents' willingness-to-pay to reduce skin cancer risks to themselves and their children. They found that parents value children's risk reductions at least as much as their own reductions. Using a similar contingent valuation approach, Dickie and Ulery (2002) found that mothers valued the relief of various acute health symptoms in their children roughly twice as highly as their own symptoms. Dockins et al. (2001) review three additional studies which conclude that adults value children's health greater than their own health. Though these three studies appear to have been performed by noneconomists, their approach is not inconsistent with the unitary framework and their benefits measures are consistent with willingness-to-pay. All three employed a survey technique similar to contingent valuation (stated preferences) to acquire their data.

In a contingent valuation study of the health risks posed by household chemicals, Viscusi et al. (1987) conclude that parents are willing to pay more to reduce risks to their children than to reduce own risks. In another contingent valuation exercise, Liu et al. (2000) found that mothers in Taiwan were willing to pay twice as much to relieve cold symptoms in their children as they were to relieve the same symptoms in themselves. Blomquist et al. (1996) found in yet another contingent valuation study that the VSLs they infer from parents' valuations of car safety equipment are at least as great for children as for the parents. Agee and Crocker (2003b) use the public bad of indoor air pollution generated by parents' observed smoking behaviors to infer that parents value their children's health roughly twice that of their own health. Nastis and Crocker (2003) use mothers' observed behaviors on the public good of participation in prenatal care to conclude that mothers-to-be value the expected postnatal health of their unborn child as much as 6 times more than the expected post-partum state of their own health.

Except for Nastis and Crocker (2003), all the studies immediately above deal with children, not infants. The Nastis and Crocker (2003) result of a 6-to-1 prenatal tradeoff is consistent with the Dickie and Ulery (2002) conjecture that the tradeoff may approach 10-to-1 for infants and decreases at a decreasing rate toward unity as the child nears adulthood. Dickie and Gerking (2002) conclude that parents' own risk beliefs are a determinant of their beliefs about the risks environmental hazards pose to their children. They do not address, however, the question of whether these beliefs influence the adult-child health benefit tradeoff.

A number of empirical parallels about sources of variation in health valuations regularly turn up in the extensive literature on adult health valuations only and in the limited literature on child health only. First, value increases with income (e.g., Viscusi and Moore, 1989, on adults; Agee and Crocker, 1996a, on children). Second, the value of reducing the risk of acute illnesses increases at a decreasing rate with illness duration (e.g., Alberini et al., 1997, on adults; Liu et al., 2000, on children). Third, what a specific acute illness implies for restrictions upon regular activities contributes more to value than the illness itself (e.g., Johnson et al., 2000, on adults; Dickie and Ulery, 2002, on children). Fourth, the value of an individual's health declines with the fertility of family adults (e.g., Becker, 1981, on adults; Agee and Crocker, 1996a, on children). However, the results in Dickie and Ulery (2002) suggest that these sources of variation in the absolute values of adult and child health make little, if any, difference in their relative values.

An unacknowledged source of the variation in adult-child relative health values referenced above is the social value of child health. The value parents attach to children's health may underestimate the value society attaches to children's health, given that society cares (exhibits paternalistic altruism) about investments in and parental treatment of children. For example, miserable-looking children in public venues may detract from the adult community's safety or utility of these venues. Child health subsequently becomes adult productivity that benefits entire communities. Improved health for children enhances their education efficiency and thus increases, when adults, their productivity and demands for public goods that benefit the entire community. The very limited available empirical evidence suggests that parental investments in children do not fully account for these social benefits. Joyce et al. (1989) conclude that mothers' marginal willingness-to-pay for prenatal care is less than its marginal social value; Agee and Crocker (1994) find that parents underinvest from a social perspective in acquiring information about the risks body burdens of lead pose to

their children's intellectual development; and the findings of Agee and Crocker (1996a, 2002b) imply that the discount rates many parents apply to investments in their children may be socially excessive.

Using an intrahousehold allocation model to estimate

Adult-child relative health benefits: an example

Whether or not the investments parents make in their child capture all the paternalistic social benefits of investing in children, the fact remains that the tradeoffs resource-constrained parents make among own consumption, own health, and child health provide a preference-based vehicle fully consistent with economic theory and a potentially complete and thus accurate means of assessing the relative weights adults assign to their own versus their children's health. These private weights derived from intrahousehold decisions are undeniably a core component of the social weights. In the unlikely event that society's interest in children is strictly nonpaternalistic, private weights would represent social weights (Lazo et al., 1997). We now condense an empirical example (Agee and Crocker, 2003a) of how the previously discussed issues regarding health measures, benefit measures, etc. might be implemented empirically using a unitary model of intrahousehold allocation designed to assess adult-child relative health values.

Below we sketch and estimate a latent variable model of the parental value of own versus child health. In addition to its explicit treatment of the intrahousehold allocation issue, the model specifies a comprehensive measure of general health to be included in parental health care demand estimates from which willingness-to-pay measures for own and for child health can be derived. This latent variable approach has distinct analytical and empirical advantages over the use of health status proxies such as self-assessed subjective health, time spent ill, or self-reported or clinical disease records measures discussed earlier. Health status is a multidimensional phenomenon; but clinical measures usually focus on a single condition. Subjective measures plausibly get at the multidimensional feature of health, but provide no tie to an objective (clinical) measure. Incomplete or inaccurate measures of underlying health are likely to introduce bias in health-related demand estimates from which willingness-to-pay measures of the value of health are derived (Wolfe and Behrman, 1987; van der Gaag and Wolfe, 1991).

Model and Econometric Procedures

Consider a unified family framework in which parents make utility maximizing decisions to consume health-care services, M, for themselves and their children; and these decisions are characterized as a function of several exogenous "predisposing" factors, X (such as geographic variables, household resources, and personal characteristics), together with several imperfect but observable measures of health-care "need" (such as those discussed earlier) that serve as indicators, I, for a comprehensive measure of parent and child health status, H, as determined by the following simultaneous system:

(3) $$H = \alpha X + \delta$$

(4) $$M = \beta X + \gamma H + \varepsilon$$

(5) $$I = dH + f$$

where M is measured by family health-care utilization observed as the number of physician visits conditional on the decision to use a physician, and the matrix B and vectors a, c, and d denote unknown parameters. Error terms δ, ε, and f are assumed to be mutually independent and normally distributed each with zero mean.

Substituting (3) into (5) gives

(6) $$I = d(a + cX + \delta) + f,$$

which makes evident the link between unobserved health status and health status indicators, including unobserved stochastic influences. It can be shown that a reduced form version for physician use of expressions (3) through (5) provides restrictions on the coefficients of the exogenous variables and the variance-covariance matrix of the reduced form disturbances.

Empirical implementation of the above system for the purpose of parent-child health valuation introduces three estimation issues. First, to uniquely scale the parameters in (3) and (4), a common unit must be established for at least one of the unobserved health status parameters in d linking H to its list of indicators (mobility-limiting impairments, prescription medications being taken, number of chronic illnesses, etc). Moreover, to maintain consistency across all individuals, the normalized d parameter must also link H to an indicator which is common to parents and children. This is easily accomplished by using the number of short-term illnesses each sample adult or child has experienced within the same time period as the health indicator for normalization. Choice of this indicator is also preferable on theoretic grounds given its consistency with the general health and environmental economics literature—which often posits an association between a reduction in illness resistance (interpreted as general health) and an increase in short-term illness incidence (e.g., Cropper, 1981; Berger et al., 1994; Dickie and Gerking, 2002). Furthermore, normalization by short-term illnesses allows us to easily generate a rough estimate of parents' relative values of own versus child short-term illness reductions, thus enabling us to compare our modeling and estimation results to short-term illness value estimates from prior studies.

A second estimation issue arises from the structure of the system set forth in expressions (3) through (5), wherein there exists a unidirectional dependency between the endogenous variables H and M. This system is thus estimated recursively in which H is initially estimated by exogenous variables, and M is determined by the estimate for the endogenous variable, H, and by exogenous variables and health indicators. That is, predisposing and enabling factors determine health status, and health status along with a set of additional predisposing, enabling, and need factors sufficient to establish identification determine the physician services used.

A third issue arises from our tangential objective of getting at the value parents attach to own health versus child health. Since the basis of above model (see e.g., Grossman, 1972b; Anderson, 1968) is a unified family utility function which contains own and child health as arguments—with associated choice variables such as parental time and physician services which serve as health production inputs—an optimization problem based on these elements underlies parental demands for own and child

physician services, *M*, as estimated by expression (4). A parent's marginal willingness-to-pay (MWP) for an increase in own or child health reflects her utility substitution rate between family income and her own or her child's health; and the ratio of MWP's for own and child health reveals her relative value (substitution rate) of own versus child health. Since the above system estimates the parental demand for physician services *conditional* on the decision to use a physician, an estimate of parental MWP for own and child health improvements can be inferred directly from the conditional demands for parent and child physician services. The approach we use to infer these values is due to the results of Small and Rosen (1981), who specify an individual's conditional demand for a consumption good (e.g., parent or child physician services analogous to (4)), and derive an expression for MWP for a qualitative change in that good (e.g., health) as a function of the individual's probability of good use and the associated marginal impacts of income and good quality on the probability of use.[17]

Results

Table 1 (see Annex) displays results we obtain from applying the aforementioned framework and estimation procedures to a U.S. representative sample of 6,572 parents with an own child (who reside together) from the 1999 National Health Interview Survey. As mentioned earlier, estimates of individual parents' MWP's for health status changes will depend on the unit scale of *H*—which depends on the indicator variable chosen for normalization. However, regardless of the indicator selected, individual marginal rates of substitution between own and child health do not change since these rates depend upon parental (conditional) demands for own physician-care use relative to their child's use, *given H*. Normalization by means of short-term illnesses experienced provides us supplementary comparative estimates of parental willingness-to-pay to avoid an own versus child short-term illness which we report in row one of Table 1 (see Annex). For example, normalization by short-term illnesses—i.e., a one-unit increase in health status converts to one less short-term illness experienced (respiratory allergy, cold, flu, cough/chest congestion)—implies a parental willingness-to-pay of $31.06 to avoid one (own) short-term illness versus $71.93 to avoid one (child) illness. By comparison, Liu et al. (2000) found that mothers in Taiwan were willing-to-pay an average of $34 ($71 for their child) to avoid a cold, and Alberini et al. (1997) and Johnson et al. (1997) found that adults were willing-to-pay an average of $17 to $50 to avoid an episode of cough, shortness of breath, or fever/ache.[18] In general, Table 1 (see Annex) estimates suggest that parents' marginal valuations of child health are, on average, at least twice as large as their valuations of own health. The lower panel of Table 1 (see Annex) shows parental substitution rates estimated for selected subsamples that have been identified in the household economics literature as important determinants of parental resource allocation decisions within families. Table 1 (see Annex) displays few significant differences among these determinants. However, as found by Dickie and Ulery (2002), the estimated marginal rate of substitution between own and child health appears to decline monotonically with child age.

Conclusions

This paper addresses issues likely to arise in any exercise involving the transfer of health benefits measures from adults to children. The paper suggests that if transfer exercises are to avoid misleading results, they must be founded on analytical as well as statistical commonalities. A common vision across studies of what health is and of the

economic structure underlying investment behaviors that influence health must also prevail.

In particular, estimated health benefits and/or subsequent benefits transfers for environmental hazard reductions will be biased downward if the researcher does not recognize all of the opportunities individuals have to adapt to hazards. The list of possible adaptations for individuals in families versus stand-alone individuals is extensive (e.g., improved information acquisition about hazard risks and protection technology effectiveness, consumption smoothing and insurance, 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). Stand-alone individuals need not worry about transferring their resources to children. Since children have limited opportunity sets which are linked to their caregivers' decision sets, use of an intrafamily allocation framework as the common analytical structure to infer adult values of own health relative to children's health makes the most sense. Given this common analytical structure as the protocol for studying adult-child allocation processes, statistical syntheses of such studies can then proceed on more solid grounding by determining those differences in allocation outcomes (given relative prices, hazard attributes, and alternative adaptation technologies) that give rise to differences in adult-child relative health values. Most of the adult health benefits studies that might be used for transfers to children are likely biased by a failure to embed the adult individual in a family. This bias is likely to be especially serious when children are at issue since their health and prospects are widely acknowledged to increase with the quality of their home environment.

Most empirical studies to date on the adult-child health benefits tradeoff—which account for intrahousehold allocation—have assumed some form of unified household preferences or allocation process. Although too few studies yet exist to synthesize the adult-child health benefits tradeoff statistically, a couple of key similarities frequently appear in these studies: adults tend to value their children's health more than their own health; and this tradeoff tends to increase with family income, decrease with family size and as children approach adulthood, and vary with illness severity and duration and extent of physical limitations.

An example application of a unitary model of intrahousehold allocation provided insight into how one might go about obtaining measures of household adults' own versus child health valuations. The model derives a set of willingness-to-pay expressions which analytically link the values an adult parent attaches to own versus child health. The estimates provided in this example suggest that parents value own health improvements, on average, roughly 50 percent less than equivalent child health improvements. This result suggests that the pattern or form, not just the amount, of household adult consumption affects and reflects adult valuations of own and child health. Along with the other sources of variation in the relative value of adult and child health that empirical studies consistent with economic theory have found, the result promotes caution about use of a one-size-fits-all constant to transform adult health valuation measures into those for children.

Notes

1 A paper prepared for the OECD Workshop on the Valuation of Environmental Health Risks for Children, Paris, France, September 11-12, 2003. Although the U.S. Environmental Protection Agency provided partial financial support through Grant #R82871601, the research has not been subjected to the Agency's required peer and policy review and therefore does not necessarily reflect the views of the Agency. The helpful comments of Bengt Kristöm are gratefully acknowledged. The views expressed in this chapter are those of the authors and do not necessarily reflect those of the institutes with which they are affiliated, or the OECD.

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4 However, see McConnell (1999) on outdoor recreation.

5 Rather than using the current decisions of the existing generation of adults or children as the basis for value inference, one might instead use what existing adults would like to have had invested in themselves when they were children, given their current resources (Agee and Crocker, 2002a). Though this last base is fully consistent with the individual sovereignty foundation of welfare economics, its practicality has not been explored. We choose not to explore it here.

6 These summaries, which have mainly focused on outdoor recreation and residential properties, find that the robustness in statistical terms of transfers is quite problematic, even when the conditions of transfer seem highly favorable. See, for example, Downing and Ozuna, Jr. (1996), Feather and Hellerstein (1997), Bergstrom and De-Civita (1999), Brouwer and Spanicks (1999), and Chattopadhyay (forthcoming).

7 In the simplest model of measurement error where demand expressions are determined by only one variable such as the stock of health measured with random error, the estimated effect of the stock of health on demand will be biased downward. This "attenuation bias" varies in proportion to the ratio of the variance of the measurement error to the variance of the measured health stock variable. If more demand determinants are included in an effort to reduce omitted variable bias, the measurement error bias will increase when the added demand determinants are correlated with the true health stock, thus increasing the noise-to-signal ratio. It is thus unclear whether estimates of the effect of health status upon the demand for a commodity are improved by including more control variables, even if these controls are correlated with demand and are exogenous. See Leamer (1978) and Atkinson and Crocker (1992) for treatments of these issues.

8 Empirical problems raised by both the multidimensional nature of health and multiple measurement errors may be tempered by treating health status as a single latent variable for which the researcher observes and estimates some function(s) of a subset of measured health indicators simultaneously with a set of incomplete but observable measures of health care "need," such as utilization of health-care. In the few empirical applications of the latent variable approach in environmental and health economics (Wolfe and Behrman, 1987; van der Gaag and Wolfe, 1991; Moore and Zhu, 2000), no explicit account is taken of the intrafamily allocation problem.

[9] Witness the following statement from a prestigious medical journal (Lefant, 1996, p. 1605): "Research on exogenous sources of hypertension has focused on diet, physical activity, and psychological factors."

[10] Given the role played by respondents' utility assessments of health states, QALYs appear susceptible to the same inconsistencies with economic theory as contingent valuation (CVM) survey methods: the absence of arbitrage which forces rational behavior and of a binding budget constraint making scarcity real rather than hypothetical.

[11] Ethical objections to the substitution of money for health fall into two broad classes (Anderson, 1993): (i) that money and health are incommensurable values; and (ii) that tradeoffs between health and other sources of value appropriate if and only if the relative weight given health is greater than that which the market gives it. Neither we nor reality grant the first objection; the second objection need not be inconsistent with the economic approach when market imperfections influence the tradeoff.

[12] Nearly 25 years ago, Johnson and Pencavel (1980) found that time costs of children are considerably greater than their money costs. Modern life likely has caused these costs to increase.

[13] A more-or-less exhaustive listing would include Aigner and Leamer (1984), Atkinson and Crocker (1992), Atkinson et al. (1992), Parsons and Kealy (1994), and Leon et al. (2002). Desvousges et al. (1998) briefly mention exchangeability in a health benefits transfer context but do not make empirical use of it.

[14] Presumably, enough accumulated knowledge of the statistical commonalities among existing studies would ultimately allow identification of similar features in contexts not yet studied and thus transfer of estimates from studied contexts to them.

[15] Smith and Pattanayak (2002) and Smith et al. (2002) suggest that meta-analysis can better accord with Becker's (1976) "economic approach" by having the researcher specify a preference function he considers to be common among all studies used in the analysis, and then defining each benefit estimate in terms of the parameters of this common preference function.

[16] We limit our review to original empirical studies explicitly focused on the adult-child value of health tradeoff. Each study reviewed thus applies a common framework, health measure, and benefit measure to adult and child. We do not attempt to compare separate studies of adult values of own health to studies of adult values of child health, since their frameworks, health measures, benefit measures, and estimators generally differ. See Neumann and Greenwood (2002) for a review of these separate studies.

[17] See Agee and Crocker (2003a) for further empirical details. See also Dickie and Gerking (1991), Desvousges, et al. (1998), and Agee and Crocker (1996a) for health valuation applications using the demand for medical services. The conditional demand for medical services is typically specified as a function of variables related to regional price differences in physician services and availability, household resources, perceptions of physician quality and access, as well as individual health status.

[18] All willingness-to-pay comparisons are in 2000 U.S. dollars.

Annex 4.A
Parental Marginal Rates of Substitution between Own and Child Health

Mean Parental MWTP for Health Improvement (standard deviation)			Mean Marginal Rate of Substitution (standard deviation)
Full sample (n=6572)	Child Health	Own Health	2.32 (0.21)
	$71.93 (2.17)	$31.06 (6.27)	
By Sample Household Characteristics:			
Income > 1999 U.S. average (n=3704)			2.34 (0.17)
Income < 1999 U.S. average (n=2868)			2.30 (0.25)
Public or no health insurance (n=1721)			2.20 (0.33)
Two parents present (n=4667)			2.34 (0.21)
One parent present (n=1905)			2.27 (0.21)
Family size < 4 (n=2663)			2.30 (0.19)
4 £ Family size £ 7 (n=1528)			2.34 (0.21)
Child age £ 6 (n=2543)			2.49 (0.16)
Child age > 12 (n=1835)			2.16 (0.20)
Child age = 17 (n=361)			2.0 (0.20)
Female child (n=3161)			2.31 (0.21)
Male child (n=3411)			2.34 (0.20)

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Chapter 5

Discounting of Children's Health: Conceptual and Practical Difficulties

by

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Discounting the future benefits and costs associated with a given risk reduction is required to estimate the total costs and benefits associated with a specific policy, and thus to know whether this policy will be efficient, *i.e.* whether it will generate benefits greater than costs. However, a number of issues arise when discounting health, in particular in the case of children. Given the scarcity of studies having considered the discounting of benefits to children's health, this chapter raises several problematic points when considering discounting children's health.

One of the most important points relates to the appropriate discount rate: in the case of children, should we use a constant discount rate or a time-varying discount rate? In addition, given that children have a greater number of years to live long term benefits should also be taken into account with care. However, these issues make the discounting of children's health benefits far from straightforward and may have serious policy implications.

Introduction

Discounting practices can play a crucial role in determining the relative cost-effectiveness of different interventions. This is particularly likely when the costs or effects of an intervention are long-lived as may often be the case with respect to children's health. If evaluations are undertaken on an incorrect basis the quality of decision making will suffer and efficiency will be reduced. Moreover, confusion or lack of agreement over standard discounting practice potentially undermines the credibility and value of economic evaluation.

This report is comprised of four parts. In the first part, discounting practices in the economic evaluation of health are briefly reviewed. The second part considers: the issues raised for discounting by health benefits not expressed in monetary terms; the relevance of individual time preferences to the social discount rate; the measurability of time preferences over future health events; and alternatives to constant rate discounting. The third part considers children's health: whose preferences are to count; what is being valued; the elicitation of children's preferences; and the relationship between age and time preferences. The final part introduces a taxonomy of the elicitation methods used in empirical work, and considers criteria for choosing one over another.

A dichotomy between children and adults is alluded to throughout. But clearly a case can be made that there is a continuum running from children through to younger adults. Children do not suddenly and uniformly become adult except with respect to legal status (and of course this age can differ across jurisdictions). The arguments against including children's preferences are, in any case, generally not expressed in terms of legal status but rather are put in terms of decision making capacity and experience. The boundary between children and adults is blurred once the heterogeneity of both children and adults regarding relevant characteristics with respect to the elicitation of preferences such as, age, education, and capacity to participate in decision making, is recognised.

Discounting practices in the economic evaluation of health

Methods are required to take into account the timing of costs and benefits when undertaking economic evaluation of health care (or related) interventions so that interventions with different time profiles of costs and benefits can be more easily compared. This is achieved by discounting future costs and benefits to present values whereby smaller and smaller weights are attached to future events the further in the future they occur. These declining weights or discount factors are equal to $(1+r)^{-t}$ where r is the discount rate and t is the year in which the event occurs.

Where there is recognition of the need to discount future costs and effects there is a large measure of agreement with respect to discounting practice. Specifically, there is agreement in guidelines and in actual evaluations regarding the discounting model to apply. This reflects the dominance of the discounted utility model in economics, in general. Alternatives to the traditional constant rate or exponential model are receiving increasing attention. A recent example, a paper written as part of the Disease Control Priorities Project, provides a theoretical underpinning for nonconstant rate discounting (Jamison and Jamison, 2003). Also other disciplines, for example, psychology, have embraced alternative models – in particular, a variety of hyperbolic models. However,

these alternatives have yet to make any significant headway with respect to discounting practice.

To the extent that alternatives have been considered in economics it is fair to say they have largely been as theoretical possibilities rather than in direct application. There is one recent exception to this, namely the recently issued guidance of Her Majesty's Treasury in the United Kingdom in which time-varying discount rates are recommended – 3.5% (years 0 to 30), 3.0% (years 31 to 75), 2.5% (years 76 to 125), 2.0% (years 126 to 200), 1.5% (years 201-300) and 1% thereafter (HM Treasury, 2003).

The area where discounting practices have shown the greatest variation is with respect to the rates of discount applied. However, even here there has been considerable agreement reflected in the use of rates from a relatively narrow range, and the impact of this variability has been mitigated, to some extent, by consideration of alternative rates in some species of sensitivity analysis. Smith and Gravelle (2001), in a review of discounting practice in ten countries, found that most guidelines suggest the use of a number of alternative rates, frequently in the 3-5% range.

One departure from uniform discounting practice arose with respect to the treatment of future health effects expressed in non-monetary terms, such as years of life saved or QALYs (quality-adjusted life-years) gained. In England and Wales, the Department of Health did recommend that the health effects be discounted at 1.5 % and costs at 6% (Department of Health, 1996, National Institute for Clinical Excellence, 2001). However, this departure from discounting costs and health effects at a common rate has now ended with NICE and the Department of Health following the government-wide 3.5% rate of discount for both costs and benefits (including non-monetary health benefits).

A further issue regarding discounting practice in health economic evaluation concerns the separation of valuation from discounting. The usual practice, so usual that it scarcely deserves comment, is to identify costs and effects in the year in which they occur and then to use a discount rate to re-express these future streams in terms of present values. The possibility exists to do otherwise. For example, the future gains might be valued directly in terms of willingness-to-pay in current prices. Also, where the effects are measured in terms of gains or losses in QALYs, there is the possibility of time preferences having already been taken into account, and thus of "double discounting" should a discount rate be separately applied to the stream of future QALYs (MacKeigan *et al*., 2003).

Difficulties for discounting health

A number of difficulties must be confronted when discounting health. The most obvious difficulty is the decision as to what is the appropriate rate of discount to use. But lying behind this simple question are much deeper issues. First, is it the case that there is a particular rate to be applied to both the future stream of costs and the future stream of benefits? This is an issue largely because of the widespread use of cost-effectiveness analysis (and cost-utility analysis) and the relatively limited use of cost-benefit analysis in health care evaluation. Second, what is the relationship between individual preferences over future events and the choice of a social discount rate? Third, are time preferences with respect to future health events measurable? Fourth, are constant rate discounting models the most appropriate for use in economic evaluation?

Discounting benefits

The issue of how the future changes in health are measured is potentially important. There has been a debate with respect to discounting peculiar to health economics because it has generally been the case that health gains, for instance, are generally not valued in monetary terms but rather are quantified in terms of years of life gained or QALYs gained. Where the costs and effects (in this case health gains) have been valued in monetary terms there is consensus that they should be discounted at a common rate. However, where the health gains are not expressed in money terms there has been a sustained debate as to whether they should be discounted at a different (generally lower) rate.

The orthodox view is based on two main arguments, one concerning eternal delay, and the other concerning consistency. Keeler and Cretin (1983) highlight a paradox that could arise if a lower discount rate were to be applied to health benefits than the one applied to monetary costs. A project could always be made to appear more attractive by delaying its implementation. Their solution is to require that costs and benefits are discounted at the same rate. This has provoked a number of responses. For example, van Hout (1998) has argued that the typical problem faced by decision makers does not concern when to implement a particular policy but rather which of several project to implement currently. More fundamentally, Gravelle and Smith (2001) argue that the Keeler and Cretin solution does not recognise that the underlying problem is that the CEA decision rule cannot cope with timing decisions.

The consistency argument was first made explicitly by Weinstein and Stason (1977) and has perhaps received more sustained support, for example, it has been endorsed in the recommendations of the Washington Panel (Gold *et al*., 1996). But it also has been questioned, specifically on the basis of a strong assumption regarding the future value of health benefits. Weinstein and Stason (1977) assume that "life-years are valued the same in relation to dollars in the present as in the future". Without this assumption the consistency argument disappears (van Hout, 1998). Gravelle and Smith (2001) argue that the value of health will increase over time as society becomes richer.

The monetary valuation of health effects and specifically the difficulties encountered in achieving such valuations lies at the heart of the issue of appropriate discounting practice. If the stream of future health effects resulting from any particular intervention could be accurately represented in monetary terms there would surely be unanimity in the economics profession that the monetised streams of costs and benefits should be treated identically. There would be no grounds for using a lower rate of discount for those parts of these future streams that arise from changes in health.

Disagreement arises when the health effects are measured in physical non-monetary terms. This is not the place to explore issues such as whether health effects can be satisfactorily valued in monetary terms, or how such valuations should be made. For whatever reason, the monetary valuation of health effects is relatively uncommon in the extensive literature on the economic evaluation of health care. If an intervention results in increased survival should the life-years gained be left undiscounted, be discounted at the same rate as used for future costs, or be discounted but at some rate lower than that applied to the costs?

The shadow price of health is central to answering this question. To see this, note that the present value (in money terms) of a future stream of life-years gained may be viewed as the sum of a series of products, each product has three elements - a discount factor, a marginal valuation of additional life-years, and a quantity of additional life-

years. If the life-years gained were to be left undiscounted and are simply summed, this is equivalent to assuming that the fall in the discount factor as the life-years gained recede into the future is exactly balanced by a rise in the marginal valuation of the additional life-years. If the physical quantity of life-years gained in any future year present value is weighted by the discount factor implied by the discount rate for costs, this is equivalent to assuming that the marginal valuation of life-years remains constant over time. It appears plausible to suggest that neither practice will invariably yield the correct answer. Both will involve an element of approximation.

Encouraging explicitness is ultimately one of the major justifications for undertaking economic evaluation. In this spirit it would appear to be best to adjust explicitly the future stream of life-years gained to take account of changes in the valuation of these life-years and then apply a common discount rate to all the costs and benefits. There is a clear analogy here to the treatment of risk and uncertainty. While it has been suggested that discount rates could be adjusted using risk premia, the balance of opinion suggests that this is unlikely to be a satisfactory means of taking risk and uncertainty into account.

But given the practical, and possibly political, difficulties involved in placing a monetary valuation on health effects is it really plausible that we could specify how this valuation is likely to change over time? The change in the marginal value of health benefits will depend primarily on the rate of growth of income and how the valuation of health changes vis-à-vis other goods as income rises. It could also be affected by shocks to health, for example, if new threats to health markedly reduce life expectancy.

Clearly we have something of an impasse. If we can assume that the marginal valuation of life-years will rise over time we could use a lower discount rate for unadjusted health effects. But if the information is available to enable us to identify how much lower the discount rate on health effects should be we might be better served by explicitly adjusting the valuation of the future effects and using the common discount rate.

This is an issue of more than academic interest since discounting practice is likely to influence the relative priority assigned to different programmes, particularly if their effects are long-lived. While it may appear to have become a less pressing issue because of the agreement in practice to use the same rate for costs and health effects, the danger of building a systematic bias into methods of evaluation suggests that further research into the valuation of increments to health, and how these valuations are likely to change over time, is clearly warranted. These arguments for a lower discount rate for valuing health benefits are quite different from the arguments reviewed below for using a lower rate for benefits (and costs) arising in the more distant future. Although they share a common desire to avoid systematic bias.

What is the relationship between individual preferences over future events and the choice of a social rate of discount?

The relationship between individual time preferences and the social rate of discount of course has a long history and links back to fundamental issues in welfare economics. This paper does not seek to address this important normative question. One view is that the discount rate that best represents individuals' preferences should be used to discount future health benefits. The growing interest in the estimation of individuals' time preferences for health can be regarded as in part a consequence of this view. An alternative view holds that it is inappropriate to base a social discount

rate on individual preferences. However, even if this position is taken an enquiry into the nature of individual time preferences is important for understanding health-affecting behaviour as a precursor to informing the development of policy.

It has been remarked previously that it is odd to insist on capturing individual preferences over health states but not over their timing (Lipscomb, 1989). Let us assume that individual preferences over future health states are of importance and relevance, at this stage, for whatever reason. Later it will be appropriate to consider how the source of our interest qualifies our conclusions. Of course just because a case can be made for letting (adult) individual preferences inform social decision making this need not imply that children's preferences should be accorded a similar status.

Are time preferences with respect to future health events measurable?

This is an important question. If the answer is no the issues surrounding the appropriate evaluation of health risks to children are, if not simplified, greatly reduced in number. This, however, is not a straightforward question to answer. For example, what level of precision is required in order to inform decision making and how is the validity or otherwise of the estimates of these preferences to be established?

Before anyone had attempted to measure time preferences specifically for health events, Gafni and Torrance (1984) expressed some early (with hindsight excessive) optimism. They suggested that time preference could be "measured by asking conventional time preference questions ... but cast in the health, as opposed to financial domain" and claimed that it was not necessary to speculate on the nature of time preference "...since it is empirically determinable" (p.449). However, about a decade later, drawing on Loewenstein and Prelec (1993), which highlighted the importance of sequence effects, Gafni (1995) argues robustly that no measurement technique allows pure time preference to be distinguished. There is evidence that the order in which health events occur influences an individual's valuation of the profile as a whole. Thus the best that can be achieved is a measure of time preference for a given sequence of events. This may be true of preferences over one's own future health states. However, it is less clear that the sequence of events will be an important influence when considering preferences over life-saving profiles. Although there is some recent evidence of a sequence effect with respect to lives saved (Frederick, 2003).

In any case, Gyrd-Hansen and Søgaard (1998) argue that for economic evaluation we do not require a measure of pure time preferences but that we also wish to include diminishing marginal utility and uncertainty. From this perspective, it is an advantage if more than pure time preferences are captured by the elicitation method.

Reviewing the growing number of studies that have the aim of eliciting time preferences over future health events, there are sufficient empirical regularities in individuals' responses to suggest that something is being measured. The key question concerns the validity of these measurements which is considered below in section 4. Again, it should be recognised that while it might be possible to measure the inter-temporal preferences of adults, this need not imply that similar preferences can be measured, or measured as accurately, in the case of children.

Alternatives to constant rate discounting

Alternatives to the exponential model are receiving increasing attention. Other disciplines, for example, psychology, have largely eschewed the exponential model and have focussed instead on a number of different hyperbolic models. Also,

economists are showing increased theoretical interest in hyperbolic models, however, these models have yet to make any significant headway with respect to discounting practice. Interest in alternatives has had two main sources: evidence on individual time preferences; and a concern that constant rate models attach a very low weight to events in the distant future.

Studies of time preferences over future health events, employing a constant rate model, have repeatedly suggested that rates of discount decline as the period of delay increases. Such a relationship is not consistent with the discounted utility model but is characteristic of hyperbolic models. However, for delays between a few years and 20 years it can be quite difficult to distinguish empirically between hyperbolic and exponential models (van der Pol and Cairns, 2002). Moreover, while some economists have been exploring hyperbolic models, their unfamiliarity and the normative appeal of dynamic consistency (a characteristic of the discounted utility model) has ensured that alternatives have made little ground.

A perhaps more significant development is the case made a discount rate that falls over time. A case made without abandoning the constant rate model with respect to individual time preferences. This has been doubly appealing because it to some extent reduces the evident tension between (constant rate) discounting and inter-generational equity.

Concern over the very low weight attached to the distant future as a result of constant rate discounting has led to new guidance recommending the use of time-varying discount rates by UK government departments (HM Treasury, 2003). This change in guidance reflects recent theoretical developments with respect to long-term discounting. The key insight is that, given uncertainty over future discount rates, the certainty-equivalent rate is found by taking the average of the discount factors rather than the average of the discount rates (Weitzman, 1998, Newell and Pizer, 2003). The difference can be substantial given a long time horizon. For example, a discount rate of four per cent implies a discount factor of 0.00034 in year 200, whereas the expected discount factor in year 200 if discount rates of one and seven per cent are considered equally likely is 0.068. In the former case $1000 in year 200 has a present value of 34 cents, whereas in the latter case it has a present value of $68The effect of time-varying discount rates will depend on the size of the steps but will generally have little impact on the evaluation of the future health of current adults and rather more impact on the evaluation of the future health of current children. However, the most marked effect is going to be on the evaluation of the health of successive generations. One consequence might be that the case for investment in projects with benefits stretching into the distant future is strengthened *vis-à-vis* investments with consequences largely to the current and next generation.

Valuation of children's health

This section considers three issues: whose preferences are to count – adults', children's or both; what is being valued - children's health (in the future) and/or the future (adult) health of children; and finally the elicitation of children's preferences.

Whose preferences are to count – adults', children's or both?

What is the status of children's time preferences as opposed to adults' time preferences. It is telling that we generally do not need to specify that if we are interested in individual preferences as opposed to social preferences that our concern is

with the preferences of adults. It is not part of the remit of this paper to explore the arguments for and against particular alternative means of treating children's *health* preferences *per se*. Rather it is the implications for discounting of different judgments regarding the treatment of children's preferences which are to be explored here.

As Dockins *et al*. (2002) argue "Ideally, we wish to estimate the value of a given risk reduction that children themselves would pay if they had mature reason and financial resources". They assert that children lack well-defined preferences and lack the cognitive ability to make the trade-off choices. Further, specifically with respect to WTP they lack the control of financial resources. Some would go further and suggest that lack of experience with a meaningful budget constraint is grounds for excluding the preferences of young adults until they are financially independent (Hoffmann *et al*., 2003). The consensus appears to be that there must be recourse to the preferences of adults – possibly the parents of the children in question.

Thus one position would be that children's inter-temporal preferences are not to be a consideration in social decision making. If so, any enquiry into the nature of these preferences would then be driven solely by a desire to understand the health-affecting behaviour of children. Children's preferences in any broader sense do not count and should have no impact on social decision-making. There is a sub-category where certain of children's preferences are admitted as relevant but others are not. For example, it might be argued that children's preferences over what constitutes good health are likely to be better defined, more readily measured and meaningful, whereas their preferences over the *timing* of events might be undefined, unmeasurable or not meaningful.

An alternative perspective would be to treat children's time preferences on a similar basis to those of adults, that is, subject to any caveats that are ordinarily applied to adult preferences. So where adult preferences are viewed as important elements informing social decision-making, children's preferences should be assigned a similar status. By the same token, children's time preferences might be disregarded not because they belong to children but because they display the same myopia that might be used to justify exclusion of adult preferences from any social calculus

Rather less likely, but at any rate possible, a case might be made for giving children's preferences priority over adult preferences because they are thought to be significantly different from those of adults and in terms of attaining our objectives children's preferences are of greater relevance. As a possibly trivial example, consider the content of TV programmes for children, might it be appropriate to take account of children's rather than adults' preferences with respect to their structure, content, appearance *etc*.? In a discounting context an argument which might be developed is that decisions over the more distant future may directly affect current children but only indirectly affect current adults, and thus children's preferences are of greater significance.

What is being valued - children's health (in the future) and/or the future (adult) health of children?

There is an important distinction between the valuation of future children's health and the valuation of the future (adult) health of children. The former concerns explicitly issues of inter-generational equity in that future children clearly belong to a future generation whereas the latter albeit implicitly relates to a current generation at points in the future.

A distinction can be drawn between intra-generational and inter-generational discounting. Discounting the future costs and benefits to the current generation is fairly uncontroversial. However, as is well known the use of any positive discount rate, given a sufficiently long time horizon over which to operate, will generate very small present values. It is often argued that this is unfair to future generations.

Collard (1978) made an early proposal for dealing with intergenerational equity and discounting but not in a health context. He suggested that the stream of benefits for each generation be discounted to their own present and that these present values be combined not by discounting to our present but by using weights which reflect our altruism towards the future generations. A broadly similar two-part approach has been suggested in the health economics literature (Lipscomb, 1989, Gold *et al*. 1996). Individuals would use their own private rates to re-express the stream of benefits to them in present value terms and a social discount rate is then used to adjust this future stream of present values.

Brouwer *et al.* (2000), following a tradition stretching back at least to Pigou, question the use of individual values which they believe reflect myopia and fear of death. They argue that the societal decision-maker should overrule such preferences and that "…the amount of future effects should only be adjusted for their timing when obvious differences between people at different points in time are present or can be rightfully expected" (p.133). The obvious differences that they have in mind are those that change the relative valuation of health effects.

A small number of empirical studies have considered periods of delay sufficiently long that the preference elicited is presumably an inter-generational one. For example, Cropper *et al*. (1991) and Johannesson and Johansson (1996) elicited preferences with respect to delays of up to 100 years. More recently there have been experiments with delays of up to 900 years (Chapman, 2001). The period of delay over which to elicit preferences must be guided by the purpose for which a rate of discount is sought. Is a social rate of discount wanted for weighting future present values, or is the private rate that an individual uses to re-express a stream of future benefits to themselves sought? To what extent is the widely observed inverse relationship between the implied rate of discount and the period of delay picking up preferences for inter-generational equity? One recent study, focussing on 25 year and 100 year delays and comparing alternate elicitation procedures, found evidence to suggest that lives in this and future generations are valued about equally (Frederick, 2003).

Either adults could be given inter-temporal choices concerning children's health, or actual inter-temporal choices could examined (Agee and Crocker, 1996), and the implied rate of time preference might then be used to inform decision making with respect to policies influencing children's health. Adults could, moreover, be asked to answer the questions as if they are children and it is their future health. This is less outlandish than it might first appear. The widely used generic measure of health, the Health Utilities Index (HUI), has been derived from the responses of adults asked to imagine that they were ten year olds. Similarly, some of the studies eliciting time preferences for health have explicitly involved respondents imagining they were a particular age, although none of these studies have involved young ages.

It is not known whether parents discount future benefits to themselves at the same rate as they discount future benefits to their children. The only study to address the question whether or not people discount their own future health at a different rate from others' future health found no difference (Cairns and van der Pol, 1999). An adult

sample drawn from the general public was randomised to questions about their own future health or to questions about others' future health where the others were described as middle-aged. The estimated discount rates barely differed across the two groups.

Eliciting children's preferences

So what discount problems arise with respect to the valuation of children's health. The answer depends in part on what is being valued and with respect to whose preferences is valuation being made. Time preferences over future health events are challenging to elicit from adults and there is no reason whatsoever why they will not be equally difficult for children.

First, there is the unfamiliarity with this sort of decision making. Individuals generally have available to them a wide range of financial vehicles with which to optimise their consumption over time. This is not to deny the uncertainties which make such decision making harder or the imperfections of the capital market which constrain efforts to redistribute consumption over time. The point is that most individuals have substantial direct experience of such decision making. However, health is different. Certainly the means exist to influence one's future health through current consumption and investment choices. However, the uncertainties are greater and scope to make inter-temporal trades is for most people more limited. It is relatively straightforward to postpone current consumption in order to secure increased future consumption. It is much harder generally through current actions to assure a particular future improvement in health. Children lack the experience of financial vehicles for redistributing consumption over time and thus the unfamiliarity of inter-temporal choice is even greater for them.

Second, related in part to this, the tasks that it is necessary to set individuals in order to elicit time preferences for health events generally appear not only unfamiliar but also artificial and implausible. One common difficulty is the need to assume a degree of certainty over future health events which are inherently uncertain. This artificiality may influence not only the response rate but also might make it more likely that responses depend on the way a question is asked and less on the underlying preferences of the respondent.

Third, the tasks are often cognitively demanding. There is usually a trade-off such that the information content of more cognitively demanding questions is much greater but the likelihood of securing meaningful answers is reduced as the tasks get harder. A number of examples are provided in the next section which reviews the empirical attempts to elicit these preferences. The importance of the degree of difficulty involved in answering the questions clearly relates to the capacity of those answering the questions to engage in meaningful decision making. There must be a presumption that children are less able to provide meaningful responses than adults but clearly not all adults are better able to participate than all children.

Fourth, the meaningful description of the future health events over which preferences are elicited may generate an additional challenge. In the case of future lives saved there may not be a problem. But if the health events relate in part to the quality of life rather than simply the quantity the differences in perception of what constitutes health may become important. It is not that there is a child-adult dichotomy but rather an age spectrum. Thus health to an old adult may well differ from that of a young

adult. However, this is more acute in the case of children because childhood spans a period of rapid developmental change (Petrou, 2003).

It is notable that the potential challenges identified are largely obtained from extension of experience eliciting preferences from adults. Economists have made relatively few attempts to elicit preferences from children. Certainly no direct enquiries into the nature of child time preferences over future health events have been reported. Even if children are viewed as not having standing in private or social health care decision-making, this represents an important gap. Information on the nature of children's inter-temporal preferences could cast substantial light on their health-affecting behaviour.

Relationship between age and time preferences over health events

There are no empirical studies of children's time preferences over future health events. Indeed time preferences elicited from children with respect to the periods of delay relevant to economic evaluation over any kind of future event are rare. Implied discount rates have, however, been estimated for a wide age range for adults. Also, arguments have been adduced for an age-discount rate relationship. This suggests a possible line of enquiry - namely using the age-discount rate relationship to make predictions regarding the discount rates of younger age groups.

Sozou and Seymour (2003) predict that time preference will be lowest in middle age. As a consequence of facing a high environmental hazard rate, young adults apply high time preference rates. Whereas, the middle-aged have survived and thus know that their environmental hazard rate is low (and are experiencing a relatively slow physiological decline). The combined effect is to give them fairly low rates of time preference. In contrast, old adults experience increasingly rapid physiological decline (declining fertility including declining ability to nurture young and attract and retain a mate, and of course increasing mortality). Consequently, older adults exhibit higher rates of time preference.

A general increase in implied discount rates with increasing age is apparent in the empirical literature, and some studies have found the U-shaped relationship predicted above (Cairns, 1994, Read and Read, 2004).

There are practical difficulties with making predictions regarding the discount rates of children. The available data are not sufficiently rich to enable an age-discount rate relationship to be specified with much precision. Also, there are challenges in establishing such a relationship. It is important to control for the period of delay when eliciting discount rates because of the repeated finding that rates fall with increases in delay. The periods of delay over which it is relevant to enquire will tend to be longer for younger respondents and shorter for older respondents. This will be particularly true if attention is focussed on future health at a given age. There is then a possibility that part of any decline in rates at older ages has been dampened by a "rise" associated with the consideration of shorter delays. But if younger and older respondents are not presented with choices with respect to a common age there is a potential problem that the benefits being compared differ (an improvement in health enjoyed when 40 years of age may have quite a different value from the "same" improvement enjoyed at 75 years of age).

Empirical treatment of discounting problems

A substantial body of empirical work focussed largely on the elicitation of time preferences for future health events has emerged within the last fifteen years (van der Pol and Cairns, 2003). This has been the result of two major underlying factors.

First, economists (and others) working in the area of health economics have displayed a willingness and propensity to investigate individual preferences to some extent more intensively than other economists. Or to be more precise because of the nature of health and health care have had the opportunity and encouragement for such a *direct* uncovering of preferences. Witness the large body of work developing the quality adjustment that is central to the estimation of QALYs, the continued growth of contingent valuation studies, and the recent emphasis on discrete choice experiments. All these endeavours have in common a much greater emphasis on stated preference than is generally the case in economic analysis elsewhere - where empirically revealed preference is clearly dominant.

Second, and also having its source in the nature of health and health care, health benefits have largely not been valued in monetary terms but have been quantified in physical units or measures involving differing degrees of valuation but all falling short of monetary valuation. This has happened probably because it was necessary if an economic approach was to make ground in the initially resistant world of medicine. As an aside it might be noted that there are signs that this is increasingly seen as a limitation and the future clearly holds more in terms of willingness to pay for a QALY, cost effectiveness acceptability curves, value of information analysis etc. As indicated above an important stimulus to interest in discounting in the economic evaluation of health has been the challenges set by the absence of monetary valuations.

As a consequence the body of empirical work on the elicitation of preferences for future health events is large enough to allow a detailed classification of methods. However, note that all of the thirty or so empirical studies have involved adult subjects albeit, owing to the widespread use of university students as subjects, some of them are relatively young adults.

Taxonomy of methods for eliciting time preferences

Two broad approaches have been used to estimate time preference rates - revealed preference and stated preference. The distinction is that the former involves observing actual behaviour whereas the latter involves asking individuals what they would do in particular *hypothetical* circumstances. Revealed preference methods for estimating time preference can be divided into a number of categories: deriving time preference rates from behaviors that involve tradeoffs between outcomes over time such as the purchase of consumer durables (Hausman, 1979), or by observing how individuals trade off wage and risk, which can be interpreted as a trade-off between quality of life and life expectancy (Viscusi and Moore, 1989), or finally through the estimation of structural models of lifecycle saving behaviour.

In the health sphere there are relatively few opportunities to obtain valuations from observed behaviour. This is especially so in the case of *time preferences* for health. Individuals can invest in their future health by adopting a healthy lifestyle now or they can purchase health insurance but these opportunities to trade are limited especially compared to the opportunities to trade wealth across time. Another limitation of using revealed preference methods is that the estimation of time preference rates is relatively

indirect and quite complicated. There are often many confounding factors present. One of the relatively few studies using revealed preference methods identified (parental) discount rates implied by decisions regarding the protection of their children from lead exposure (Agee and Crocker, 1996). Because the scope for using revealed preferences to derive time preferences for health is limited, and because of difficulties controlling for confounding factors, economists' general preference for revealed preference methods over stated preference methods has been set aside.

The stated preference methods that have been used to elicit preferences with respect to future health events can be classified as open-ended (or matching) methods, closed-ended (or choice) methods, and rating/pricing methods. Matching studies have been undertaken as fully open-ended or using the time preference equivalent of a payment scale. Four different approaches have been adopted to estimate time preference using choice or closed-ended questions: discrete choice; discrete choice with follow-up; discrete choice with repeated follow-up; and discrete choice experiments. Rating methods elicit a score for a temporal prospect, for example, a health profile. An implied time preference rate is estimated by comparing scores for different temporal prospects. Pricing methods are similar to rating methods but elicit willingness to pay for temporal prospects instead of a score. Rating and pricing methods differ from the open-ended and closed-ended methods in that they do not present individuals directly with trade-offs between outcomes at different points in time. For a list of the studies using each of these methods see van der Pol and Cairns (2003).

When using stated preference approaches to elicit time preferences for health there are numerous potential differences in design between studies in terms of the way in which the questions are framed. For example, in the case of non-fatal changes in health state there can be differences with respect to: base health state; number of different health states; time horizon; and whether or not the comparison is between points in time or profiles. The base health state can be full-health and subjects make choices with respect to the consumption of ill-health (Redelmeier and Heller, 1993) or the base health state is ill-health and subjects make choices with respect to the consumption of full-health (Chapman and Elstein, 1995). Some studies consider only one ill-health state (Cairns, 1992), others have considered more than one ill-health state (Dolan and Gudex, 1995). A limited time period can be considered (Chapman, 1996) (for instance five years), or a scenario can describe remaining life (Enemark *et al*., 1998). Subjects can be asked to consider two points in time or they can be presented with a profile. The standard approach has been the former, with few studies comparing profiles (Chapman *et al*., 1999).

In principle, studies asking matching questions could ask subjects to specify: the *timing* of a given change in health; or the *magnitude* to be experienced at a certain point of time; or possibly the health-related *quality of life* to be experienced. However, as yet no study has asked individuals to specify timing or quality of life. Studies have asked individuals to specify the magnitude of a specified health benefit to be enjoyed at a particular point in the future either in terms of: lives saved (Olsen, 1993); or duration of health state (Cairns and van der Pol, 2000); or frequency of symptoms (Chapman *et al.*, 1999).

For detailed stylised examples of each of these approaches for private preferences elicited for non-fatal changes in health framed in terms of losses, specifically, durations of ill-health see van der Pol and Cairns (2003). While further methods of eliciting time preferences may yet be developed, it seems likely that if empirical work is to be

undertaken in the near future with respect to eliciting preferences over children's health that it will use a variant of one of the approaches outlined above. This leads directly to the question as to which of these methods might be best suited for this purpose.

Choice of elicitation method

The primary concern is with the validity of the time preferences elicited by a particular method, that is, do the estimated preferences represent the individual's true preferences. Evidence of validity can take a number of forms, for example, close agreement between stated preference and revealed preference methods, and differences in observed behaviour being predicted by differences in estimated time preferences. There is, however, relatively little evidence available on the validity or otherwise of the different preference elicitation methods in the case of adults, let alone children. In the absence of data on revealed preferences, the convergent validity of different stated preference approaches might be considered, although different methods giving similar results does not guarantee that they are accurate representations of individuals' preferences. Only two studies have been designed to compare directly estimates of time preference rates across methods (Cairns and van der Pol, 2000, and Gyrd-Hansen, 2002). See also Frederick (2003) for a demonstration of the marked influence of the elicitation method on the imputed time preferences.

Validity has been explored indirectly by examining the relationship between time preferences and individuals' characteristics. Successful prediction of the determinants of individual time preference rates might be taken as indirect evidence of the validity of the method. The individual characteristic most commonly found to be significantly associated with the implied time preference rate is the age of the subject. As might be anticipated older subjects tend to have higher time preference rates. There is limited evidence of significant associations between implied time preference rates and a number of other variables including presence of young children in the household, ethnic group, smoking status, and gender.

Since choice of method cannot currently be based solely on evidence of validity, other characteristics, or advantages and disadvantages, of the different methods become of increased importance. The main potential differences between the methods are in terms of statistical efficiency, richness of the data, cognitive difficulty, strategic behaviour, and potential biases.

Closed-ended methods are generally less efficient than open-ended and rating/pricing methods (Carson, 2000). In particular, the single discrete choice is statistically inefficient in that large sample sizes are required to identify the underlying distribution of time preferences with any given degree of accuracy. The difference in statistical efficiency across methods becomes important when the sample size available to researchers is considerably restricted, for example, by resources available to conduct the research. In such circumstances eliciting time preferences using, for instance, a single discrete choice is unlikely to be feasible.

Open-ended and rating/pricing methods generally produce richer data and as a result time preference rates can be identified for individual subjects and not just for the group. Time preference rates can only be estimated for the group when using closed-ended methods with the exception of the discrete choice with repeated follow-up. For some purposes individual level data are essential, for example, when modeling alternative discount functions. For other purposes, some measure of group preferences is adequate and closed-ended methods become feasible.

The degree of cognitive difficulty is likely to be an important consideration. The Psychology literature shows that closed-ended questions are generally easier to answer than open-ended questions (Tversky *et al.*, 1988). To answer open-ended questions subjects have to make quantitative comparisons. Rather than accepting or rejecting a bid subjects return a specific value that represents their preferences. It should be noted that discrete choices may still require considerable cognitive effort in the case of time preferences. It could be argued that the rating/pricing methods are cognitively less demanding since the subject does not have to directly trade-off two different health outcomes at two different points in time.

A further concern is the potential for biased responses. Van der Pol and Cairns (2003) identify a number of potential biases which can be associated with different methods.

Despite the numerous studies eliciting time preferences over future health events it is difficult to make a strong recommendation with respect to most appropriate method. Partly, this reflects the small number of studies which allow a direct comparison of different methods. Because of the many potential differences between studies, for example, the period of delay, the sample of respondents, and the health event being valued, relatively little can be drawn from the comparison of individual studies. Moreover, these empirical studies have had adults rather than children as their subjects. Van der Pol and Cairns (2003) concluded that there was neither a uniformly superior nor a uniformly inferior method and that the weight attached to the different criteria will depend on the particular aims of the study. When using open-ended questions or the discrete choice with repeated follow-up, there is a trade-off between the richness of information collected and sample size, and cognitive difficulty and bias. The opposite holds for the single discrete choice with or without follow-up. The rating/pricing method scored quite well on most factors but is also most likely to produce biased estimates.

Conclusion

The elicitation of time preferences with respect to future health events has been a particularly vigorous field of enquiry in the past fifteen years, and it can potentially inform policy with respect to discounting children's health. But this literature has two significant limitations: first, the inter-temporal preferences elicited are adult preferences, there have been no attempts to elicit children's preferences; and second, the empirical focus been on the exponential model and while perhaps not the near future certainly not the more distant future.

Does this matter, are children's time preferences likely to be different from those of adults, and in any case if they are, are they a more appropriate basis for decision making? The exponential model, while not without its critics, is widely embraced by the economics community. Is it feasible to supplant it with an alternative model, and would an alternative lead to different (and better) decision making?

Unfortunately we are not yet in a position to answer these questions. However, these are questions which carefully focussed research could hope to provide useful answers.

Notes

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Chapter 6

Economic Uncertainties in Valuing Reductions in Children's Environmental Health Risks[1]

by

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This chapter examines possible effects of economic uncertainties on the valuation of environmental health risks to children. Economic uncertainty includes uncertainty about physical factors that determine the level of benefits from children's environmental health programs and uncertainty about how to represent and measure the value people attach to these benefits. Examples of these uncertainties include uncertainty in measuring baseline health and change in health status and uncertainty about representing changes in children's welfare. The paper identifies how these sources of uncertainty are likely to affect valuation of children's benefits from environmental health programs. The paper specifically examines how economic uncertainty may affect use of three standard benefit measures: cost of illness, willingness-to-pay, and quality-adjusted life years indices. Failing to account for important economic uncertainties may ultimately result in poor measures of the effectiveness of environmental policy, inappropriate policy priorities, or poorly targeted policy instruments.

What Is "Economic Uncertainty"?

There is growing concern in industrialized nations about the impact of environmental pollution on children's health. This concern comes from increased recognition by governments that environmental hazards may affect children differently and more severely than adults. The result has been an increased commitment to ensuring that environmental policies take this vulnerability into account, as evidenced by, for example, creation of a special office for children's health in the U.S. Environmental Protection Agency in 1997[5], and work on a children's environment and health action plan for Europe at the Fourth Ministerial Conference on Environment and Health in Budapest, in June 2004[6].

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; Grasso and Pareglio, 2002). This 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 that can be used to value children's health improvements and the economic uncertainties inherent in valuing children's health.

This paper focuses on the influence of "economic uncertainty" on valuation of children's benefits from environmental health programs. By *economic uncertainty*, we mean uncertainties in factors that influence behavior and preferences, and uncertainty about the physical and financial effects of environmental hazards on children. Failing to account for important economic uncertainties can result in poor measures of the effectiveness of environmental policy, inappropriate policy priorities, or poorly targeted policy instruments.

From an economics perspective, 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 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 regarding physical factors that affect the level of benefits from the program, **x**, and uncertainty regarding 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 measurement/forecasting uncertainty and modeling uncertainty in estimating the value of reducing risk to children's health. In section 3, we examine the ways economic uncertainty affects the use of standard economic and non-economic approaches to health benefits valuation and the implications of economic uncertainty for operationalizing these measures. These methods include willingness-to-pay measures (WTP), cost-of-illness (COI) and human capital measures, and quality-adjusted life years (QALYs) and related non-economic measures. We end 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. We conclude by discussing seven important sources of economic uncertainty that can affect valuation of children's health: risk context, time, irreversibility, children's preferences, proxies for children's preferences, household structure, and altruism.

Identifying Sources of Economic Uncertainty

In this section of the paper we focus on identifying important ways in which economic uncertainty can influence measurement of environmental health policy benefits (measurement error and forecasting uncertainty) and ways in which it affects modeling of preferences or economic choice.

Measurement error and forecasting uncertainty

Error in measurement—of both baseline conditions and expected change in baseline conditions—is always a fundamental concern in benefits analysis. The fact 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 for change in the labor markets, may be of very direct interest to health valuation. Other parts of this literature may simply serve as a source of ideas for issues that may be important but are unaddressed in environmental health valuation generally. 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. Within 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:

1) changes in the underlying structure of the economy;

2) uncertainty and therefore misspecification of the relationships modeled;

3) mismeasurement of the data in the base period from which forecasting begins;

4) inaccuracies in estimation of the model's parameters;

5) changes in variances of errors over time; and,

6) 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 forecast uncertainty. The sources of forecasting uncertainty can be either deterministic (e.g., trends and shocks) or stochastic (e.g., randomness in income). Theoretical research on time series forecasts suggests that the behavior of

deterministic model terms has a greater influence on forecast uncertainty than that of stochastic terms (Hendry and Ericsson 2001).

As environmental policy focuses more on the differential impacts of environmental hazards on subpopulations, in this case children, it is important to ask whether forecasting uncertainty is different for this 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 that 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 this 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.

Error in measurement of baseline conditions

All health valuation starts with an estimate of the physical impact of the environmental program. Error in the measurement of these physical impacts can be propagated through the rest of the valuation exercise. There are reasons to think 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 many environmental toxins and the resulting adverse health outcome. Even with adult exposure 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, they will be exposed to environmental hazards over a longer period of time, with potentially more complex interactions between hazards. This suggests greater difficulty in measuring effect using epidemiological studies. Second, differences between children's and adults' biological response to environmental hazards means that animal models that seem appropriate to assess adult sensitivity to hazards may not accurately represent children's response. Use of these 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 understanding the health states and risks still more difficult, 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 to children's health. To our knowledge, this premium has not been measured. We expect it to account for a large proportion of the WTP 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 the value of program benefits is usually assessed – in particular, the accounting for the influence of social and economic factors on physical outcomes experienced by children. In general, these

benefits assessment are viewed as a "snapshot" 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.

An important lesson to take from the economic forecasting literature is that time matters not only because one is measuring an inherently dynamic process (e.g., a child's development) but also because the process will be different depending on when it starts. Demographers and economic forecasters recognize this fact in the use of birth cohort analysis (Mason and Fienberg 1985; Becker H. 1992). Cohort effects may be important to children's health valuation for several reasons: recognizable trends are occurring that 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 will affect health and life outcomes. It is beyond the scope of this paper to comprehensively review the ways these cohort effects may 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 neonate 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 neuro-developmental 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, there will likely be more widespread and more serious effects from air pollution. Uncertainty about the trend, coupled with modeling misspecification if the trend is ignored (as it is likely the case with current cost-of-illness analysis), increases forecasting uncertainty. Second, any illness – but neuro-developmental problems in particular – can reduce the effectiveness of human capital investments in childhood, and this, in turn, could potentially 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 neonate care increases the number of children with neuro-developmental problems associated with premature birth, this may compound the impacts 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 suffering from a developmental disability. This structure is affected both by discrete policy changes and by trends or evolution of social norms over time. Similarly, there are temporal changes in household structure. For example, there is more heterogeneity in household structure in developed countries in 2000 than there was in 1950. To the extent that household structure influences investment in children's health or education, this 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. The emergence of new immunosuppressive diseases, such as AIDS, has shifted the dose response curve for waterborne bacteria.

We are not suggesting here that program evaluation be conducted using dynamic models. Rather, we are suggesting that there are lessons from forecasting that can be applied within a static analysis. The implications of these lessons from time series analysis for static analysis of program benefits are considered below, in section 3. 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 cognitively provide information on their health preferences. One must therefore find a proxy for children's own utility 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 over 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. 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 be 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

$$W = W(\mathbf{U}_c(\mathbf{x}_c), \mathbf{U}_p(\mathbf{C}_p(\mathbf{x}_c)), \mathbf{U}_p(\mathbf{x}_c), \mathbf{U}_p(\mathbf{U}_c(\mathbf{x}_c)), \mathbf{U}_o(\mathbf{C}_o(\mathbf{x}_c)), \mathbf{U}_o(\mathbf{x}_c), \mathbf{U}_o(\mathbf{U}_c(\mathbf{x}_c))) \quad (1)$$

It is possible that the model is actually even more complex, however. For example, older children's concern about their own health may include altruistic concerns about the impact 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. Much of this complexity is often ignored in measuring the benefits of these programs. One question is whether this complexity is 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 regarding when children can be considered "sovereign"

It is clear from the social welfare function (eq. 1) that children's own health benefits from environmental programs need to be included in a measure of the benefits of environmental policies for children's health. The question is how these benefits should be represented. In social welfare terms, benefits are defined in terms of changes in utility level.

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 other's 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 (see Millstein and Halpern-Felsher 2001, and Fischhoff and Parker 2000 for recent discussions). Schlottmann (2001) found functional understanding of probability and expected value in children as young as 5 or 6 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's choices underweight low-probability events and overweight high-probability events and that this tendency 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 from some cause in the near future (contributing to a "so why not take risks, I'm going to die soon anyway" attitude). It seems somewhat early to draw generalizations from much of this literature, however.

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 5 typically view death as like sleep; elementary school children understand the finality of death but not its inevitability; by the age of 9 or 10, 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 in press).

Although emerging research suggests that children develop competencies in evaluating risk and managing hazards earlier than previously thought (see, e.g., 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) shows that when consumers' subjective probabilities diverge from the true probability of events or exhibit socially unacceptable levels of risk tolerance or aversion, and the uncertainty is resolved over time, 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 their own adult risk aversion are a form 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 that consumer sovereignty seeks to respect. 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 could be made for not including a person's preferences until she has reached voting age. One rationale – that the benefits valuations are informing choices over public provision of health protection – is consistent with the practice of using 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 bearing 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 issues. For example, one clearly might use the legal driving age as a cutoff rather than voting age [7].

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 could either use an average developmental age or perhaps in a survey format, one could 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 making certain 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 on their lives and 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 decisionmaking 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 want a valuation to reflect a child's own evaluation of risks, hazards, and financial trade-offs, there may be situations where capturing their preferences over outcomes is desirable. The psychometric literature presents strong arguments for using the child's preferences when it is the child's own experience of current condition that matters (Petrou in press). 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 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 of vulnerability of the brain and other organ systems at early stages of development and are therefore most likely to be the beneficiaries of 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 for reducing health effects to their children as representing children's own benefit from environmental programs. Parents have legal responsibility for their own children's welfare, and their preferences are likely included in parents' preferences through nonpaternalistic altruism. Going back to the social welfare function as an accounting framework, one sees that parents' utility should be counted as representing parents' benefit from protecting children's health. Thus, use of measures of parents' utility derived from environmental programs to count for both their own utility *and* children's utility could underestimate program benefits.

Yet an imperfect world may only allow 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 count both parents' and children's benefits. Unfortunately, we are aware of no studies that have estimated the relationship between the preferences of the target of the altruism (here the child) and 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). Similarly, the intrahousehold allocation literature has focused in only limited ways on separating children's and parents' consumption (e.g., see Gronau 1991). But 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 unlikely that this issue can be resolved empirically through measures of parents' (or nonparents') utility from programs protecting children associated with nonpaternalistic altruism. It is difficult to conceive of a study that could measure this. 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 in for both 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 use of a number of 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 from the program and to use parental willingness to pay plus adults' own WTP to reduce risk in their own childhood as an upper bound.

Another alternative might be Harbaugh's (1999) recommendation to use adults' own willingness to pay for safety as a proxy for children's own willingness to pay for safety. 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 (see Harris and Olewiler 1979 and 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 own WTP, when children are deemed unable to appreciate risk or alternative health outcomes, would appear to be an improvement.

Uncertainty in measuring parents' benefits

There is also uncertainty about how to measure parents' benefit from programs protecting 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" risks than those 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, Agee and Crocker 2002). It is not clear whether this contextual difference (child versus adult) arises from adult preferences over their own children (and 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 decisionmaking within a household may affect either an individual parent's WTP or household WTP to protect children's health.

Theoretical and empirical research, following Becker (1974), on household economics has developed two basic views of the household: unitary and collective models of household resource allocation (see also Berstrom 2003). The few studies that value parental WTP 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 also assume that individual preferences matter, but also assume that income and/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 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 (e.g., 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 risk perception differences 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 WTP 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 regarding 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 is in part recognition of the public goods aspect of having a well-educated, productive citizenry and workforce (Folbre 1996). There is uncertainty involved in the measure of this source of program benefit because there is an endogeneity problem in distinguishing between public investment in programs benefiting children and willingness to pay for these 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 of it is also motivated by altruistic preferences. Conceptually, for both nonparents and parents, there is some uncertainty about whether or when these altruistic preferences should be

included in measures of social welfare from programs protecting children's health. Bergstrom (1982) established that when safety is a private good, including nonpaternalistic altruism in measures of 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 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 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 that Bruce and Waldman's (1990 and 1991) results suggest that the major expense in making cash transfers to children is their distortionary impact on children's investment and savings. 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 passive-use value elicitation 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 behaviour, and other reasons make elicitation complex. In the U.S. Environmental Protection Agency's recent analysis of the U.S. Clean Air Act, 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 in this issue is that the cohort of children is changing in size (generally toward smaller families in developed countries), and 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?

Valuation approaches

There are two broad classes of indices for aggregating across different types of health effects to capture the benefit of policy interventions on health. The first is monetary indices: willingness to pay and cost of illness. The second is quality-adjusted life years, 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,[8] 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 table 4.3; Gold et al.

1996) and the way those weights are combined into scoring equations to score the effects of specific medical interventions or policies.

Monetary valuation

The monetary value of health improvements can be estimated in two broad ways: through measures of what individuals would be willing to give up to obtain health improvements, such as willingness to pay (WTP) for health decline or, less commonly, willingness to accept (WTA) compensation, and through measures of monetary outlays and forgone compensation, termed the cost-of-illness (COI) approach. 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.

Willingness to pay

The WTP approach is based on the trade-offs that individuals must make between health and wealth or income (or other goods). Such trade-offs in daily life are easily recognized and sometimes observed. 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).

WTP 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 WTP for mortality risk reductions are converted to a value of a statistical life (VSL) by dividing the WTP 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 modelled 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.[9] 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.

WTP and WTA health valuation studies 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 behaviour, either in the marketplace or elsewhere, to discern WTP. The most widely used revealed preference methods for estimating health benefits are two hedonic models, one based on choices in the labour market and the other in the housing market. Two approaches to stated-preference are also in use. Contingent valuation (CV) 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 CV is conjoint analysis (or choice experiments), which is 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.

Stated preference methods have also been used to estimate WTP for reductions in risks of death. These methods involve placing people in realistic, if hypothetical, choice settings and eliciting their preferences. In CV surveys, individuals are not asked how much they value life because WTP to avoid certain death is limited by wealth, and WTA 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 WTP to reduce the chance of death by some small probability. Framing the question in this way highlights an important point: a WTP 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 WTP for small changes in risk.

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 – labour market approach, which involves estimating the wage premiums paid to workers in jobs that have high risks of death (Viscusi 1992).

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 prime working-age individuals. 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

COI 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 a relatively transparent. Historically, this is an important approach 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 in particular feature this measure in their cost-benefit analyses (Kuchler and Golan 1999). Cost-of-illness measures are generally at least several times lower than WTP 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 a five-year-longer life 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 health state.[10] One year lived in extreme pain with a utility score of 0.5 is worth 0.5 QALYs ($0.5 \cdot 1$). A basic assumption is that the QALY values are additive, so a treatment that eliminates extreme pain for one year for two individuals ($2 \cdot 0.5$) 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.[11]

Calculating QALYs gained from an intervention requires the following steps. First, choose the time period of interest. Second, identify all possible health states with and without intervention within that period. Third, develop utility weights for each health state either by mapping these states into an existing index or by using visual analog scales (VAS), standard gamble (SG), time trade-off (TTO), or other estimation approaches to develop new weights. Fourth, determine the duration in each health state with and without intervention in the time period. Fifth, weight each health state by its utility weight and multiply by its duration to compute QALYs in that health state. Sixth, add together QALYs for all health states over the time period with and without the intervention. Seventh, 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 $/QALY factor and then can be used either like cost-benefit analysis in calculating net benefits, or like cost-utility analysis in calculating 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 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 from $25,000 to $100,000 or more ($222,000). These numbers are generally taken from ceilings on the cost-effectiveness of various medical interventions. For example, it is stated that if an intervention costs more than $50,000 per QALY gained, it could be judged as inefficient or ineffective. Thus, some practitioners favour the use of such a number for QALY conversions. This approach, however, fails to recognize that the cost of an intervention—$50,000 in this case—may have nothing to do with the benefit and is therefore arbitrary.

Valuation methods and uncertainties introduced when valuing children's health

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 (in press), the issues include the choice of health dimensions, context effects, and survey response validity issues.

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, such as a mental functioning dimension, 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 do poorly at characterizing health of infants.

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, and these uncertainties are similar to those confronted when estimating WTP.

Uncertainty about the duration over which the quality of life improvement will be experienced is probably exacerbated for children's health valuation, compared with adult valuation. 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—again probably more uncertain in children's valuation than in that of 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 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 TTO 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.

Evidence on the validity of preference weighting surveys of children's health is mixed. The QWB performed poorly in terms of construct validity, but HUI and EQ5-D did well. Test-retest reliability was fine for HUI, but the EQ-16D and 17D did poorly.

Most studies take preference weights from parents, on the assumption that children are not capable of making trade-offs involving their health status. For WTP, that trade-off was defined in terms of money. For QALYs, that trade-off 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, this introduces uncertainty about whose preferences are measured and the motivation of 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. Or, as a somewhat better approach, preference weights may be developed for the particular child's health effect, where parents are asked 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 WTP area, while having parents fill out special surveys to derive weights for children is akin to asking parents their WTP 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 the VAS, the HUI (Mark III), and the TTO 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 in 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.

Willingness-to-pay approaches and children

Parental valuations versus child valuations

Clearly, 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 WTP for children's health from a child's perspective or formally in a household framework. Some parental valuation approaches have included household structure as factors in the analysis (e.g., Agee and Crocker 1996a). Several authors have employed a unitary model assumptions is examining children's health-related issues (Rosenzweig and Schultz 1983; Grossman and Joyce 1990). Other authors have

elicited valuation results from parents for their child's health (e.g., Liu et al. 2000). 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 parental WTP for a child's health constitutes a form of benefit transfer. This in itself is a form of uncertainty introduced into the analysis. Taking a household position is more easily justified where the household system includes children's health as an input into the overall system and WTP for children's health can be derived from the household. The household position raises a number of practical uncertainties. First, intrahousehold relationships and dynamics generate significant uncertainty for the analyst. A single adult cannot generally be asked a valuation question, since the value will depend on the budget dynamics of the family and the decisionmaking structure. The question of whom to ask in a stated preference context is 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.

Revealed preference approaches suffer from a different challenge: the decisions made in a household framework are not easily untangled into the actions and power of the individual agents. For example, 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, with certain budget responsibilities assigned to adult members of the household, then WTP will be more difficult to calculate. The research on intrahousehold structure shows that changes in income accruing to one partner result in different expenditure patterns than changes in income accruing to another (Browning and Chiappori 1998). This suggests that definition of the "income" variable in valuation research needs to be carefully examined, and more information on income, sources of income, and financial management may be important in such research.

Differences between parents in preferences, perceptions of risk, risk preferences, discount rates, decision-making power, and other factors make the family decision a complex combination of factors. Furthermore, heterogeneity among households adds to the complexity. Accurate valuation may require untangling these factors.

An interesting example of such issues is the recent research on charitable giving (which includes an altruism component) indicating that men are significantly different than women in donation behaviour (Andreoni et al. 2003). Furthermore, married couples tend to behave more like men, or 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.

Other uncertainties in measuring WTP for children's health

Other uncertainties in measuring WTP 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 non-market goods is increasing relative to market goods (Costa and Kahn 2003); thus the value of marginal health improvements in the distant future may be much more valuable 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 increases the value of preventing exposure: compared with a 70-year-old, a 10-year-old exposed to a toxic hazard simply 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 this value requires understanding the risks of the irreversible loss and the values associated with the health states. Paying a premium to avoid the irreversible states is probably embodied in the valuation results expressed by parents.

Cost-of-illness estimates and children

Estimates of the impact of children's health effects arising from COI 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. Complexities and uncertainties arise nevertheless. 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, and thus uncertainties about these states will affect the cost estimates produced. In general, COI estimates for children's health will be more uncertain than for adults' health because of the longer time horizon and the increased uncertainty of the impact on health (dose-response uncertainty) of young people. The longer timeline

involved in estimates of children's health effects makes estimation of the effects of latency more challenging for children's health than for adult health changes. The presence of irreversible health effects also affects COI 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 those and other sources of forecasting uncertainty on children's health valuation can be reduced through better data and more careful modelling. Once recognized, the influence of trends in critical factors affecting valuation can be explicitly accounted for in time series modelling with a deterministic trend variable. But because appropriate time series data may not be available, a more practical alternative might be conducting 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 (i.e., 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 valuation of program benefits as a way of reducing uncertainty introduced by unanticipated shocks. Another alternative that may be useful where there is periodic updating or review of policies is to periodically reanalyze COI estimates, taking into account any changes that may have occurred. Such reanalysis could also incorporate more complex relationships, such as relative cohort size effects.

Conclusions

The valuation of children's health raises questions that are not typically addressed in traditional valuation exercises. Health valuation for adults is complex, but several factors increase the complexity for children's health issues. Some of these arise from the physiological aspects of children relative to adults; others arise 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 (i.e., forecasting uncertainty) and uncertainty about the relationships being modelled (i.e., modelling 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 decision-making helped us identify seven major sources of economic uncertainty in valuation of children's benefits from environmental health policies:

1. Risk context. Risks to children, especially susceptible children, are always perceived as more "important" risks than those to adults. Given this stylized fact, transferring measures of the benefit of reducing risk to adult health 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 over their own children (and will be captured in preference elicitation tasks at the household level) or if these values are related more fundamentally to an "existence value" regarding children and/or investments in future human capital.

2. 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 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.

3. Irreversibility. Since many children's health issues involve irreversible or potentially irreversible effects, understanding the 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 of a premium on children's health associated with the likelihood of irreversible effects means that the use of adult health values understates those of children. To our knowledge, this premium has not been measured, but we expect it would account for a large proportion of WTP to reduce risks that involve irreversible harm.

4. 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, for example, 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.

5. Proxies for children's preferences. If children's own evaluation 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 this 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 these children's health risks in their own childhood.

6. 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 added to considerations in developing scenarios related to uncertainty associated with the

passage of time. The structure of households has changed over the past 50 years, and these changes may affect valuation.

7. 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 investment in children's health on their subsequent consumption and investment behaviour. 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 quality-adjusted life years and related indices. In each, these sources of uncertainty have been overlooked, contributing to less accurate measures of the benefits of environmental programs. We have suggested approaches to increase the credibility of these measures in the face of uncertainties, such as making COI measures dynamic to better capture uncertainties over time and using QALY surveys to better describe preferences of children and then provide these descriptions to parents who are proxies for their children's valuation decisions.

A fundamental issue involves the questions of whose preferences should count and when they should count. Society has not resolved these issues. For economic analysis of environmental health impacts, these issues influence whether children and their preferences are the focus of valuation efforts or whether parental preferences matter. In addition, the timing of transition from child to adult 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, WTP measures would seem the most appropriate because very restrictive assumptions are needed to make QALYs a valid welfare measure (Krupnick, 2004), and COI has acknowledged limitations as such a measure. If WTP is used, it is clear that the child's WTP will generally not be appropriate because children are incapable of making money-health trade-offs 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, while the QALY paradigm has not.

Notes

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[5] http://yosemite.epa.gov/ochp/ochpweb.nsf.htm (accessed August 2003).

[6] http://www.who.dk/childhealthenv/Policy/20030625_1 (accessed August 2003)

[7] Another source of information is cultural norms and legal rules that reflect experience with the capacity of children to make such judgments. In legal rules there are two related questions, when and why are children allowed to take on adult privileges and 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, 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 are considering modified 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 regarding the age and circumstances under which they will enforce contracts entered by children. The ages are usually different for when a contract will be enforced against the party contracting with the minor and when it will be enforced against the minor. Similarly, legal systems have rules regarding when civil actions can be maintained against minors for injuries they have caused, and many societies have debated these juvenile justice systems and when and how minors are 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.

[8] The DALY approach is unique in two respects. First, 0 is perfect health and 1 is death, where the other indices reverse this nomenclature. Second, life years over certain ages are discounted.

[9] In this case, the value of a statistical case of chronic illness is (the WTP for a risk reduction in chronic illness)/ (risk change).

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

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

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Chapter 7

Willingness to Pay and Quality Adjusted Life Years

by

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Reductions in environmental health risks to children may be obtained using either of the most common preference-based methods of valuing health: quality-adjusted life years (QALYs) and willingness to pay (WTP). Although both methods are based on individual preferences, the underlying assumptions differ. The different bases yield systematically different conclusions about the relative value of reducing health and mortality risks to individuals that differ in age, pre-existing health conditions, income, and other factors. The choice of which method to use depends on judgments about what constraints should be placed on individual preferences and what factors should be considered in aggregating preferences across people. Application of these methods to valuation of environmental risks to children is considered in this chapter, with reference to the question of whose preferences should be considered.

Introduction

Methods for valuing health risk are useful for evaluating whether environmental regulations and other interventions are beneficial to a society or not. Answering this question is not straightforward, because these interventions may have multiple effects on health, ecosystem quality, resource use, and other factors of concern. Within each of these domains, the same intervention may have beneficial and adverse effects on individuals, or on different people. For example, interventions to discourage consumption of some forms of fish in order to reduce risks of cancer or developmental effects associated with dioxins or methyl mercury may increase risks of cardiovascular disease by reducing intake of omega-3 fatty acids.

An extensive literature on valuing health risks has developed over several decades. This literature divides into two streams: one based on "willingness to pay" (WTP) and similar economic measures of welfare, and a second based on "quality adjusted life years" (QALY) and related health-utility measures. Both of these approaches provide methods for identifying a change in one attribute of concern that is "equivalent" to the change in another attribute that is to be valued. QALYs are used routinely in the medical and public-health fields, whereas WTP is widely used in evaluating environmental and transportation-related risks. The WTP approach identifies the change in money that is available for spending in a wide range of welfare-enhancing ways that is equivalent to a specified change in risk of illness or fatality. The QALY approach identifies the change in longevity (in full health) that is equivalent to a specified change in health status.

Most of the work on these approaches focuses on valuing risks to adults, with relatively little directed toward risk to children. This paper describes and compares the theoretical underpinnings of these two approaches and the methods for obtaining numerical estimates, and discusses the application of these methods to valuing risks to children. Although they have been developed in different application areas, the QALY and WTP frameworks share important similarities: both are justified as representing the preferences of individuals, and both are summed across individuals to represent the social value of a change in health risk. However, the specific assumptions underlying the approaches differ in ways that produce systematic differences in the relative values of changes in risks. These differences may lead to different conclusions about whether a policy increases or decreases aggregate health risk.

The paper is organized as follows. In Section 2, the differences between children and adults that are important for valuation are discussed. Section 3 reviews the theoretical assumptions of the two approaches. Section 4 examines the implications for valuing current mortality risk and aggregating values of mortality-risk changes across individuals. Section 5 describes empirical methods for estimating values under the two approaches. Section 6 discusses how health risks are aggregated across people or combined with other endpoints under the two approaches, and Section 7 concludes.

Children and Adults: Whose Preferences?

The literature on valuing health risks has focused on valuing risks to adults. The fundamental concept in the valuation approaches is that the "value" of a change in health risk can be defined and quantified as the change in some other attribute of concern that is "equivalent" to the change in health risk. "Equivalent" is defined in terms of the contribution of the health risk or other attribute to the individual's welfare.

Thus, an individual's WTP to avoid a defined illness is the maximum amount of money he would give up in exchange for avoiding the illness.

As described below, the utility-theoretic justifications for the WTP and QALY measures assume the existence of an autonomous individual having at least implicitly a utility function defined over health status, longevity, and possibly other attributes, such as money available for spending on consumption or other uses. The individual's preferences over these attributes determine her WTP or change in QALYs associated with a particular health effect. Empirical methods to estimate WTP or QALY values assume that the individual is sufficiently well informed about the characteristics of a health risk and its implications for her well being that she can choose from among the available alternatives whatever action best promotes her well being. Typically, the individual is assumed to maximize the expected value of her utility, weighting the utility of alternative possible outcomes by their respective probabilities, conditional on the action chosen.

This idealized rational, informed, and autonomous individual is not an accurate picture of a typical child, and society does not generally view children as autonomous economic agents. Most children do not earn income or make economic choices regarding their health and well-being. Children also differ from adults in their view of death, and may exhibit higher degrees of risk-taking behavior, perhaps because of their undeveloped cognitive abilities and limited practical experience (Harbaugh, 1999). Young children often have difficulty imagining and understanding death in the same way that adults do. They may instead view death as a type of sleep or as an event that happens only to bad people (Carey, 1985). Another difference from adults is that both children and adolescents may have shorter time horizons, discount the future at higher rates, and often underestimate the value of future consumption (Krause and Harbaugh, 1998; Harbaugh, 1999). In short, all of these observed differences present problems for the standard economic assumptions of informed and rational behavior.

This distinction between adults and children, in terms of rationality and autonomy, may be overdrawn, however. It is well known that adults often make decisions and express preferences that are inconsistent with basic axioms of rational decision making. There is a wealth of experimental evidence showing violations of expected utility theory, and decisions are often influenced by which of several alternative but logically equivalent descriptions of a choice are presented (Kahneman et al., 1982). Responses to contingent valuation questions that are widely used to estimate WTP to reduce health risk almost invariably violate the prediction of standard economic theory that WTP should be nearly proportionate to the change in probability of death or illness (Hammitt and Graham, 1999).

Moreover, "no man is an island." Few adults are autonomous. Most function as part of a multi-person household and perhaps a larger community, which influences their decisions and control over resources. Although conventional estimates of WTP are often described as measures of individual preferences, it seems more tenable to interpret them as measures of household WTP. In some cases, the change in health risk is to a defined individual (e.g., the worker in studies of compensating wage differentials). In other cases, the risk change may benefit the entire household (e.g., studies valuing the risk of residential proximity to hazardous-waste sites, Smith and Desvousges, 1987). In all cases, the opportunity cost of a mortality risk reduction is smaller household income. Depending on how households allocate consumption among their members, some or all of them may have lower consumption as a result.

The difference between "children" and "adults" is in many ways more a continuum than a discrete difference, with many children gradually merging into adults as they age. From a economic-theory perspective, the reason to reject basing a measure of valuation on children's own preferences is not that children are qualitatively different from adults, but rather because children differ more from the idealized theoretical decision maker than adults differ from this idealization.

An alternative reason to treat children and adults as distinct arises from social policy judgments. Legal distinctions are frequently made between adults and children concerning rights and responsibilities, including a wide range of behaviors (driving, drinking, voting, making contracts) and sanctions (different criminal justice systems). Societies always face the issue of defining membership, rights, and responsibilities, and a common position is that children are qualitatively different from adults and do not have the same legal standing. There are no bright lines between "child" and "adult" and so legal definitions differ between issues and societies. From this perspective, the child's preferences about health risks could be judged to be of limited relevance to policy decisions, even if there were no concerns about children's decision-making abilities.

For WTP measures of value, household WTP appears to be an appropriate starting point. Understandably, parents know and care about their children's health, and they are accustomed to making economic decisions that affect their children. To some extent, economists may view parental choices as altruistic behavior, but they may also regard households as unitary economic agents, with preferences and behaviors that are the result of some intra-household decision-making process.

For QALY measures, two views may be supported. The utility-theory justification for QALYs is based on an individual's preferences, and surely the individual is the one who most directly experiences his or her health status and longevity. But other household members are influenced by an individual member's health and longevity as well, and so it is possible that a household could be viewed as having a utility function defined over its members' health, just as it can be viewed as having a utility function over its members' consumption of conventional goods. Alternatively, QALYs are sometimes viewed as a standard measuring rod, independent of any specific individual's preferences. One example is when values are derived from generic utility instruments (described in Section 5.2.2) which assign a fixed value to defined health states, ignoring heterogeneity of preferences within a population. Another example is provided by the extra-welfarist perspective, in which QALYs are justified as a socially adopted measure, not because they represent any individual's preferences but rather because society adopts them as the measure to be maximized. Similarly, the closely-related "disability adjusted life year" (DALY) values time spent at different ages and with different levels of disability independent of individual preferences in a society.

It should be noted that adopting a household perspective raises complications that the idealized individual perspective avoids. First, it is well known that methods for group decision making typically do not result in choices that can be described as maximizing a standard utility function (Arrow, 1963). A variety of household allocation models have been developed, including consensus parental preference models, in which parents act as if they are maximizing a single utility function (Behrman et al., 1995; Dockins et al., 2002). Conditions for testing whether households act as if they maximize a single utility function have been developed by Browning and Chiappori (1998). Moreover, household composition changes over time, in both predictable and surprising ways. Households may gain members when new children

are born or are adopted, may lose members through death or when a child matures and establishes her own household, and may dissolve entirely through divorce. In principle, the current preferences of a household should recognize these future possibilities and their implications for members' welfare.

Utility-Theoretic Foundations

An individual experiences various "health states" over her lifetime. The time-path of health states experienced, ending in death, is a "health profile." Risks to health and/or longevity may be represented as lotteries (probability distributions) over alternative health profiles, and policies or other interventions that alter health risks alter the probabilities associated with experiencing different health profiles. (Note that a health profile experienced with certainty can be represented as a degenerate lottery that assigns probability one to the certain health profile and probability zero to all other profiles.)

A utility function is any function that summarizes an individual's preferences, in the sense that it assigns a higher number to a more preferred lottery. Both WTP and QALYs are justified as representing individual utility functions. QALYs assume that preferences over health and longevity depend only on health consequences, and do not depend on other characteristics of the individual or the risk.[3] In contrast, WTP allows for the possibility that preferences over health outcomes depend on individual characteristics such as wealth, as well as on characteristics of the risk such as whether it is perceived to be uncontrollable, unfamiliar, and dreaded.

WTP

The WTP approach reflects conventional microeconomic principles. Anything over which an individual has preferences, including lotteries on health profiles, can be described as an "economic good." An individual's preference for one lottery over another can be represented in terms of a change in income or wealth, which can be used to purchase other goods.

There are two alternative measures of an individual's willingness to trade money and health: WTP and willingness to accept (WTA). Consider the value to an individual with wealth w_0 of moving from health profile H_0 to a preferred health profile H_1. Her utility is a function of the health profile and wealth, u(H, w). The value of the improvement may be measured as:

1. WTP for improvement (compensating variation), the value of c_0 satisfying $u(H_0, w_0) = u(H_1, w_0 - c_0)$. The name implies that the loss of wealth c_0 *compensates* for the gain in health, leaving the individual no better or worse off than without the health improvement.

2. WTA in place of improvement (equivalent variation), the value of e_0 satisfying $u(H_0, w_0 + e_0) = u(H_1, w_0)$. The payment is *equivalent* to the health gain, in that the individual is equally well off whether she obtains the payment or the health improvement.[4]

Figure 7.1 (see Annex) illustrates WTP and WTA for changes in current-period mortality risk, holding the lottery on health and survival in future time periods constant. The figure illustrates two indifference curves for the probability of surviving a specified period (e.g., the current year) and wealth available for spending on other goods. An indifference curve is defined as a set of points such that the individual

judges all points along it to be equally desirable. Points above and to the right of the indifference curve are preferred, as they represent larger survival probability and/or greater wealth. Under plausible assumptions (described below), the indifference curves relating survival probability and income are downward sloping and convex, as illustrated.

The initial position with survival probability p_0 and wealth w_0 is labeled A. An increase in survival probability to p_1 would shift the individual to B, on a higher indifference curve. The individual's WTP for this increase in survival probability is given by the vertical distance between the two indifference curves at p_1, B – C. Alternatively, the individual could achieve the same increase in utility by moving to point D, which involves no change in her survival probability but an increase in her wealth. The individual's WTA compensation in lieu of the survival improvement is given by the vertical distance between the two indifference curves at p_0, D – A.

If the risk reduction $p_1 - p_0$ is small, the two indifference curves will be nearly parallel between p_0 and p_1 (indifference curves cannot intersect). In this case, WTP and WTA will be nearly identical. If the risk reduction is large relative to the curvature of the indifference curves, WTA and WTP may be substantially different, with WTA > WTP.[5] For large changes in mortality risk, an individual's WTA compensation in place of an increase in survival probability may be much larger than her WTP for the same survival gain (note that WTP is limited by ability to pay, but WTA is not).

In principle, the choice of whether WTP or WTA is the appropriate measure of a change in risk may depend on the "property right" in the situation. If the individual having wealth w_0 is entitled only to the inferior health profile H_0, then it may be appropriate to compare her WTP for the improvement to H_1 with the costs of providing the improvement. Alternatively, if the individual is entitled to H_1, then it may be appropriate to compare her WTA to forego the improvement with the costs that can be saved by not providing H_1. At the social level, when the costs of reducing risk are born by the beneficiaries, this distinction breaks down. If starting at H_0, the question is whether the individuals' collective WTP for an improvement exceeds the cost of improvement and, if starting at H_1, whether their collective WTA compensation for an increase in risk is less than the costs saved by allowing the increase. The situation in which individuals are entitled to H_1 without paying for it is not logically available in this case (Mitchell and Carson, 1989).

In practice, separate estimates of WTP and WTA can be most easily obtained using contingent valuation or other approaches in which respondents are questioned about their choices in hypothetical situations (see below). In these cases, estimated WTA is often much larger than estimated WTP. Estimated WTA is often viewed as implausibly large, and so attention has focused on estimating WTP even when WTA might be conceptually more appropriate.

QALYs

The QALY framework provides a method for measuring the value of a health profile in terms of the duration of an equally preferred health profile free of any health impairment. The number of QALYs in a specified health profile is calculated as the quality-weighted lifespan

$$QALYs = \sum_{i=1}^{M} q_i T_i \ . \qquad (3.1)$$

In equation (3.1), lifespan is divided into M periods that are indexed by i. The periods are defined so that only one health state is experienced in each period. The duration of period i is T_i and the "health-related quality of life" (HRQL) associated with that period is characterized by a weight q_i. The value of an intervention that affects health and/or longevity is measured as the difference in QALYs between the health profiles obtained with and without the intervention, as illustrated in Figure 7.2 (see Annex).

The HRQL is a number that represents the quality of health.[6] It is scaled so that a value of one corresponds to perfect or excellent health, and a value of zero corresponds to health that is equivalent to death (i.e., an individual would not care if she were to live the rest of her lifespan in such a state or die immediately). Typically, q is between one and zero, but values of q less than zero can be used to represent states of health that are worse than death.

The conditions under which QALYs represent a valid individual utility function were identified by Pliskin et al (1980). These authors restrict their attention to the special case of chronic (constant) health states, for which equation (3.1) simplifies to

$$QALYs = q\,T \qquad (3.2)$$

where T is remaining lifespan and q is the HRQL for the constant health state in which the individual will live until death. In this case, QALYs represent a valid utility function for an individual if her preferences satisfy the following conditions:

1. *Mutual utility independence*. This condition has two parts: (a) preferences between lotteries on health states, holding duration of life constant, do not depend on remaining lifespan; and (b) preferences between lotteries on lifespan, holding health state constant, do not depend on health state. An example of part (a) is that, if an individual is indifferent between living 40 years in "good" health and a 70-30 lottery between living 40 years in "excellent" health or in "fair" health, she is also indifferent between living 25 years in "good" health and a 70-30 lottery between living 25 years in "excellent" or "fair" health.[7] An example of part (b) is that, if an individual is indifferent between living 30 years and a 50-50 lottery between living 40 years and 25 years, with all years lived in "excellent" health, then she is also indifferent between living 30 years and a 50-50 lottery between living 40 years and 25 years, with all years lived in "fair" health. Mutual utility independence is necessary for utility to be represented as a product of separate health and longevity terms (Keeney and Raiffa, 1976).

2. *Constant proportional tradeoff of longevity for health*. The fraction of remaining lifespan the individual would be willing to sacrifice to improve her health from one state to another does not depend on her remaining lifespan. For example, if an individual is indifferent between living 40 years in "fair" health and 30 years in "excellent" health, she is also indifferent between living 20 years in "fair" health and 15 years in "excellent" health. This condition implies that the HRQL associated with a health state does not depend on the length of time spent in that state.

3. *Risk neutrality over lifespan*. Holding health state constant, the individual prefers whichever lottery on longevity provides the greatest life expectancy. For example, the individual would prefer to live 41 years to a 50-50 lottery between living 50 and 30 years, and she would prefer that lottery to living 39 years (where all years are lived in the same health state, e.g., "excellent" health). A risk-adjusted form of QALY (which does not require risk neutrality) has also been developed (Pliskin et al., 1980) but is

rarely used in practice. In the risk-adjusted case, the simple and ethically appealing calculation of changes in social utility as the population sum of individual changes in QALYs is inconsistent with individual preferences. This follows because the value of a health profile to an individual is a nonlinear function of duration, and so the individual's utility is not equal to the sum of her quality-weighted life years.

Bleichrodt et al. (1997) and Miyamoto et al. (1998) have proposed alternative and simpler conditions that imply an individual's preferences over lotteries on chronic health profiles can be represented by QALYs. One condition is that the individual is indifferent among all health states when her lifespan is zero (the so-called "zero condition"). If, in addition, she is risk neutral over lifespan for each health state (which implies that longevity is utility independent of health state), then her preferences can be described by equation (2.2) (Bleichrodt et al., 1997). Alternatively, if her preferences for lotteries on lifespan holding health constant do not depend on the health state (i.e., lifespan is utility independent of health), then her preferences can be represented as a form of risk-adjusted QALY (Miyamoto et al., 1998).

For the more general case in which health can vary over the lifespan (equation (3.1)), an additional condition is required:

4. *Additive independence across periods.* The individual's preferences for lotteries on health in any subset of the periods do not depend on health in other periods (Dolan, 2000). For example, if the individual is indifferent between (a) spending 10 years in "good" health and (b) spending 5 years in "good" health followed by a 70-30 lottery between 5 years in "excellent" health and 5 years in "poor" health, then she is also indifferent between (c) spending 5 years in "excellent" health followed by 5 years in "good" health and (d) spending 5 years in "excellent" health followed by a 70-30 lottery between 5 years in "excellent" health and 5 years in "poor" health.[8] Additive independence also implies that the individual is indifferent between health profiles offering the same total time spent in each health state, regardless of the sequence in which the health states are experienced. This condition is necessary for QALYs to be calculated as the sum of HRQL-weighted time spent in each health state.

When QALYs are added across individuals (in order to evaluate social policies) it is generally considered appropriate to discount future QALYs at the same rate at which future monetary costs are discounted (Dolan, 2000). Discounting QALYs is justified as treating individuals equally when resources are allocated using cost-effectiveness ratios: if the costs of an intervention are discounted but the effects (added QALYs) are not, then an intervention can be made to appear more favorable simply by postponing its implementation (Keeler and Cretin, 1983). Discounting future QALYs conflicts with the utility-theoretic justification, although the conflict could be remedied by substituting the present value of duration (using the appropriate discount rate) in conditions 2 and 3 above (Johannesson et al., 1994).

Empirical research suggests that individual preferences for health and longevity often violate the conditions under which QALYs provide a valid utility function for individual health (Pliskin et al., 1980; Johannesson et al., 1994; McNeil et al., 1981; Miyamoto and Eraker, 1985; Loomes and McKenzie, 1989; Maas and Wakker, 1994; Stiggelbout et al., 1994; Verhoef et al., 1994; Bleichrodt and Johannesson, 1996; Stalmeier et al., 1996). These violations are often small and idiosyncratic, and QALYs are considered by many to provide a reasonable starting point for representing preferences (Gold et al., 1996; Dolan, 2000).

Two alternative measures, DALYs and HYEs, are closely related to QALYs. "Disability Adjusted Life Years" (DALYs) (Murray, 1994; Murray and Acharya, 1997) are similar to QALYs except they incorporate a weighting factor that depends on age and measure the loss of longevity and health from an idealized health profile.[9] The age-weighting factor represents a judgment that years lived in young adulthood and middle age contribute more to a society than years lived as a child or in old age. The factor is equal to $c \bullet y \bullet e^{-\beta y}$ where y is age in years and β is a parameter conventionally set equal to 0.04; the normalization constant c equals 0.16243 (Murray, 1994). For this value of β, the weighting factor is largest at age 25; it is about three-fourths as large at ages 10 and 50, and half as large at ages 6 and 67. For evaluating changes in health risk, the measurement of health as a deficit from a reference health profile has no effect as the reference health profile cancels.

"Healthy Years Equivalent" (HYEs) (Mehrez and Gafni, 1989) may be viewed as a less restrictive form of QALYs. The HYE for a specified health profile is simply the number of years lived in perfect health that the individual judges to be as desirable as a specified health profile. There is no requirement that HYEs satisfy any of the four assumptions required of QALYs, so they are much more flexible. Concomitantly, because HYEs impose so little structure on preferences, it is necessary to elicit the HYE directly for each health profile of interest; it cannot be calculated from data on duration and preferences for different health states. For example, because HYEs do not require that constant proportional tradeoff (assumption 2) is satisfied, one cannot assume that the ratio of HYEs to time spent in a chronic health state is independent of lifespan. The HYE framework admits the possibility that an individual may be indifferent between 40 years in "poor" health and 20 years in "excellent" health, and also indifferent between 10 years in "poor" health and 9 years in "excellent" health. Perhaps because they impose so little structure on preferences, HYEs have not been widely used in practice.

Valuing Mortality Risk

In many cases, the health effect of greatest concern is fatality. The effects of individual characteristics, including age, health, competing mortality risk, and income, on the value of reducing mortality risk differ systematically between QALY and WTP approaches. In this section, the effects of these characteristics on the value of reducing a specific current risk (defined as a probability of dying within the current period from a specified cause) are examined under each framework.

WTP

Under the WTP approach, the value of reducing mortality risk is measured as the "value of a statistical life" (VSL). VSL is an individual-specific value defined as the marginal rate of substitution between mortality risk and wealth or income, i.e., the individual's WTP for a small reduction in mortality risk divided by the risk change, which is equivalent to the WTA for a small increase in mortality risk divided by the risk change and to the slope of the indifference curve illustrated in Figure 7.1 (see Annex) at the individual's wealth and risk level.

VSL depends on wealth, current mortality risk, and the lottery over future health profiles the individual faces. The standard model (Drèze, 1962; Jones-Lee, 1974; Weinstein et al., 1980) assumes the individual maximizes her expected utility

$$EU(p, w) = (1 - p)\, u_a(w) + p\, u_d(w) \qquad (3.3)$$

where p is the individual's chance of dying during the current period and $u_a(w)$ and $u_d(w)$ represent her utility as a function of wealth conditional on surviving and not surviving the period, respectively. The function $u_d(\cdot)$ incorporates the individual's preferences for bequests and can incorporate any financial consequences of dying (such as medical bills or life-insurance benefits). In this single-period model, wealth and income are treated as equivalent. In multi-period models, the difference between wealth and income and the opportunities for future earnings can be important.

The individual's VSL is derived by differentiating equation (3.3), holding utility constant, to obtain

$$VSL = \left.\frac{dw}{dp}\right|_{EU=k} = \frac{u_a(w) - u_d(w)}{(1-p)u_a'(w) + pu_d'(w)} = \frac{\Delta U}{EU'} \qquad (3.4)$$

where prime indicates first derivative.

The numerator in equation (3.4) is the difference in utility between surviving and dying in the current period. The denominator is the expected marginal utility of wealth, that is, the incremental utility associated with additional wealth conditional on surviving and dying in the current period, weighted by the respective probabilities. Assuming that survival is preferred to death (i.e., $u_a(w) > u_d(w)$) and that greater wealth is preferred to less (i.e., $u_a'(w) > 0$, $u_d'(w) \neq 0$), both numerator and denominator are positive and so VSL is positive and the indifference curves in Figure 7.1 (see Annex) slope downward.

Under the WTP approach, the value of reducing a specific mortality risk in the current period depends on life expectancy, competing mortality risk, and the individual's health if she survives the specific risk. In addition, the value under the WTP approach also depends on baseline risk and on income or wealth.

First, consider the effect of baseline (total) risk on VSL. It is natural to assume that $u_a'(w) > u_d'(w)$, that is, the increased utility provided by greater wealth is larger if the individual survives and has the opportunity to spend it. If the utility functions are interpreted as applying to a household, this assumption implies that marginal utility of wealth is greater in the event the member in question survives. This seems reasonable except in the case where the household member at risk is the primary income earner, in which case wealth may be much lower in the event of her death. If the assumption holds, an increase in the baseline risk p decreases the expected utility-cost of spending (the denominator in equation (3.4)). The utility associated with survival (the numerator in equation (3.4)) is unaffected by baseline risk, so the individual would be willing to spend more to reduce her mortality risk. For small changes in risk, this "dead-anyway" effect (Pratt and Zeckhauser, 1996) is small. Assuming that $u_d' \neq 0$ (i.e., the individual prefers more wealth to less, even if she dies), the proportional effect on VSL of a change in baseline risk is less than the proportional change in the survival probability (1 - p).

The value of reducing the specific mortality risk is smaller if the individual also faces a competing mortality risk. The existence of a competing mortality risk reduces the magnitudes of both the numerator and the denominator in equation (3.4). The numerator decreases because the total probability of survival is smaller, and the denominator decreases because of the dead-anyway effect. It can be shown, however,

that the effect in the numerator dominates, and so competing mortality risk reduces WTP to reduce the specific mortality risk (Eeckhoudt and Hammitt, 2001).

VSL may depend on the individual's future health if she survives the specific mortality risk, but the sign of the effect is ambiguous. Survival in good health rather than poor increases the value of the numerator in equation (3.4). However, if the marginal utility of wealth is higher in good health than in poor health, the value of the denominator is larger and the effect on the ratio is indeterminate. As noted above, limited empirical evidence suggests that the marginal utility of income is smaller in a state of chronic health impairment (Sloan et al., 1998; Viscusi and Evans, 1990), and some empirical studies suggest that VSL is larger for people with cancer (Krupnick et al., 2002; Smith et al., 2001) or angina (Smith et al., 2001) than for people without those impairments.

As with most goods, WTP for reduction in mortality risk depends on ability to pay and is likely to increase with wealth. The assumption that additional wealth is more valuable in life than as a bequest (i.e., $u_a'(w) > u_d'(w)$) implies that the numerator of equation (3.4) increases with wealth. Individuals are generally averse to financial risk. If so, the denominator declines with wealth (the second derivatives of $u_a(w)$ and $u_d(w)$ are negative), and VSL increases. If the individual is indifferent to financial risk, the denominator is constant and again VSL increases with wealth. Only in the implausible case in which the individual prefers to bear greater financial risk (for the same expected return) can the denominator increase with wealth, making the effect on VSL indeterminate.[10]

The effect of life expectancy on VSL is influenced by two competing factors. A greater life expectancy increases the utility of surviving the current period (the numerator in equation (3.4)). Greater life expectancy may also increase the denominator, because of the desire to save wealth for consumption in future periods, or because the opportunity cost of current spending to reduce mortality risk is larger for individuals with a longer investment horizon. The effect of life expectancy also depends on whether the individual is able to borrow against future income and on any difference between the rates at which she discounts future utility and the rate of return to savings.

A number of investigators have developed theoretical models to examine how VSL varies over an individual's life cycle. These models extend the one-period model described in equation (3.3) by assuming the individual seeks to maximize the expected discounted value of the utility of consumption

$$EU = \sum_{t=0}^{\infty} p_t \alpha^t u(c_t)$$

where p_t is the probability of surviving at least to age t, c_t is consumption at age t, and α is the individual's discount factor (i.e., $\alpha = 1/(1+r)$ where r is the rate at which the individual discounts future utility). As these models represent decisions of a rational autonomous agent over time, they cannot necessarily be assumed to apply to young children.

In models that assume an individual can borrow against future earnings, VSL declines monotonically with age. Under this assumption, Shepard and Zeckhauser (1984) calculate that VSL for a typical American worker falls by a factor of three from age 25 to age 75. If individuals can save but not borrow, VSL rises in early years as the

individual's savings (and earnings) increase before it ultimately declines. In this case, Shepard and Zeckhauser calculate that VSL peaks near age 40 and is less than half as large at ages 20 and 65.

Ng (1992) suggests that individuals may discount their future utility at a rate smaller than the rate of return to financial assets, whereas Shepard and Zeckhauser assume these rates are equal. If the utility-discount rate is less than the rate of return, individuals should save more when they are young and consume more when old. Under these conditions, VSL may not peak until age 60 or so (Ng, 1992). Even if they discount future utility at the rate of return, prudent (Kimball, 1990) individuals might be anticipated to save more and spend less on reducing mortality risk when they are young, because of the greater range of financial contingencies they face.

WTP may depend on characteristics of the risk other than the probabilities and possible health outcomes. Limited empirical evidence suggests that average WTP to reduce fatality risks may be somewhat larger for risks that are perceived as involuntary, uncontrollable, unfamiliar, or dreaded (McDaniels et al., 1992; Savage, 1993; Jones-Lee and Loomes, 1995; Subramanian and Cropper, 2000).

For evaluating social programs, it is possible to ignore the effects of individual differences in wealth or other factors that are considered ethically inappropriate by replacing individual VSLs with a value that is obtained by averaging over the objectionable characteristics. This approach is often taken in practice, where differences in wealth and health quality are generally ignored. An alternative approach is to consider how individuals might choose to incorporate differences in wealth and other factors in allocation of social resources if they were to make the decision behind a Rawlsian veil of ignorance, before they knew their own characteristics. Pratt and Zeckhauser (1996) use this approach to argue that the appropriate VSL for use in social policy choices increases with income, although at a smaller rate than empirical estimates suggest. They also argue that differences in VSL due to differences in baseline risk (the dead-anyway effect) should not be incorporated.

QALYs

The value of a change in a specific current mortality risk under the QALY approach is the change in the expected number of QALYs. It depends on life expectancy and expected future health state, but not (with limited exceptions described below) on income or other factors.

If the probability of dying from a specific cause in the current period is p, the individual faces a lottery with a p chance of dying in the current period, and a complementary chance of surviving the specific risk and facing the lottery over health profiles that is determined by all the other health risks she faces in the current and future periods. Assuming the current period is one year, the health profile if the individual dies from the specific risk provides approximately one-half QALY (assuming she is equally likely to die at any time during the year and that her HRQL until then is nearly one). The value of a small reduction in the specific fatality risk is

$$V = \Delta p \, E(QALY) - \Delta p/2 \qquad (3.1)$$

where Δp is the change in the specific risk and E(QALY) is the expected number of QALYs if she survives the specific risk. Assuming the expected future QALYs are large compared with 1/2, the second term in equation (3.1) can be neglected, yielding

$$V \approx \Delta p \, E(QALY). \qquad (3.2)$$

As shown by equation (3.2), the value of reducing a specific mortality risk depends on the health lottery the individual faces if she survives that risk. Indeed, it is nearly proportional to the expected number of QALYs the individual will live if she survives. This implies that the value of reducing the specific mortality risk is directly related to the individual's life expectancy conditional on surviving the specific risk, and to her expected future health state. For an individual who is likely to survive in very good health ($q \gg 1$), the value of reducing the specific mortality risk is proportional to life expectancy.

Figure 7.3 (see Annex) illustrates the relative value of reducing mortality risk to individuals as a function of age under three measures—life expectancy (i.e., expected life years), expected discounted life years (equivalent to discounted QALYs in the special case where HRQL equals one at all ages), and DALYs. For both discounted life years and DALYs, the calculations use a recommended discount rate of 3 percent per annum (Gold et al., 1996). The three approaches are calibrated so that assign the same value to reducing mortality risk to a 40 year old, since this is about the mean age for many of the compensating-wage-differential studies, which are considered to provide the most reliable estimates.

Note that the relative value of reducing mortality risk falls nearly linearly with age for the case of life expectancy. The value of saving a 10 year old is about 75 percent larger than the value of saving a 40 year old and the value of saving a newborn is almost twice the value of saving a 40 year old. For discounted life years, the value falls more slowly with age. The relative value of saving a 10 year old is 29 percent larger than the value of saving a 40 year old, and the value of saving a newborn is only slightly larger, 33 percent more than the value of saving a 40 year old. For DALYs, the relative value of reducing mortality risk first rises then falls as a function of age, because years lived in early childhood count substantially less than years lived as a young adult. The relative value of saving a 10 year old is about 64 percent larger than that of saving a 40 year old, and the relative value of saving a newborn is 42 percent larger than the value of saving a 40 year old.

The effect of a competing mortality risk is to reduce the value of mitigating the specific mortality risk in direct proportion to the magnitude of the competing risk. This follows because the competing risk reduces the expected QALYs conditional on surviving the specific risk.

The value of reducing a specific mortality risk is also proportional to the individual's expected future health. Hence, the QALY approach implies it is more valuable to reduce a current mortality risk for someone whose survival would be in very good health than for someone whose survival would be in impaired health. For example, the HRQL for life after a myocardial infarction has been estimated as about 0.9 (Salkeld et al., 1997). Under the QALY approach, the value of reducing current mortality risk to someone who has survived a myocardial infarction is about 90 percent as large as the value of an identical risk reduction to someone who will survive with the same life expectancy but with no significant health impairment. Similarly, if people at risk of death from air pollution have low HRQL because of pre-existing illness, the QALY value of reducing mortality risk from air pollution may be lower than the value of reducing risks to healthier people.

The relative value of reducing mortality risks to different individuals under the QALY approach is generally considered to be independent of individual economic circumstances, because life years (adjusted for health status) are counted equally

regardless of personal characteristics. However, this claim must be qualified, as wealth can have several effects on HRQL, which represents the rate of substitution between longevity and health quality.

First, HRQL may depend on individual characteristics and circumstances. For example, the utility consequence of a health impairment may depend on the individual's ability to mitigate it, which may depend on economic circumstances. If the effects of an adverse health condition on individual well-being can be substantially offset using market goods (e.g., personal assistants or mechanical devices), an individual's well-being in that state may be positively related to her wealth or income. However, since HRQL measures utility in the impaired health state relative to utility in perfect health, the effect of wealth on HRQL will depend on the relative degree to which it improves well-being in the two states. Under the assumption that QALYs are a utility function for health and longevity, the incremental effect of wealth on welfare is positively associated with health and longevity, except in the implausible case in which incremental wealth is more valuable as a bequest than in life. Limited empirical evidence also suggests that the marginal utility of wealth is smaller in impaired health states than in full health.[11]

Second, under the approach recommended by an expert panel (Gold et al., 1996), the effects of health status on earnings capability and income are incorporated in HRQL.[12] The effect of a health impairment on income is likely to depend on both income and the individual's job. Individuals whose income is more sensitive to health status may have a smaller HRQL for the same health impairment (e.g., a physical disability might cause a greater income loss to a construction worker than to a writer).

For evaluating the social value of changes in health risk, the effects of income or other individual characteristics on HRQL can be eliminated by valuing all changes using population-average values of HRQL. Indeed, this is the recommended practice (Gold et al., 1996). However, if HRQL depends on income, this approach does not aggregate individual changes in welfare and so may lead to ranking health interventions in an order different than the affected individuals would rank them. Note that the same approach — using population average values — can be (and usually is) used to remove the effect of income differences on WTP.

Since QALYs depend only on the duration and severity of health effects, the value of a risk reduction is independent of other characteristics of the risk, such as whether it is perceived as controllable or dreaded. In principle, the HRQL associated with a health state might be allowed to depend on these characteristics, but this extension has not been investigated.

Methods for Estimating Values

Information about preferences, in the form of HRQL or WTP, can in principle be obtained using stated-preference or revealed-preference methods. Stated-preference methods have been used to estimate both HRQL and WTP, but to date revealed-preference methods seem to have been used only to estimate WTP.

Stated-preference methods rely on asking individuals either to report their preferences directly, or to report how they would behave in a specified hypothetical situation. They are extremely flexible, as individuals can be questioned about how they would choose in a great variety of hypothetical situations. The hypothetical nature of the choice is also the greatest weakness of these methods, as individuals may be

unfamiliar with the choices and have inadequate incentive or opportunity to provide thoughtful answers.

Revealed-preference methods rely on observing behavior in situations that are more consequential than answering survey questions. They assume that people act in their own best interest, and so the chosen alternative must be preferred to the rejected alternatives. In revealed-preference studies, subjects have an incentive, and may have the opportunity, to seek information about the alternatives and to consider the choice carefully. Nevertheless, individuals may be poorly informed about the differential health risks associated with the choices they face. Also, although the analyst observes the alternatives that individuals choose, she does not observe the alternatives they reject and the attributes of those alternatives.

This section provides a brief overview of the methods used to estimate HRQL and WTP. The identification of possible health states and probability distribution over time spent in each state which is required for calculating QALYs can be developed using risk-assessment methods.

WTP

WTP for reductions in health risk can be estimated using either stated- or revealed-preference methods. These are described in turn.

Stated Preferences

The most commonly used stated-preference method is contingent valuation (CV), in which survey respondents are asked to choose between alternatives that differ in the attribute to be valued and in cost. CV has been used to value a range of health risks, beginning with Acton's (1973) study of emergency-response services for heart attacks. The most common application has been to transportation risks, although risks associated with food, medical technologies, hazardous waste, and other sources have also been examined (Hammitt and Graham, 1999).

CV results can be sensitive to apparently inessential aspects of the choice (e.g., question ordering and the format in which risks are presented) but insensitive to essential aspects, such as the quantity of the good to be valued (Hammitt and Graham, 1999; Baron, 1997; Covey et al., 1998; Frederick and Fischhoff, 1998). CV estimates of WTA are often much larger than estimates of WTP, perhaps because of framing effects (Mitchell and Carson, 1989; Horowitz and McConnell, 2002).

For estimating VSL, the apparent insensitivity of WTP to the magnitude of risk reduction is important because the estimated VSL (WTP divided by risk reduction) will strongly depend on the magnitude of the reduction specified in the survey. Standard theory (Section 3.2) suggests that WTP for mortality-risk reduction should be nearly proportionate to the magnitude of the change in probability (i.e., VSL should be insensitive to small changes in baseline risk and wealth). The modest number of studies that have tested for sensitivity to magnitude have found that estimated WTP is usually less than proportionate to the change in probability, and in some cases WTP is not even statistically significantly related to the magnitude of risk reduction (Hammitt and Graham, 1999).

Corso et al. (2001) investigated the extent to which difficulties in communicating small risks to survey respondents might account for the inadequate sensitivity of estimated WTP to magnitude of the risk reduction. In separate subsamples, they

elicited WTP for a side-impact automobile airbag that was described as reducing the annual chance of dying in an automobile crash by either 5/100,000 or 10/100,000. Respondents were presented with one of three visual aids (a logarithmic risk ladder, a linear risk ladder, or a field of 25,000 dots), or with no visual aid. Corso et al. found that estimated WTP was proportional to the stated risk reduction for the respondents who were presented with the 25,000 dots, and WTP was close to proportional for the respondents presented with the logarithmic risk ladder. In contrast, WTP was not significantly related to the stated magnitude of the risk reduction for respondents who were not provided with a visual aid.

Revealed Preferences

Revealed-preference studies of WTP for health risk reductions require that individuals choose between alternatives that differ in health risk and monetary consequences. Most have examined the incremental pay workers receive for accepting hazardous jobs. Choices among consumer products (e.g., cigarettes, smoke detectors, automobiles) and the use of protective equipment (e.g., seat-belts, motorcycle helmets) have also been examined (Viscusi, 1993).

Studies of compensating wage differentials suffer from data and statistical limitations. Fatality risk is usually based on industry or occupational averages, which are likely to conceal much variation between jobs (Garen, 1988) and workers (Shogren and Stamland, 2002). Inability to control for all the other job and worker attributes that may be correlated with fatality risk leads to potential biases (Leigh, 1995). For example, many studies do not control for nonfatal-injury risk. This omission is likely to bias estimated VSL upward because part of the observed wage differential compensates for injury risk, which is positively correlated with fatality risk. The bias is estimated as 20-150 percent using actuarial data on risks to US workers (Viscusi, 1978) and 100 percent using survey data on perceived risks to Taiwanese workers (Liu and Hammitt, 1999), although a recent meta-analysis (Mrozek and Taylor, 2002) suggests the bias is negligible.

Although it may appear that studies of compensating wage differentials estimate workers' WTA compensation for job risk, these studies equally measure workers' WTP to reduce risk. A worker is assumed to prefer the job he holds to all the alternative jobs available to him. Implicitly, he reveals that his WTA compensation to bear additional risk is larger than the incremental pay offered by more dangerous jobs, and that his WTP for risk reduction is smaller than the pay cut he would take by choosing a safer job.

Application to Children's Risks

Although a number of studies have estimated the cost of illness associated with children's health effects, only a few have estimated household WTP to reduce risks to children. Viscusi et al. (1987) used CV to estimate WTP to prevent the risk of injury associated with household pesticides. They found that WTP to reduce risks to one's children exceeds WTP to reduce risks to oneself, but could not distinguish between the effects of parental altruism and injury severity. Viscusi et al. (1988) examined household WTP to reduce risks of injury associated with household insecticides, for injuries to adults and children within and outside the household. They found that household values for a statistical case of child inhalation poisoning were about 75 percent larger than for a statistical case of adult skin poisoning. Unfortunately, this

research does not allow estimation of the relative value of adult and childhood risks of the same injury.

In the same study, Viscusi et al. (1988) elicited WTP to reduce these risks to people in other households, both in the same state (North Carolina) and in the United States as a whole. Viscusi et al. found that altruistic WTP to reduce risks to other households was substantial and was greater for reducing risks to children than for reducing risks to adults. In particular, the probability of contributing to a program to reduce risks in the state was 79 percent for a program that reduced risks to children, and 57 percent for a program that reduced risks to adults. Average contributions to each program, accounting for the probability of contributing, were $11.53 for reducing risks to children and $8.75 for reducing risks to adults.

In anther CV study, Liu et al. (2000) estimated mothers' WTP to protect themselves and their children from suffering a cold. WTP was positively associated with the severity of symptoms and the duration of illness. In addition, mothers' WTP to protect their child from a cold was nearly twice as large as their private WTP to protect themselves from a cold of equivalent severity and duration, an indication that mothers value their children's health more than their own.

Several studies have used revealed-preference methods to estimate WTP. Agee and Crocker (1996) estimated parental WTP to reduce the risk of neurological impairments from childhood exposure to lead using a revealed-preference approach based on the parents' decision to obtain chelation therapy for their child. Two studies examined purchase and use of safety devices to reduce the risk of fatality. Carlin and Sandy (1991) studied the use of child safety seats, and Jenkins et al. (2001) examined purchases of bicycle helmets. Similarly, Maguire et al. (2002) considered the price premium paid for organic baby food as an indicator of household WTP to reduce risks associated with childhood exposure to pesticides.

QALYs

HRQL is typically elicited directly or calculated from a generic health utility scale. The generic scales are themselves calibrated using direct elicitation.

Direct Elicitation

The HRQL may be elicited from individuals directly, using any of several question formats: standard gamble, time tradeoff, visual analog scale, and person tradeoff. In general, HRQL for a health state is elicited assuming the health state will be chronic (constant).

The *standard gamble* (SG) format requires the respondent to indicate the smallest chance of survival in perfect health she would accept in a lottery where the alternative outcome is immediate death. This may be motivated by considering a surgery that would alleviate a health impairment without affecting longevity, except for the chance of dying in surgery. For example, if the respondent is indifferent between living 20 more years in a particular impaired health state and a lottery which offers her a 75 percent chance of living 20 more years in perfect health and a complementary chance of immediate death, the value of q for the impaired health state is 3/4, and both the certain health profile and the lottery offer an expected value of 15 QALYs.

The *time tradeoff* (TTO) format requires the respondent to indicate the number of years in perfect health (with q = 1) she considers to be indifferent to a specified chronic

health profile. For example, if the respondent indicates that she is indifferent between living 20 years in a particular impaired health state and 15 years in perfect health, the value of q for the impaired health state is calculated as 15/20 = 3/4. Both health profiles offer 15 QALYs.

The *visual analog scale* (VAS) is a linear scale with one end representing perfect health and the other representing health states as bad as death. The respondent is asked to place a mark on the scale representing how desirable the specified health state is to her, relative to the endpoints. A similar verbal format may be used where the respondent is asked to report a number representing her preference for the health state between zero and 100, where zero represents a state as bad as death and 100 represents perfect health.

The *person tradeoff* (PTO) format asks the respondent to consider the relative value of improving health for people in different health states. For example, she might be asked to judge the relative value of extending longevity for people in different health states, e.g., if one were to choose between extending the life of 1,000 healthy people for a year and extending the life of x blind people for a year, for what value of x would she be indifferent? The HRQL of living with blindness is estimated as 1,000/x. Alternatively, the respondent might be asked to judge the relative value of improving health for people in one state and extending life for people in another state, e.g., if one were to choose between extending the life of 1,000 healthy people for a year and restoring the site of z blind people for a year, for what value of z would she be indifferent? In this case, the HRQL of living with blindness is estimated as 1 – (1,000/z) (Murray and Acharya, 1997).

Risk-tradeoff questions have been used to evaluate preferences for environmental and motor-vehicle related risks (Viscusi et al., 1991; Magat et al., 1996; Jones-Lee et al., 1995; Carthy et al., 1999). In a risk-tradeoff question, respondents are asked to choose between situations offering higher risks of one health outcome (e.g., chronic bronchitis) and lower risks of another (e.g., motor-vehicle fatality). The risk-tradeoff approach is similar to SG. A respondent who is indifferent between reducing his motor-vehicle-fatality risk by 3 per 10,000 and his risk of chronic bronchitis by 1 per 1,000 can be interpreted as having an HRQL for chronic bronchitis of 0.7.

If the conditions under which QALYs provide a valid utility function are satisfied (Pliskin et al., 1980; Bleichrodt et al., 1997; Miyamoto et al., 1998) and an individual's answers to elicitation questions are consistent with her utility function, then both SG and TTO formats should yield exactly the same value.[13] The claim that SG incorporates risk preferences whereas TTO only captures preferences about risk-free outcomes is incorrect (Dolan, 2000). In practice, the results of SG and TTO elicitations differ, perhaps because individuals' preferences are not exactly consistent with the required conditions and because the formats make different aspects of the health profiles more salient: SG emphasizes risk and uncertainty, while TTO emphasizes relative preferences for near-term and future health. In practice, SG values may be slightly larger than TTO values Torrance, 1986). VAS values, because they are not tied to an explicit decision, have a weaker utility-theoretic justification. In practice, however, they may be more reliably assessed (i.e., vary less on repeat measurement) than TTO or SG values. VAS values are typically smaller than TTO or SG values, but are sometimes adjusted using an empirically-estimated formula to approximate the results of TTO or SG formats. Unlike the other methods, PTO has the potential to incorporate judgments about distributional equity. PTO measures preferences over

other people's health, and so values elicited using PTO need not correspond to values of HRQL that represent an individual's preferences for her own health.

An important question in eliciting HRQL is whose values to elicit? Possible respondents include those randomly sampled from the general public, individuals experiencing the health states of interest, and health-care providers or others knowledgeable about the health state. Experience suggests that individuals in an impaired health state assign a larger HRQL to that state than do healthier individuals. Whether this reflects improved understanding of the condition by people experiencing it or adaptation to adverse circumstances is not clear. All the choice-based elicitation methods require comparing two health states, at least one which is not currently experienced by the respondent at the time of elicitation.

Generic Health Utility Scales

A number of generic health utility scales have been developed. These scales can be used to describe health states in terms of their levels on several attributes, and the HRQL associated with the state may be obtained from a table or calculated using an arithmetic formula. In principle, all such scales are examples of multi-attribute utility functions, although the extent to which the scales are explicitly based on multi-attribute utility theory varies. The scales have been calibrated by fitting them to preference values elicited using one or more of the direct methods reviewed above. Among the more popular generic health utility scales are the Health Utilities Index (Feeney et al., 1996), the EuroQol EQ-5D (Kind, 1996), and the Quality of Well-Being Index (Kaplan and Anderson, 1996).

The Health Utilities Index Mark 3 (HUI3) classifies health states using a system of eight attributes: vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain. Each attribute has either five or six levels, yielding a total of 972,000 possible health states. The attributes are designed to be structurally independent so that all of the possible combinations are logically possible. The attributes are approximately mutually utility independent (for an average respondent) and the multi-attribute utility function defining HRQL is a product of the factors corresponding to each attribute level. The function has been calibrated to HRQL values elicited using SG and VAS format questions from a general population of about 500 Canadians (Furlong et al., 1998).

The HUI formula and attribute levels are reported in Table 7.1 (see Annex). As an example, an individual with functioning at the highest level on all attributes except vision (level 3: able to read ordinary newsprint with or without glasses but unable to recognize a friend on the other side of the street, even with glasses) and ambulation (level 4: able to walk only short distances with walking equipment, and requires a wheelchair to get around the neighborhood) would have HRQL = 1.371 * (0.89 * 1 * 1 * 0.73 * 1 * 1 * 1 * 1) - 0.371 = 0.52.

The EuroQoL EQ-5D classifies health states using a system of five attributes: mobility, self-care, usual activity, pain/discomfort, and anxiety/depression. Each attribute has three levels, yielding a total of 243 health states. Two additional states, dead and unconscious, have been added for a total of 245. Values for EQ-5D states have been elicited using TTO and VAS format questions in numerous European and Nordic populations. As an approximation, the HRQL can be represented as an additive function of the attribute levels, as shown in Table 7.2 (see Annex). An individual with impaired mobility (level 2: some problems in walking about) and some pain/discomfort

(level 2: moderate pain or discomfort), with all other attributes at their highest levels, would have HRQL = 1 – 0.069 – 0.123 – 0.081 = 0.73. The five-attribute classification system is supplemented with a single holistic question in which the respondent is asked to rate her current health on a visual analog scale (EuroQol Group, 1998).

The Quality of Well-Being Index (QWB) (Kaplan and Anderson, 1996) is one of the earliest of the generic health utility scales. It describes health using three attributes — mobility, physical activity, and social activity — plus an attribute consisting of descriptions of symptoms or "problem complexes." Like the EQ-5D, the HRQL is an additive function of the attribute levels. The attribute levels and values are reported in Table 7.3 (see Annex). In addition, there are 27 different symptoms or complexes with values ranging from zero (no symptoms) to –0.727 (death). An individual with mobility level 2 (in hospital, health related), physical activity level 4 (no limitations for health reasons), social activity level 3 (limited in major (primary) role activity, health related) with symptom and problem complex 10 (general tiredness, weakness, or weight loss, value = –0.259) would have HRQL = 1 – 0.090 – 0.000 – 0.061 – 0.259 = 0.590.

Applications to Children's Risks

A number of studies of the cost-effectiveness of interventions to improve children's health use either QALYs or DALYs as the measure of effectiveness. A comprehensive database of cost-effectiveness studies published in peer-reviewed journals between 1976 and 2001 includes 39 such studies, of which 21 were published in 1998 or later. The health effects studied include neurological and reading disabilities, cancer, earache, and loss of hearing and vision.

Sources of HRQL used in these 39 studies vary widely. Study-specific HRQL values were developed using primary preference data (e.g., a limited survey of medical practitioners or parents) in four cases and using authors' judgment in eight cases. Values were obtained from a pre-existing study in 10 cases (the sources used by these studies are not reported). Generic utility scales were used in 11 cases, DALYs in four cases, and the source of the HRQL values is not reported in two cases (Peter Neumann, personal communication).

Aggregation of Health Risks

A fundamental difficulty in defining the social value of changes in health risk is the absence of a clear criterion for weighing gains and losses to different people. Standard microeconomic theory assumes it is impossible to measure utility or to compare utility gains between people (Samuelson, 1947). From this perspective, the choice between using years of healthy life and monetary units as a standard for comparing utility changes between individuals is arbitrary.

Choosing a standard for comparing utility changes among individuals is analogous to choosing which of a possibly infinite set of Pareto efficient allocations of welfare is the most socially preferred.[14] The choice may be based on which standard is judged to be more equitable, but other methods of addressing equity implications are also available. For example, whether utility is measured in QALYs or monetary units, changes in utility to different individuals can be weighted by some function of individual characteristics; for example, QALYs gained by people with poor health could be weighted more heavily than gains to people in good health, and WTP of people with low income could be given greater weight than WTP of people with high

income. Alternatively, interpersonal differences in QALYs or WTP that are judged to result from ethically inappropriate factors can be removed by ignoring variation in these factors and using population average values of QALYs or WTP. Ignoring the effects of individual characteristics comes at the cost of weakening the utility-theoretic basis for the measure and may lead to evaluations that contradict individual preferences.

The difference in unit also affects the ease with which changes in health risk can be compared with the resource costs of a policy and effects on other attributes of concern, such as environmental quality. WTP values can be easily combined with monetary measures of the costs of a policy and WTP for changes in other attributes, enabling one to identify an option that maximizes net benefits (as measured in monetary units). In principle, one could also measure the value of resource costs, changes in environmental quality, and other attributes in QALYs, allowing identification of the policy that maximizes net benefits (as measured in QALYs). In practice, however, values of other attributes have not been measured in QALYs, and QALYs have been restricted to use in cost-effectiveness analysis, in which policies are evaluated by the cost per QALY produced. Cost-effectiveness analysis can be used to identify the least costly methods to provide health, but it cannot be used to determine whether the health gains from a particular policy justify the costs.

If a constant WTP per QALY ratio existed, it might be possible to translate from one approach to the other, much as one can translate monetary values between currencies using established exchange rates. However, the qualitatively different effects of life expectancy, health state, baseline risk, and wealth on the QALY and WTP measures of the value of current fatality risk imply that individuals cannot be expected to have a constant rate of substitution between QALYs and wealth (Hammitt, 2002). For example, even though life expectancy and future QALYs decline with age (after infancy), there appears to be a substantial age range over which VSL is constant or increasing (Krupnick et al., 2002; Smith et al., 2001; Shepard and Zeckhauser, 1984; Ng, 1992). Over this range, the individual's WTP per QALY must increase with age.[15]

Conclusions

Even though QALYs and WTP are both justified as representing individual preferences, these two prominent methods for quantifying the social value of changes in health risk differ in their theoretical foundations, the unit by which health is measured, and in the relative values they assign to different health risks.

The different assumptions underlying QALYs and WTP have systematic effects on the quantified value of changes in current mortality risk. These are summarized in Table 7.4 (see Annex). Under both approaches, the value of reducing a specific current mortality risk is smaller when the individual faces a competing mortality risk. Greater life expectancy and the absence of comorbidities increase the value of reducing a current mortality risk under the QALY approach, but the effects of these factors are theoretically ambiguous under the WTP approach. In contrast, baseline risk increases the value of reducing the current mortality risk under the WTP approach, but has no effect under the QALY approach. WTP depends on wealth, but QALYs are generally considered to be independent of wealth subject to some qualifications regarding the extent to which wealth may help in coping with health impairment and the effect of health impairments on income.

QALYs are based on the assumption that preferences over health risks depend only on the probabilities of each health outcome. Preferences over health risks associated with other aspects of the risk, such as controllability and dread, cannot easily be incorporated in a QALY measure. In principle, the WTP approach can easily incorporate such preferences, although there have been few empirical attempts to estimate the effects of these factors.

Methods for estimating QALYs and WTP have been developed and applied to a wide set of health risks, although relative few applications concern children's health risks. Although the utility theory underlying the two approaches assumes an informed, rational, and autonomous individual, in practice WTP estimates may be interpreted as measures of household valuation, and so there does not appear to be a fundamental difficulty in using household preferences to value children's health. With respect to QALYs, the theory is more explicitly tied to individuals, but a reinterpretation involving household preferences may also be appropriate in this context.

Estimates of QALYs are likely to be less variable across people and studies than estimates of WTP, because the QALY framework imposes greater constraints. Estimates of the duration of health states are typically based on modeling and the estimated HRQL for each health state may be partially constrained by comparison with estimates of HRQL for other health states that can be judged as better or worse. Because HRQL is scaled relative to perfect health and death, standard-gamble estimates of HRQL are typically obtained using probabilities on the order of 1 in 100 or larger, which are likely to be more comprehensible to survey respondents than the probabilities on the order of 1 in 1000 or less that are often required for estimates of WTP. Small-sample studies that have elicited both WTP and HRQL using stated-preference methods suggest that WTP is less reliable (O'Brien and Viramontes, 1994; Krabbe et al., 1997).

Fundamentally, the choice between using QALY and WTP approaches depends on judgments about what constraints on individual preferences should be imposed, and what factors should be considered in forming social judgments. QALYs impose substantial and somewhat unrealistic constraints on the form of individual preferences, and combine preferences across people on a relatively egalitarian basis. Depending on the treatment of discounting (and potentially age weighting, as in DALYs), QALYs may assign substantially greater value to reducing risks of mortality or chronic illness among children than among adults. In contrast, WTP imposes few constraints on individual preferences and gives relatively greater weight to more affluent sectors of society. Theory and limited empirical evidence suggest the value of reducing mortality risk is likely to be less sensitive to age under the WTP approach.

Notes

1 Harvard University, Center for Risk Analysis, School of Public Health, Boston, USA.

2 The views expressed in this chapter are those of the authors and do not necessarily reflect those of the institutes with which they are affiliated, or the OECD.

3 Technically, preferences over health quality and longevity must be "utility independent" (Keeney and Raiffa, 1976) of other characteristics of the individual and the risk.

4 Note that WTA to forego an improvement from H_0 to H_1 is different than willingness to accept compensation for a reduction in health from H_0 to some less desired health profile. One can also define WTP to prevent a reduction from H_1 to H_0 and WTA to permit a reduction from H_1 to H_0.

5 If the indifference curve is smooth (which is the case if there are no satiation levels or other thresholds in the individual's preferences for survival probability and wealth), then WTP and WTA for infinitesimal changes in risk are equal. Hanemann (1991) shows that indifference curves for a publicly provided good may be curved sharply when no private goods provide close substitutes. In this case, WTP and WTA may diverge substantially even for small changes in the quantity of the public good. The intuition is that the quantity of the publicly provided good (e.g., mortality risk from ambient air pollution) is not subject to the individual's choice. If some private good provides a close substitute, the individual can adjust for a suboptimal quantity of the public good by purchasing more or less of the private good. Thus, if health risk from indoor air quality at home is a close substitute for health risk from ambient air quality, the individual may be able to compensate for poor ambient air quality by investing in cleaner air at home (or for excessively clean ambient air by spending less on controlling indoor pollution).

6 Several terms, including health related quality of life, health status, and functional status, are used in the literature to designate a variety of single and multidimensional measures of health. I follow the US Public Health Service panel (Gold et al., 1996) and Dolan (2000) in using the term HRQL to designate the one-dimensional utility value q_i.

7 As described below, health states are typically described in much greater detail. Simple descriptions such as "excellent, "good" and "fair" are used here for illustration. The notation "M-N lottery" denotes a lottery where the probability of the first outcome is M percent and the probability of the second outcome in N percent

8 The alternatives (c) and (d) can be obtained from alternatives (a) and (b) by changing the health state for the first 5 years from "good" to "excellent."

9 In contrast, QALYs measure the value of a health profile relative to immediate death.

10 Positive effects of baseline risk and wealth on VSL are sufficient conditions for the convexity of the indifference curves in Fig. 8.1.

11 Sloan et al. (1998) estimate that having multiple sclerosis (MS) reduces the marginal utility of income by a factor of 0.67 (estimated for people with MS) or by a factor of 0.08 (estimated for people without

MS). Similarly, Viscusi and Evans (1990) estimate that a workplace accident (which might be fatal or nonfatal) reduces the marginal utility of income by a factor of 0.78 or 0.93 (using alternative functional forms).

12 Brouwer et al. (1997) criticize the Gold et al. (1996) recommendation and argue that HRQL should be defined to measure preferences for health alone, holding income constant.

13 Risk-adjusted QALYs may be written in a form where the answers to SG and TTO questions are not equal, but are related to each other by a known transformation.

14 An allocation is Pareto efficient if it is impossible to improve someone's welfare without reducing someone else's welfare. In dividing a cake among individuals each of whom has an unlimited appetite and no concern for others, every allocation in which all the cake is eaten is Pareto efficient.

15 Similarly, individuals cannot be expected to have a constant value per discounted statistical life year.

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Annex 7.A
Supporting Data

Figure 7.1 – Indifference curves for survival probability and wealth.

Starting from A, WTP to improve the probability of surviving the current period from p_0 to p_1 is equal to the distance B – C. WTA compensation in place of improving health from p_0 to p_1 is equal to the distance D – A. The distance B – C also represents WTP to prevent a reduction from p_1 to p_0, and the distance D – A represents WTA compensation to permit a reduction from p_1 to p_0.

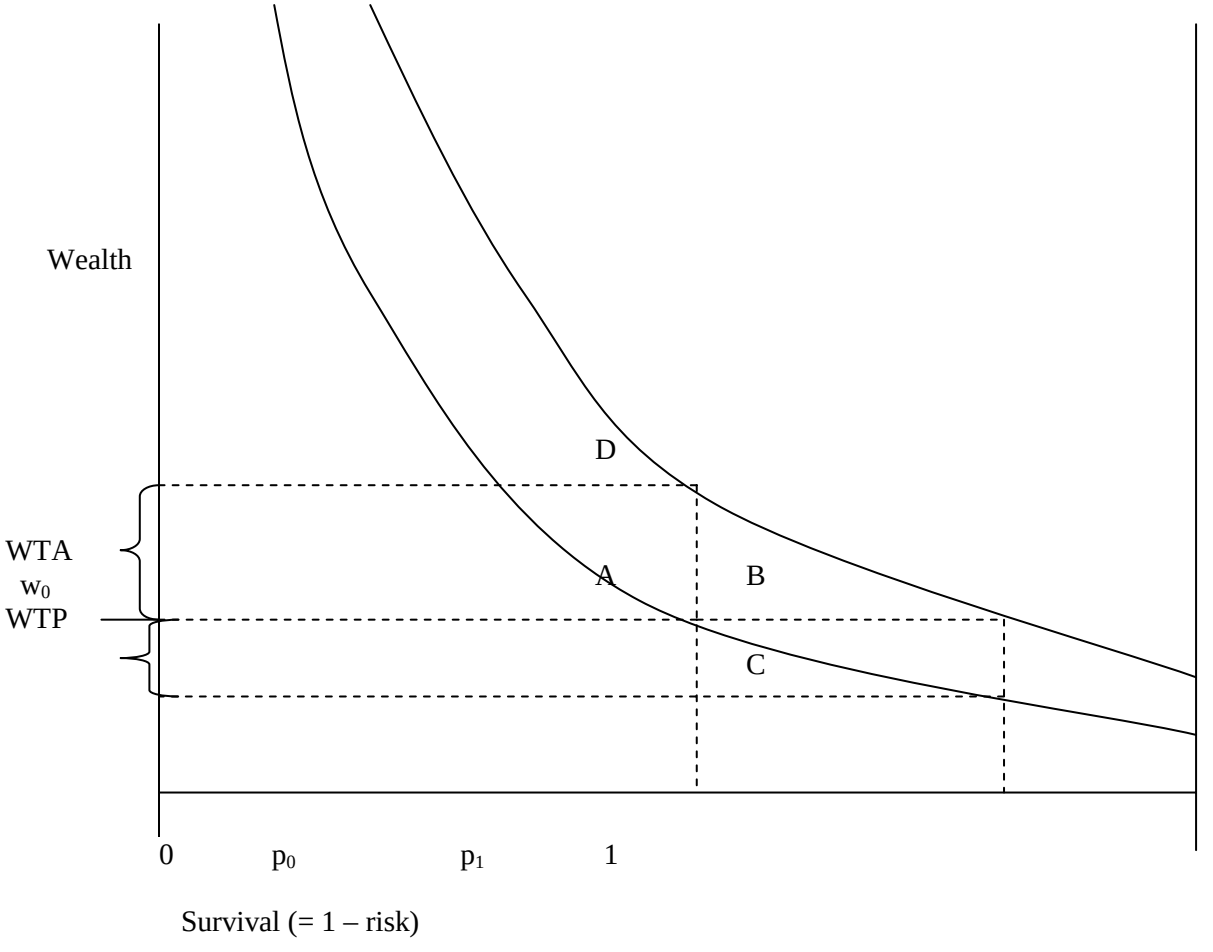

Figure 7.2 – QALYs for two hypothetical health profiles.

The intervention improves health at all ages and extends longevity from D_1 to D_2. The difference in QALYs is the area between the two health profiles.

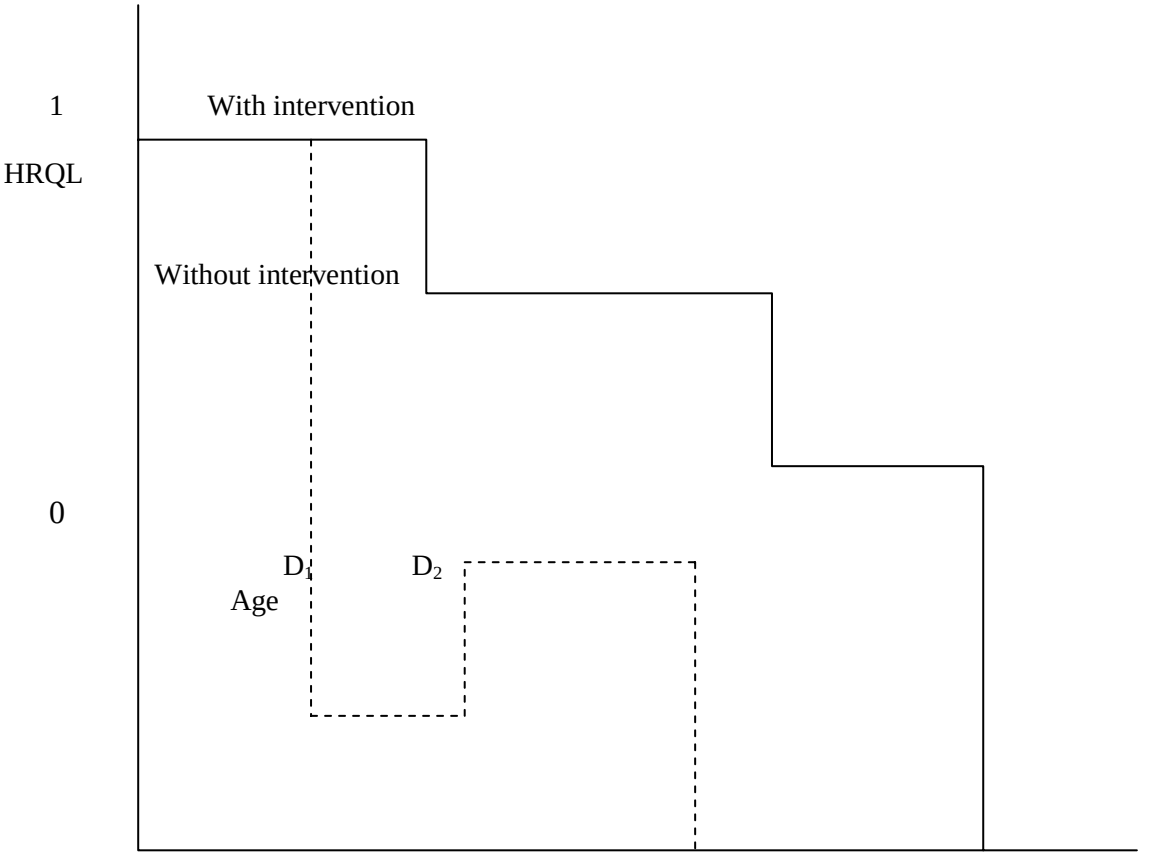

Figure 7.3 – Relative value of future life years for three measures (discount rate = 3 percent per year)

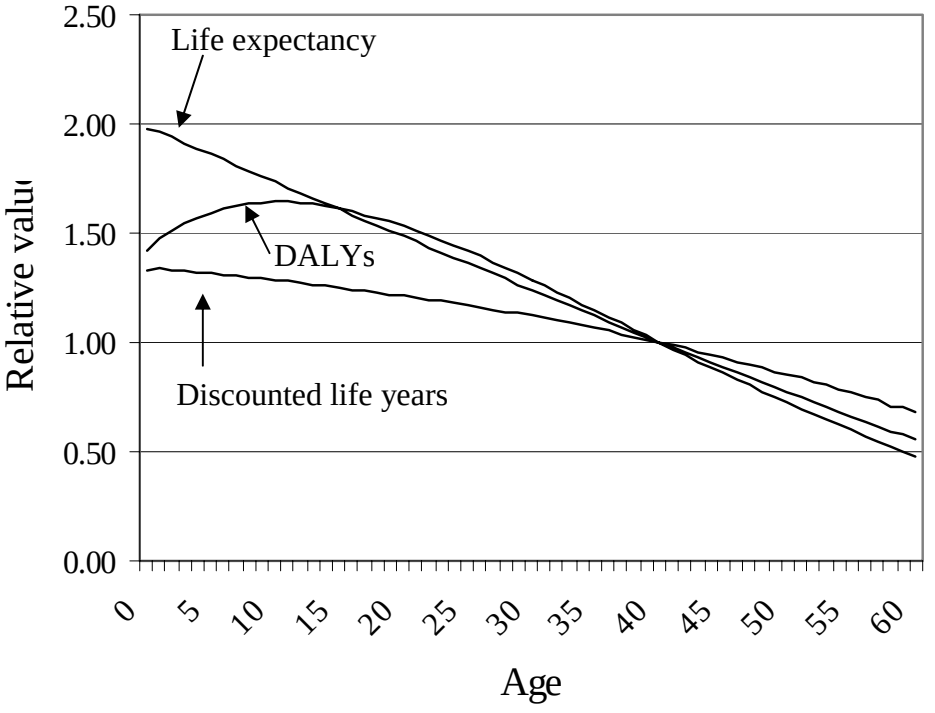

Table 7.1 Health Utilities Index Mark 3

Level	1	2	3	4	5	6
Vision	1.00	0.98	0.89	0.84	0.75	0.61
Hearing	1.00	0.95	0.89	0.80	0.74	0.61
Speech	1.00	0.94	0.89	0.81	0.68	na
Ambulation	1.00	0.93	0.86	0.73	0.65	0.58
Dexterity	1.00	0.95	0.88	0.76	0.65	0.56
Emotion	1.00	0.95	0.85	0.64	0.46	na
Cognition	1.00	0.92	0.95	0.83	0.60	0.42
Pain	1.00	0.96	0.90	0.77	0.55	na
HRQL = 1.371 (b_1 * b_2 * b_3* b_4* b_5* b_6* b_7* b_8) - 0.371 Note: na = not applicable (attribute has only five levels)						

Source: (53)

Table 7.2 EuroQol EQ-5D

	Level		
Attribute	1	2	3
Mobility	-0.0	-0.069	-0.314
Self-care	-0.0	-0.104	-0.214
Usual activity	-0.0	-0.036	-0.094
Pain/discomfort	-0.0	-0.123	-0.386
Anxiety/depression	-0.0	-0.071	-0.236
HRQL = 1 – sum of relevant item weights. The additional constant 0.081 is subtracted if any attribute is level 2, and 0.269 is subtracted if any attribute is level 3.			

Source: (55)

Table 7.3 Quality of Well-Being Index

	Scale		
Step	Mobility	Physical activity	Social activity
5	-0.000	na	-0.000
4	-0.062	-0.000	-0.061
3	na	-0.060	-0.061
2	-0.090	na	-0.061
1	na	-0.077	-0.106
HRQL = 1 – sum of scale weights – additional term for relevant symptom and problem complex. Note: na = not applicable (not all scales use all steps)			

Source: (55)

Table 7.4 Effects of Individual Characteristics on Value of Reducing a Current Mortality Risk

	QALYs	WTP
Competing risk	Decrease	Decrease
Life expectancy	Increase	Ambiguous
Comorbidities	Decrease	Ambiguous
Baseline risk	No effect	Increase
Wealth	No effect*	Increase

Note: * Subject to qualifications.

Chapter 8

Methods for Valuing Health Losses and Health Gains in Children

by

Erik Nord[1]

When the purpose of assessing health problems and health benefits is to set priorities across programs, it is not sufficient to measure objective health. One needs to look at the value of different health states and health gains – to the individuals concerned (*individual utility*) and/or to society (*societal value*). There are various direct, holistic techniques available for eliciting such utilities and values. However, the techniques are too demanding to be used in children. An alternative is to collect objective health profile data in children and transform these data into overall, single index values by some procedure that more or less bypasses children. For this purpose, several multi-attribute utility instruments are available. Utilities from these instruments need corrections in order to be consistent with observed time trade-off and person trade-off preferences in the adult population in many countries. This chapter proposes a comparison of the various techniques that exist for valuing health and health outcomes, assessing their strengths and limitations, more particularly in the context of valuation of health risks to children.

Background

There is an interest among policy makers in the OECD and the WHO in quantifying (a) environment related health problems in children and (b) health benefits from programs directed at preventing and/or reducing such problems. The quantification of health *problems* is supposed to help policy makers determine the relative burden to society of different environmental risk factors. This can be useful as a first step to clarifying which factors deserve most attention in research and planning. The quantification of health *benefits* is supposed to help health policy makers compare competing health programs in terms of their value for money and thus set priorities across programs. My task is to discuss methods for quantifying health problems and benefits.

Aim of paper

I shall relate my discussion to the following concrete scenario: Health authorities in a given country wish to address some specific health problems in children believed to be related to environmental factors. Examples of such problems may be asthma aggravated by air pollution and anxiety/feelings of insecurity caused by stress factors in urban family life. Various policies are under consideration with a view to reducing these problems. The policy makers want to quantify the health benefits (= the reduction of problems) from each of these candidate policies. To do this, they need to estimate the level of health in the target children population before and after each kind of policy implementation. This requires the following research:

1. Assessment of current health in a representative sample of the target children population.

2. Estimation of health in those children at various points in time after policy implementation based on a review of the best available epidemiological evidence.

The policy makers' question is: In what terms, and by means of which data collection techniques, should they go about the task of specifying, *i.e.* describing and quantifying, such "before" and "after" levels of health in their sample and thus in their target child population?

When addressing this question, I distinguish between children and adolescents. The latter are from 12-13 years up to 18-19 (Hornby et al, 1974). The theme here is children. I shall therefore limit my discussion to those below 13 years of age.

I first discuss some possible notions of "quantification" of health. I argue that for the purpose of making comparisons across risk factors, diseases and programs, levels of health need to be estimated in terms of *valuations* rather than categorical (nominal) descriptions. I then explain the various techniques that exist for valuing health and health outcomes and review some general problems with these various techniques. I proceed to discussing the specific problems that need to be addressed if one tries to apply these techniques to children's health problems. Finally, I comment on some published studies in which techniques for valuing health states have been used in children. Unfortunately, there seems to be few studies that address environment related health problems specifically. On the other hand, the methodological challenges are much the same in measuring non-environment related health problems.

Given my focus on *valuations*, there is much literature on measuring health and quality of life in children that falls outside the scope of this paper. For a comprehensive review of this general literature readers are referred to Eiser and Morse (2001).

Quantification as valuation

It is common to distinguish between three types of quantification of health and health benefits:

Objective health: Specifications of symptoms, physical, mental and social capabilities, and life expectancy.

Individual utility: Individuals' personal valuations of health states, determined by their subjective perceptions of quality of life associated with those states.

Societal value: Judgements by representatives of society at large of the relative goodness of different health programs (determined by objective health gains, gains in subjectively perceived quality of life and concerns for fairness and equity across individuals).

There is also a fourth concept: Individuals' valuations of health programs from behind a so-called "veil of ignorance"about consequences for themselves. This may be seen as a mixture of individual utility judgement and societal value judgement. For a thorough discussion, see Menzel, 1999.

People tend to agree more easily on statements about objective health gains than on statements about utility or societal value, since the latter are more broad and judgemental than the former and refer to subjects' inner feelings rather than to observable behaviour. A priori this is an argument for measuring levels of health in terms of objective health gains in health policy assessment and priority setting. But priority setting presupposes comparisons of health gains from different programs in terms of their *size*. Quantifications in terms of objective health gains sometimes allow such comparisons, but quite often they do not. For instance, ten gained life years is twice as much as five gained life years, and ten life years gained in a healthy person may be said to be a bigger health gain – meaning a bigger production of "well-life" - than ten life years gained in a disabled person. On the other hand, one cannot say that getting one's eye sight back is a "bigger" or "smaller" gain than getting one's hearing back, or "bigger" or "smaller" than getting to live five extra years. Nor can one say that a movement from "bedridden" to "bound to a wheel chair" is "bigger" or "smaller" than a movement from "bound to a wheel chair" to "dependent on crutches". To make such comparisons, one has to look at the *value* of the gains – to the individuals concerned (=individual utility) or to society (=societal value). This is why the Quality Adjusted Life Year (QALY), which is based on valuations of health states, has come to be regarded as a potentially useful concept in health planning and priority setting.

QALYs

The QALY is a measure of the value of health care outcomes. It was developed in the sixties and early seventies with a view to resolving the problem of comparing "apples and oranges" in priority setting in health. The idea was to refer such different outcomes as saved lives, increases in life expectancy, different kinds of functional improvement and different kinds of symptom relief to the same value scale, whereby it would be possible to compare these different kinds of outcomes with each other.

The value of health states is expressed on a scale from zero to unity, where zero is the value of the state "dead" and unity is the value of the state "healthy". The lower the quality of life associated with a health state, the lower is its score on this scale. For instance, being dependent on crutches for walking might score 0.9, while sitting in a wheel chair might score 0.8.

Basic methodological issues in valuing health states

To obtain values for health states, researchers ask people to judge the degree of badness of different health problems. In this research, there are two main choices that need to be made: Who should be the judges, and what kinds of questions should they be asked?

Whom to ask

The history of health state valuations consists mainly in the valuation of health in adults. The most common thing to do is to take (more or less) representative samples of the general adult population and ask each subject to express how bad they personally think various states of illness or disability would be to live in. These are often referred to as "hypothetical" or "ex ante" valuations. In most cases they refer to health states in which the subjects have limited insight.

An alternative approach is to ask people who actually are in a state of illness or disability, or who have fairly recently experienced such a state, to value that specific state in terms of its effect on their own quality of life. The advantage of this approach is of course that personal experience with a state greatly improves judgement of it.

A third approach is to ask health workers, and particularly medical doctors, to value different states, under the assumption that they through their daily work have gained much insight in the burdens of differents kinds of health problems.

Generally speaking, the second of these approaches, *i.e.* asking patients and disabled people to value their own state, yields higher values for chronic health states than the two other, "arms length" approaches (Nord, 1999). The explanation seems to lie in human beings' vast capacity for adaptation and coping, which turns many highly undesirable conditions into quite liveable ones after some time. It seems to be difficult for both lay people and health workers to take these human adaptive resources fully into account when they *ex ante* judge health problems which they themselves are spared of.

In the field of QALYs, most researchers have chosen to elicit hypothetical health state valuations from the general public. A defense given for this is that since health state valuations are supposed to inform resource allocation decisions, and these decisions may affect anyone in society, everybody should have a vote in deciding the values that are to inform the decisions (Gold et al, 1996). Therefore the general public should be asked, and not only those who happen to have experience with illness. I believe this defense is based on a conflation of issues. It is true that everybody should have a say in determining criteria for resource allocation. But measurement of health related quality of life is a factual issue. Such measurement, which is one of many to be fed into resource allocation decision processes, needs to be as consistent with actual experience as possible. For this reason I and others have recommended that questions regarding the value of health states, *i.e.* the quality of life associated with these, should

be addressed to patients and disabled people rather than to the general public (Nord et al, 1999).

In principle this implies that health problems for children should be valued by samples of children who actually have those problems. But as we shall see, this may not be feasible, given the complexity of the *kinds of questions* that are normally used to elicit health state valuations. I now turn to this second methodological issue.

How to ask

In the conventional QALY approach the 0-1 value scale is a scale of *individual utility*. There are three main techniques for eliciting a person's assessment of the individual utility of a composite (multidimensional) health state in a single, holistic operation.

The standard gamble technique (SG) is based on the assumption that individuals maximise expected utility under uncertainty. Under this assumption, when individuals are indifferent between two options one may infer that the utility of each of them is the same. Using this premise, subjects are asked to make pairwise comparisons made between states of illness and full health. For each state of illness the subjects are offered two alternatives. Alternative 1 is a treatment with two possible outcomes: either the patient is returned to normal health and lives for an additional t years (probability p), or the patient dies immediately (probability 1-p). Alternative 2 has the certain outcome of health state i for t years. The task is to establish the value V(i) of state i. Probability is varied until the subject is indifferent between the two alternatives. At this point, expected utility is assumed to be the same in both options: $p \times 1 + (1-p) \times 0 = 1 \times V(i)$. This yields a value of p for state i.

The time trade-off technique (TTO) works similarly, but uses time instead of certainty as the trade-off good. Two alternatives are offered. One is living in state of illness i for time T followed by death, the other is living as healthy for a shorter time t, followed by death. Time t is varied until the respondent is indifferent between the two alternatives, at which point the value of the two scenarios is assumed to be the same: $V(i) \times T = 1 \times t$. This yields a value of t/T for state i.

With the rating scale technique (RS), values for health states on the scale from zero to unity are obtained simply by asking subjects to locate the states directly on a linear scale. For instance, if a state is located at point 60 on a scale from zero to one hundred it receives the value of 0.6.

The person trade-off technique (PTO) is a fourth technique for valuing composite states, but unlike the standard gamble, the time trade-off and the rating scale, it has a societal value perspective. It not only allows subjects to take into account individual utility, but also concerns for distributive fairness, for instance special concerns for the worse off. Subjects are typically asked the following kind of question: "If one program can prevent a case of fatal illness, and another equally costly program can prevent N cases of chronic, non-fatal state X, what must N be for you to consider the two programs equally worthy of funding?" If the subject answers for instance "10", he/she is saying that a drop from full health to X is one tenth as bad as a drop from full health to dead. This yields a value of $1-1/10 = 0.9$ for state X.

For the same health states, the standard gamble tends to yield slightly higher values than the time trade-off does, while the person trade-off tends to produce clearly higher values than both these two. The rating scale tends to produce the lowest values (Nord,

1992; Salomon and Murray, 2002). This raises the question of which technique is more valid.

There is no clear agreement about this among researchers in the field, and many will adamantly reject the idea of their being any kind of "gold standard" methodology for valuing health states. Nonetheless, two points may be made fairly safely.

The first is that the rating scale does not yield values at a cardinal level (ratio level or interval level) of measurement. For instance, if one health state scores 0.6 on a rating scale, and another scores 0.8 on the same scale, one cannot conclude that the former is thought to be "twice as bad" as the latter. Subjects responding to rating scale tasks have been shown not to have such depth of intention or meaning in their choice of numbers (Morris and Durand, 1989; Nord, 1991). Instead, rating scales primarily seem to allow subjects to *rank* states in terms of goodness. The values do not express any kind of trade-off, and most economists therefore consider them unusable as weights for life years in cost-effectiveness analysis (Essink-Bot et al, 2002).

This does not mean that the rating scale is a useless tool. Most people find it easier to respond to a rating scale task than to express trade-offs between quality of life and certainty of survival (SG) or length of life (TTO). For this reason, a possible strategy in utility measurement may be (a) to establish empirically the mathematical relationships that exist between rating scale responses on the one hand and standard gamble and time trade-off responses on the other (i.e. describe RS-scores as functions of SG and TTO scores respectively), (b) to collect preference data using a rating scale and then (c) to transform the rating scale scores into utilities by means of the established mathematical formulas between RS and SG and TTO respectively. *The point is that rating scale values should not be used directly as utilities.*

Unlike the rating scale, the standard gamble, time trade-off and person trade-off all purport to provide values at a cardinal level of measurement. But here lies a second point which is important to note: The standard gamble and the time trade-off on the one hand, and the person trade-off on the other, measure different things, namely individual utility and societal value respectively. In the latter, strong concerns for giving priority to the severely ill tend to be included. The choice between SG/TTO and PTO thus depends on whether one in formal economic evaluation of different health programs wishes to incorporate distributive concerns that are relevant in priority setting, or whether one prefers to perform formal cost-effectiveness analyses (CEA) on the basis of individual utility assessments only and introduce distributive concerns as "judgemental correctional factors" only in final decision making. On this issue, researchers have different preferences (Dolan, 1998; Nord et al, 1999; Murray et al, 2000).

In the context of children's health it is not necessary to go further into the issue of which of the direct, holistic trade-off techniques (SG, TTO, PTO) is more valid. The reason is that none of them is feasible in children anyway. Although most adults respond sensibly to questions in terms of standard gamble, time trade-off and person trade-off, they do find them quite difficult, and there is both moderate test-retest reliability in responses (Torrance, 1986) and some uncertainty about their validity given the hypothetical nature of the questions (Nord, 1996b). Intuitively such questions seem quite unsuitable for children. This intuition is supported by some research. It has for instance been shown that subjects need a reading ability level corresponding to 6th grade to at all be able to understand standard gamble questions (Juniper et al, 1997). In addition, trade-off questions require subjects to have a rich understanding of what it is

to live and what it is to sacrifice either own life expectancy (SG, TTO) or the health of some people to enhance the health of others (PTO). Even young teenagers presumably have problems with addressing such complex and serious issues (Apajasalo et al, 1996).

From this follows a first conclusion: Valuations of environment related health problems in children can *not* be obtained by asking children the same kinds of trade-off questions as adults have been asked for many years in QALY-related research. One is obliged to look for an alternative approach. The obvious one is to ask children more simple and concrete questions about their objective health, *i.e.* about their specific symptoms and functioning, and then to transform their *health profiles* into single index values by means of some valuation procedure that bypasses children. This brings us to a well established concept in the field of QALYs called multi-attribute utility instruments.

Multi-attribute utility instruments

Multi-attribute utility (MAU) instruments are tools that allow researchers and analysts to assign individual utilities to health states indirectly. The most widely used ones are the Quality of Well-Being Scale in the US (Kaplan and Anderson, 1988), the EQ-5D in Europe (the EuroQol Group, 1990), the Health Utilities Index in Canada (Feeny et al, 1995) and 15-D in Finland (Sintonen and Pekurinen, 1993). A more recent development is the Aqol in Australia (Hawthorne et al, 1997). They are all questionnaires by which one may describe individuals on a number of different dimensions of health, like mobility, pain, hearing and seeing – *i.e.* mostly in terms of observable traits. They then offer a table or a mathematical formula which allows the analyst to transform the multi-attribute health state descriptions (= health profiles) into a single utility number. The transformation algorithms are based on previous research in which one or more of the holistic valuation techniques, *i.e.* standard gamble, time trade-off or the rating scale, were used in preference studies in the general population to establish the utility of different (hypothetical) health profiles.

It is important to note the difference between MAU-instruments on the one hand, and, on the other hand, a large number of generic and disease-specific instruments for establishing patients' functional status and quality of lifte that do *not* include an algorithm for translating multi-dimensional health profiles into single index values with cardinal properties (e.g. the Nottingham Health Profile, the Sickness Impact Profile). For cost-utility analyses of health programs, these latter instruments do not provide the necessary weights for life years.

The SF-36 falls in a middle category. Initially it simply yielded 36-dimensional health profiles, and it still does not provide a function for transforming such complex profiles directly into single index utilities. But a valuation formula for health profiles consisting of 6 "representative" SF-36 items has been developed recently, and this may be helpful in estimating utilities for full SF-36 profiles (Brazier et al, 1998).

MAU-instruments spare analysts of having to go through the relatively difficult and burdensome process of asking target populations complex preference questions every time they wish to judge burden of disease or evaluate possible interventions. Health profiles of "typical" patients in different diagnostic groups may often be supplied by health personnel working with the groups in question, and patients find it much easier to describe themselves in terms of functioning and symptoms than to respond to difficult preference questions.

I first discuss some general experiences with MAU-instruments in adults, as there is research on the validity of valuations from these instruments that casts light on the validity of applying MAU-instruments to children. I then look at some use of MAU-instruments in children in recent years.

Variability in MAU-instruments

MAU-instruments differ greatly from each other in terms of their selection of dimensions, their number of dimensions, the number of levels on each dimension and the verbal accuracy with which each level is described. Details of this variability are given in a later section. The variability may be regarded positively as an opportunity for choice for researchers and analysts addressing different patient groups with different kinds of problems and different cognitive capacities.

On the other hand, when different MAU-instruments are applied to the same patient groups, or the same health problems, they have been shown to produce quite disparate utilities (Nord, 1996). Table 8.1 summarises the results of applying the four most well-established instruments to three chronic health states of varying severity. The differences between the instruments are so large that in many cases it would matter a great deal which of the instruments was used to estimate benefits from an intervention in terms of QALYs.

Table 8.1 Utilities from MAU-instruments

Instrument	Problem level [a]		
	Severe	Considerable	Moderate
EQ-5D [b]	0.20-0.25	0.40-0.50	0.80
QWB	0.45-0.55	0.65-0.70	<0.80
HUI 2 [c]	0.40	0.70	0.90-0.94
15-D	0.77	0.86	0.91-0.93

Source: Nord, 1996

a. The three states were described as follows:
   Severe: Sits in a wheel-chair, has pain most of the time, is unable to work.
   Considerable: Uses crutches for walking, has light pain intermittently, is unable to work.
   Moderate: Has difficulties in moving about outdoors and has slight discomfort, but is able to do some work and has only minor difficulties at home.
b. Version using time trade-off values in England.
c. A later publication indicates that HUI 3 has much the same value structure as HUI 2 (Furlong et al, 1998).

Validity of MAU-instruments

As with direct, holistic valuation techniques, the variability in valuations across MAU-instruments begs the question of which are more valid. To answer this question one needs a criterion by which the validity of MAU-utilities can be assessed. There is no agreement among constructors of MAU instruments on what this criterion might be. This is not surprising, given the disagreements between the instruments and the strong personal interests among stakeholders in terms of scientific prestige and, in some cases, potential economic returns (some MAU-instruments are available for users only at a price).

I have suggested two criteria for judging validity (Nord, 1999), both of which are related to the way utilities *de facto* are used in QALY calculations and cost-utility analysis, namely to express two kinds of trade-offs. Take for example a state of illness

that is assigned a utility of 0.8. In CUA this number has (a) a time trade-off interpretation, namley that people in that state would be willing to trade-off 20 per cent of their life expectancy if instead they could live as healthy and (b) a person trade-off interpretation, namely that people in general regard the prevention of five cases of that illness as equally valuable, *i.e.* equally worthy of funding, as the prevention of one case of fatal illness. Since utilities from MAU-instruments are the result of modelling, they should be validated by examining the extent to which the TTO and PTO trade-offs they predict for given health states fit with the trade-offs that people express if asked directly about those states.

With respect to time-trade-offs, there is various evidence suggesting that people with moderate and even fairly severy illnesses or disabilities, are reluctant to trading off much life time to be relieved of their health problems. For instance, Fryback *et al.* (1993) found that the willingness to sacrifice life time was only 5-8 per cent in people with arthritis, severe back pain, migraine, angina, cataracts, ulcers, colitis and sleep disorder. In a study of 18,000 patients visiting medical centres across the US, 70 per cent of the patients, including many who were very sick, were not willing to sacrifice any life expectancy to be relieved of their condition (Sherbourne et al, 1997). Similar results were obtained by Fowler *et al.* (1995), O'Leary *et al.* (1995) and Nord (1996b). If one compares these finding with the various utilities in table 1 above, the general impression is that MAU-instruments tend to assign too low utilities for "liveable"states of illness and disability. I stress that this conclusion is based on the assumption that utilities should reflect patients' and disabled people's own perceptions of what it is like to live with illness, as opposed to the general public's hypothetical beliefs about the same, cfr the section above on "whom to ask".

Turning to evidence on person trade-offs, the conclusion is much the same. A review of the literature (Nord, 1996) suggests that person trade-offs between preventing loss of life on the one hand, and preventing states as described in the footnote to table 8.1 above, are of the following order of magnitude:

1 prevention of death = 3 - 6 "preventions of severe"

= 10 - 15 preventions of "considerable"

= 50- 200 preventions of "moderate".

These person trade-offs imply values for the three states in question of 0.65-0.85, 0.90-0.94 and 0.98-0.995 respectively. These values are very much higher than most of the utilities suggested by the MAU-instruments in table 10.1. The 15-D perform better on this test than the other instruments in table 10.1, but the deviation from the values implied by person trade-off studies is considerable also for this instrument when it comes to comparing moderate states of illness with fatal conditions.

The overall conclusion is therefore that not only do adult (= main) versions of MAU-instruments produce different utilities for the same states. They also generally tend to produce too low utilities, both from a patients' time trade-off perspective and a societal person trade-off perspective. The implication of this is that the prevention of non-fatal ("liveable") conditions is assigned too high value relative to the prevention of fatal disease.

I have suggested some very rough rules for transforming MAU-utilities into values that are consistent with the various PTO-evidence that exists (Nord, 2001) (see Figure 8.1 in the Annex). The effect of the transformations is to compress states to the upper end of the 0-1 value scale. The transformations are relatively modest for the 15-D, but

quite large for the EQ-5D and HUI 2. HUI 3 has a value structure not very different from HUI 2 and would thus require transformations of the same order of magnitude. The transformations will as a by-product also bring MAU-utilities closer to what is suggested by direct time trade-off evidence in patients and disabled people. In other words, the transformations would in one operation increase validity as judged by both the validity criteria suggested above.

MAU-instruments in children

In responding to MAU-questionnaires, children may be helped by their parents. A priori one would expect this to work quite well, since most items in MAU-instruments refer to observable capabilities with fairly distinct response categories. For example, level 2 in "mobility" in 15-D reads "I am able to walk without difficulty indoors, but outdoors and/or on stairs I have slight difficulties". In the EQ-5D, levels within each dimension are as distinct as "no problems", "some problems" and "unable to". This means that most of the items in standard MAU questionnaires can be sensibly applied to children even at low ages where reading abilities are limited. In 15-D, for instance, this is true of the following nine dimensions: Mobility, vision, hearing, breathing, sleeping, eating, speech, elimination, and usual activities. In the five dimensional EQ-5D, it is true of mobility, self care and usual activities. In the eight dimensional Health Utilities Index Mark III (HUI 3), it is true of vision, hearing, speech, ambulation, dexterity.

But other items in these instruments refer more to inner feelings, and direct observability for parents is consequently more limited. In 15-D, this clearly applies to the dimensions depression, distress and vitality, but also to some extent to mental function and discomfort/symptoms. In the EQ-5D, anxiety/depression is a difficult item for parents to judge, and to some extent also pain/discomfort. In HUI 3, emotion is clearly problematic to assess for outsiders, and cognition and pain also pose some problems.

If it is difficult for parents to accurately judge and describe the degree of emotional problems, cognitive problems and physical discomfort in their children, the question arises whether children themselves can report the magnitude of such problems in a reliable and valid way. This does not seem obvious, for two reasons. One is difficulties simply in understanding the wording of many response categories. For instance, level 3 of mental functioning in 15-D reads "I have marked difficulties in thinking clearly and logically, my memory is somewhat impaired", and level 3 of the depression item reads "I feel moderately, anxious, stressed or nervous". This is not language that children in general may be assumed to command. Similar difficulties occur in other items and in for instance HUI 2 and 3 and the QWB. The other problem is variation across age groups with respect to how verbal scales, and adjectives in particular, are used. Even if a child understands the words "moderately anxious" and "very anxious" and uses them consistently over time, he or she will not necessarily make the same choice between these two response options as an adult would do for the same degree of anxiety. When it comes do *valuing* a health profile that a child has produced, this is a serious problem.

With these general comments as a background I now turn to looking at various MAU-instruments in greater detail.

The Quality of Being Scale QWB)

The QWB has scales that assess mobility, physical activity and social activity, plus a list of 27 symptoms or "problem complexes" that assess symptoms on a specific day (e.g. pain, general tiredness, need for eyeglasses). In adults, the instrument has been shown to yield far too low values for moderate states of illness, see table 10.1. As a matter of fact, uncritical use of a telephone version of the instrument was probably the most important reason why the first attempt at setting priorities within Medicaid in Oregon in 1991 by ranking interventions according to costs-per-QALY failed so dramatically (Eddy, 1991; Nord, 1993). However, the valuations are correctable (c.f. Figure 8.1 in the Annex).

Bradlyn *et al.* (1993) used the adult version of the QWB in children 4-18 years with cancer. Parents and children filled in the questionnaire together. In case of disagreement, the parents' judgements were used. The study suggested a high interrater reliability for the QWB and good correlations (0.60-0.70) between QWB scores and scores on a simple "Play-Performance Scale for Children". Czyzewski *et al.* (1994) used the adult version of the QWB in children 0-18 with cystic fibrosis (CF). They concluded that "although there were several significant correlations between QWB scores and physical status scores from an independent scale, the lack of agreement between respondents on the scale, the small correlations, and the absence of significant relationships with well-validated measures of psychosocial functioning calls into question the use of the QWB for clinical decisions and therapy outcome measures for the general pediatric CF population". Other researchers have expressed serious concerns about the lack of adaptation of the QWB to qualify of life issues relating specifically to children and the use of preference weights derived from an adult community sample in the valuation of children's health profiles (Apajasalo, 1996; Eiser and Morse, 2001).

The EQ-5D

The EQ-5D has five dimensions (mobility, self care, usual activites, pain/discomfort and depression/anxiety), with three levels on each (no problem, some problems, extreme problems or "unable to"). It also has a rating scaling running from 0 (worst imaginable health state) to 100 (best imaginable health state). Its 5 x 3 descriptive system is by far the simplest one in the MAU family. The reason for its simplicity is that the instrument initially was designed to be used routinely alongside more complex questionnaires and serve to facilitate comparisons between studies that used *different* main questionnaires (the EuroQol Group, 1990). Gradually, however, this limited role of the instrument has been downplayed by its constructors, and the EQ-5D is now being marketed as a stand alone instrument.

As shown in Table 8.1 and Figure 8.1 (see Annex), utilities from the EQ-5D need quite strong transformations in order to reflect actual time trade-offs and person trade-offs correctly.

There is work underway to develop a children's version (Paul Kind, personal communication).

The adult version of the instrument was used in a study of children with imperforate anus (Stolk et al, 2000). Parents filled in the questionnaire for children 5-15 years old. The purpose was to examine the validity of such proxy use, by comparing the results with results with a validated proxy (parent) version of a questionnaire specifically designed and validated for the use in children (the TACQOL) and a disease

specific 7-item measure of symptoms (the Langemeijer Stool Questionnaire (LSQ)). EQ-5D utilities based on parents' classification of their children in the 5 x 3 descriptive system correlated moderately (in the order of 0.5) with these other measures. The authors conclude that the EQ-5D's principal utility model (which is based on time trade-off valuations by the general adult public in England) performs well in children and "postpones" the necessity for data collection specifically in children. I find this conclusion somewhat optimistic, for two reasons. First, the observed correlations with other measurements are only moderate. Second, the valuations elicited previously from adults are in themselves problematic, as shown in table 10.1.

The Health Utilities Index

The Health Utilities Index exists in three versions for adults. HUI 1 is now rarely in use. HUI 2 has 7 dimensions (seeing/hearing/speaking, mobility, emotion, cognition, self care, pain and fertility) with 4-5 levels on each dimension. HUI 3 has 8 dimensions (vision, hearing, speech, ambulation, dexterity, emotion, cognition and pain) with 5-6 levels on each dimension. The HUI is claimed to be applicable to all people older than 5 years of age (Furlong, personal communication). The various versions have been used in a variety of clinical studies and diagnostic groups, including some studies of children.

Utilities from the HUI need fairly strong transformations if they are to inform priority setting (see Table 8.1 and Figure 8.1 in the Annex).

In a small study of children with asthma, Juniper *et al.* (1997) found that all subjects over the age of 7 years could complete the HUI questionnaires with high test-retest consistency over a period of nine weeks with stable illness. However, the authors could not determine whether the consistency (reliability) was accompanied by validity, *i.e.* whether the verbal expressions of the children were true descriptions of the burdens of their conditions.

Trudel *et al.* (1998) found very good test-retest reliability for sensation, emotion, mobility, cognition and overall utility in mothers filling in HUI 2 for cancer children 4-17 years old. Content validity, on the other hand, was moderate. The authors conclude that in order to assess health related quality of life in cancer, the HUI 2 should be jointly used with instruments evaluating the specific immediate and longlasting physical, functional, neuropsychological and psychosocial sequelae. This viewpoint is shared by the constructors of the instrument (Feeny et al, 1995).

In a study of 41 children from 2 to 18 years who had survived brain tumours, Barr *et al.* (1999) used both HUI2 and 3. They suggest that the readability index of the questionnaires is approximately grade 6 (an average 11 year old child). 15 of the 41 children, all older than 9 years, filled in the questionnaires independently. Kappa-agreement between their self-assessments and those of a nurse who judged all the patients varied from 0.93 for objective dimensions like mobility and self care to 0.67 for emotion. On the other hand, agreement between the nurse on the one hand and four physicians on the other was mostly below 0.40.

Speechley *et al.* (1999) compared HUI 2 and 3 with the Child Health Questionnaire (CHQ) in 244 children 7-16 years old having survived cancer at least 5 years after diagnosis. Completion of questionnaires was by parents. The authors note the advantages of using more than one instrument, given that different instruments have different strengths. For instance, HUI 2 and 3 provide overall utilities, which the CHQ does not. On the other hand, HUI 2 and 3 lack a number of dimensions relevant to

children. Correlation between HUI utilities and CHQ general health scale scores was 0.43, which is moderate.

There is a new generic, comprehensive health status classification system for pre-school children (CHSCS-PS) age 2 through 4 years based on existing HUI systems (Saigal et al, 1998). It comprises 12 dimensions (vision, hearing, speech, mobility, dexterity, self care, emotion, learning and remembering, thinking and problem solving, pain, general health amd behaviour) with 3-5 levels each. Psychometric properties were studied in two samples of together 151 children. Test-retestreliability varied from very high to quite low across dimensions. Agreement betweem parents and clinicians was high for objective dimensions, while moderate (Kappa = 0.72-0.80) for subjective dimensions. Two manuscripts based on the CHSCS-PS have not yet been accepted for publication. The plan is to produce a multi-attribute utility function for the CHSCS-PS.

Aqol

The Aqol has 15 items, grouped under "illness" (3 items), "independent living" (3), "social relationships" (3), physical senses (3) and psychological well-being (3). Each item has four levels. The Aqol has a sophisticated theoretical and statistical foundation, but so far, there is less experience with this instrument than with the other MAUs. I am not aware that it has been used in children.

SF-36 / SF-6D

The six dimensional short form of the SF-36 includes physical functioning, role limitation, social functioning, bodily pain, mental health and vitality, with 5-6 levels on all dimensions except role limitation, where there are only two levels.

I am not aware that the instrument has been used in children.

15-D

The 15-D has fifteen dimensions (mobility, vision, hearing, breathing, sleeping, eating, speech, elimination, usual activities, mental function, discomfort and symptoms, depression, distress, vitality and sexual activity) with five levels on each. It has been used in a number of clinical studies in Finland. I do not comment on it further here, since there are special versions of the instruments for adolescents and children.

16-D and 17-D

Apajasalo *et al.* (1996) first developed a modified version of 15-D – called the 16-D - for adolescents aged 12-15. The questionnaire is reported to be easy to fill in (in 5-10 minutes). Judgements of the importance of different dimensions, and the relative values of different levels on each dimension, were collected from a sample of young people in the same age group, which is in principle a strength of the instrument. But the judgements were elicited by means of a rating scale. The rating scale based judgements of dimensions and levels were combined to construct an additive formula for determining utilities for 16-dimensional health profiles. This procedure is identical to the one used in the "mother instrument" 15-D. A priori there is no reason to expect this procedure to produce utilities with cardinal properties, for instance in terms of time trade-offs.

Since the theme of this paper is the health of children below 13 years of age, I do not go further into the 16-D.

Apajasalo *et al.* (1996b) also developed a 17-D for children 8-11 years old, see appendix. It includes items of special interest for children in this age group, while leaving out the sexuality dimension. The dimensions are: Vision, hearing, mobility, eating, sleeping, elimination, breathing, physical discomfort, energy, anxiety, happiness with looks, participation in school and hobbies, making friends, concentration, memory, speaking, sadness. The authors' report suggests that problems of understanding were successfully dealt with by simplifying language, adding illustrations and having interviewers help the subjects in filling in the questionnaire. In the pilot study completion of the questionnaire took 20-30 minutes and was reportedly "enjoyed" by the children. Retest-reliability was high.

Valuations for the 17-D were obtained by means of the same two-*step rating scale procedure* as was used for the 16-D. The valuations thus have the same theoretical short comings as rating scale valuations have in general, namely a lack of clear cardinal measurement properties (see above). In addition, with the 17-D 115 *parents* of the 8-11 year olds participating in the study exercised the judgements of dimensions and levels on behalf of their children, given that this abstract task was too difficult for this age group. This raises two points of uncertainty. First, one cannot be sure that parents judge the relative burden of different health problems in their children correctly. Second, the potential problem of adults and children having different verbal standards (see above) does not seem to have been addressed. Empirical research is needed to clarify both these points. On the first issue (relative burden of different problems), parents' judgements need to be compared with in-depth interviews directly with children with different problems. On the second issue (different verbal standards), a possible approach is to construct some hypothetical cases of physical and mental discomfort, specify each case in terms of the *frequency* with which the symptoms occur, and then ask both parents and children to select from a verbal scale of "badness" ("extremely bad"/"very bad"/"fairly bad"/"not so bad" etc) the label which they find most fitting for each case. Such an approach is being used by the World Health Organisation to control for differences in verbal standards between people in different cultures when comparing health system performance in different countries (Murray et al, 2002).

No studies have been conducted to test whether utilities from 17-D's valuation model fit with direct, holistic valuations of health profiles (in terms of patients' time trade-offs or the general public's person trade-offs, cfr. earlier section). But 17-D utilities are determined in very much the same way as 15-D utilities. For instance, for each drop from the best level (no problems) to the second best level on a given dimension, both instruments typically assign a loss of utility in the order of 0.015-0.025. The same similarity occurs with drops to lower levels. Since the number of dimensions is only slightly higher in the 17-D, the overall utility of comparable health profiles in 15-D and 17-D will not be very different. This means that the extent to which model based 15-D utilities deviate from directly measured holistic valuations in terms of TTO or PTO (see above), suggests the magnitude of the deviations also in 17-D utilities. This again suggests that the transformation function suggested in Figure 8.1 (see Annex) for 15-D utilities to obtain valid values for policy making may perhaps also be applicable to 17-D utilities.

Consider for example a child to needs glasses to see well, who often finds it hard to fall asleep at night, who gets out of breath when walking fast and who is not able to do sports classes. The 17-D assigns a utility of 0.94 to this condition, implying (a) that parents would be willing to trade-off 6 per cent of the child's life time (= 4-5 years) if

instead he/she could live in full health and (b) that preventing 15-20 cases of this kind would be as regarded as equally valuable by the general public as preventing the loss of a young life. My own intuition is that the implied time trade-off is too high, and the implied person trade-off too low, and that the value for the state in question therefore should be higher. But of course this should be examined empirically.

There is so far limited experience with the 17-D in application studies. However, Apajasalo *et al.* (1997) used it in 22 children 8-11 years old who had survived an organ transplantation. Half of the sample had additional conditions. Those without additonal conditions obtained the same utility as a sample of healthy controls. Those with additional conditions scored significantly lower. This is useful evidence of discriminatory capacity in the instrument.

Summary and conclusion

When the purpose of assessing health problems and health is to set priorities across programs, it is not sufficient to measure objective health. One needs to look at the *value* of different health states and health gains – to the individuals concerned (= individual utility) and/or to society (= societal value). There are various direct, holistic techniques available for eliciting such utilities and values. However, the techniques are too demanding to be used in children. An alternative is to collect objective health profile data in children and transform these data into overall, single index values by some procedure that more or less bypasses children. For this purpose, several MAU-instruments are available. The most well-established ones are the QWB, HUI, EQ-5D and 15-D. Utilities from these instruments need corrections in order to be consistent with observed time trade-off and person trade-off preferences in the adult population in many countries. Rough correction functions are available. HUI (particularly version 2 and 3 in combination) and 15-D have considerably finer (more detailed) descriptive systems than the QWB and EQ-5D and are thus more sensitive to small differences in health between groups and within groups over time. 15-D is the only instrument with a special version for children – the 17-D. It is both comprehensive in terms of health dimensions that are important to children and easy for children themselves to complete. Its valuation model needs closer inspection. Possibly the transformation function suggested earlier for 15-D utilities may be applicable also to the 17-D. But before such a conclusion can be drawn, the validity of parents' health value judgements on behalf of children needs more careful examination.

Notes

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Annex 8.A
Health State Utilities and Corresponding Societal Values

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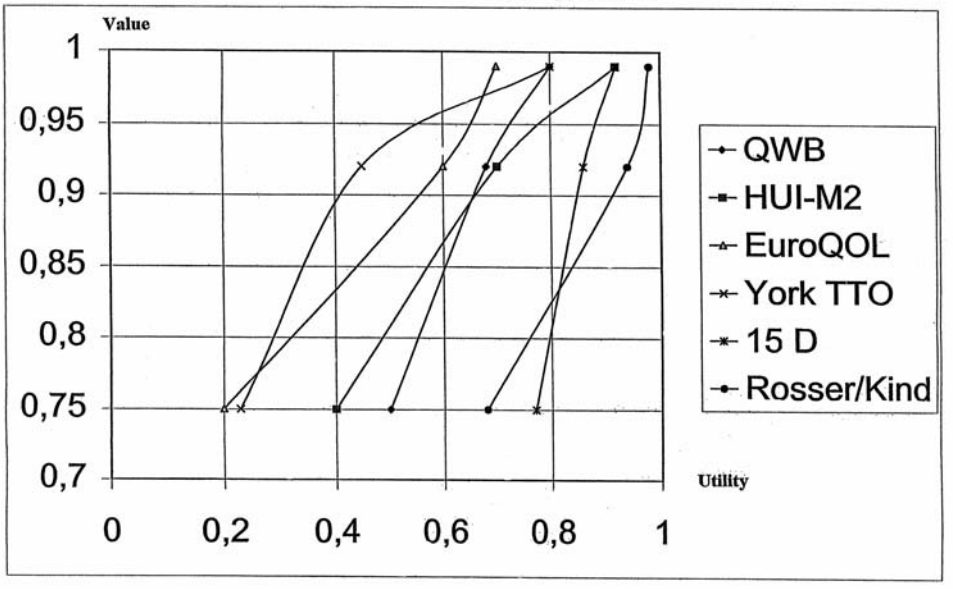


Figure 1. Health state utilities and corresponding societal values.

Annex 8.B
The 17D Questionnaire ©

This questionnaire is all about how you are right now. Please, read the questions carefully. Each question has five answers to choose from. Choose the answer that is closest to the way you are today.

Question 1 is about how well you can see: How well can you see words in books and on the classroom board?

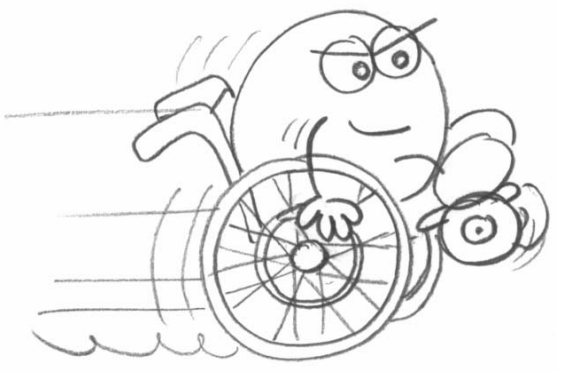
- Well, without glasses
- Well, with glasses
- Poorly, even with glasses
- I cannot see writing even with glasses, but I can see well enough to walk around without a guide
- I cannot see enough to walk around without a guide (I am almost or totally blind)

Question 2: How well can you hear?

- I can hear normal speech well without a hearing aid
- Normal speech is a bit difficult to hear, but I do not need a hearing aid
- I need a hearing aid, but I can hear well with it
- I hear poorly even with a hearing aid
- I am totally deaf

Question 3 is about moving around: Can you walk without using an aid?

- ☐ Yes, without difficulty
- ☐ Yes, but walking is hard without an aid (like crutches or wheelchair)
- ☐ I cannot walk without an aid (like crutches or wheelchair), but with it I can move around well
- ☐ Moving around is hard even with an aid (like crutches or wheelchair)
- ☐ I cannot move around at all



Question 4: Are you able to feed yourself?

- ☐ Yes, without any difficulty
- ☐ Yes, with a little difficulty (I am a bit slow, or clumsy, or I need a special aid, for example)
- ☐ Yes, if someone helps me a little all the time
- ☐ I cannot feed myself, so I must be fed by someone else
- ☐ I cannot eat at all, so I must be fed by tube or directly into my veins

Question 5: How well do you sleep?

- I fall asleep easily and I sleep well
- It is sometimes hard to fall asleep, or I sometimes have nightmares or wake up at night
- It is often hard to fall sleep, or I often have nightmares or wake up at night
- It is nearly always hard to fall asleep, or I have nightmares or wake up almost every night
- I am awake most of the night

Question 6: Do you have any problems going to the toilet?

- No
- I have small problems (sometimes it takes a long time in the toilet, or I have to go often)
- I sometimes have 'accidents' (I mess or wet my trousers or bed), or I often get diarrhoea, or I can't go to the toilet for days
- I often have 'accidents', or I need a catheter or medicine to help me go to the toilet
- I nearly always mess or wet my trousers

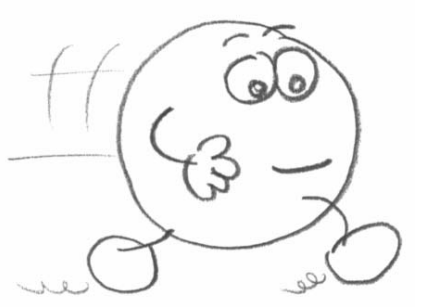
Question 7: Everyone gets out of breath when they run fast, but do you otherwise get breathless or have other breathing problems?

- No
- Yes, when running slowly or walking fast
- Yes, when walking slowly
- Yes, even after light activity like washing or dressing myself
- Yes, almost all the time, even when resting

Question 8: Do you have physical troubles or symptoms like pain, ache, feeling sick, or itchy?

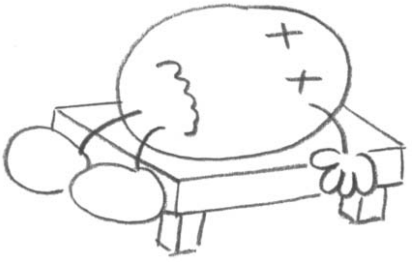
- Not at all
- A little
- Quite a lot
- Very much
- It is unbearable

Question 9: People can feel healthy and energetic, or they can feel ill, tired and weak.



Do you feel:

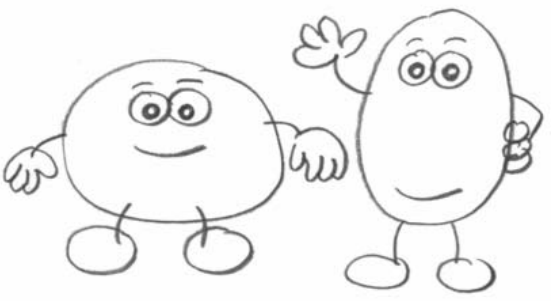
- healthy and energetic
- a little ill, tired or weak
- quite ill, tired or weak
- very ill, tired or weak
- extremely ill, tired or weak



Question 10: Do you feel scared or tense?

- Not at all
- A little scared or tense
- Quite scared or tense
- Very scared or tense
- Extremely scared or tense

Question 11: Are you happy with your weight, your height and how you look?



- ☐ I am completely happy
- ☐ I am quite happy
- ☐ I am rather unhappy
- ☐ I am very unhappy
- ☐ I am extremely unhappy

Question 12: Does your state of health make it difficult to go to school or have hobbies?

- ☐ Not at all
- ☐ A little (like not being able to do sports classes)
- ☐ Quite a lot (like I have difficulty walking or I miss school often because of sickness, or I am not able to have some hobbies)
- ☐ My state of health makes it almost impossible to go to school or have hobbies
- ☐ My state of health makes it impossible to go to school or have hobbies

Question 13: Does your state of health make it difficult to make friends or be with them?

- Not at all
- A little
- Quite a lot
- My state of health makes it almost impossible to make friends or be with them
- My state of health makes it impossible to make friends or be with them

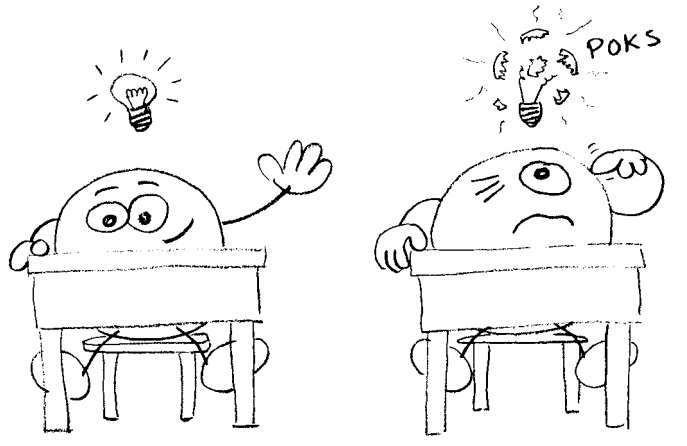
Question 14: Sometimes it is hard to concentrate on the same thing for long, when thoughts jump from one thing to another

How long can you concentrate on the same thing?

- a long time
- quite a long time
- only a short time
- my thoughts are always jumping from one thing to another, and I can't really concentrate much
- I'm so restless that I can't concentrate for a moment

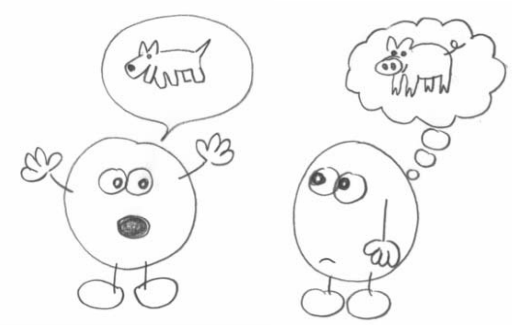
Question 15: How well can you learn new things and remember them?

- ☐ I learn new things easily and remember them well
- ☐ It is a little hard for me to learn new things or remember them
- ☐ It is quite hard for me to learn new things or remember them
- ☐ It is very hard for me to learn new things or remember them
- ☐ I cannot learn or remember things



Question 16: How clearly can you speak?

- ☐ I can speak clearly
- ☐ It is a little hard for me to speak clearly
- ☐ It is quite hard for me to speak clearly



- ☐ Most people have difficulty understanding me when I speak
- ☐ I can only make myself understood with signing

Question 17: People are not always cheerful and happy. Sometimes they can feel quite sad, unhappy and depressed.

Do you feel?

- ☐ cheerful and happy
- ☐ a little sad, unhappy or depressed
- ☐ quite sad, unhappy or depressed
- ☐ very sad, unhappy or depressed
- ☐ extremely sad, unhappy or depressed

If there is anything that you think might help us to understand your answers better, or if you have any opinions about this questionnaire, please write them in the space below:

_____
_____
_____

How easy was it to fill this questionnaire?

- ☐ Easy
- ☐ Quite easy
- ☐ Quite hard
- ☐ Very hard

Thank you very much!

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Chapter 9

Methodological Issues and Policy Implications

by
Pascale Scapecchi and Nick Johnstone[1]

The considerations arising from the previous chapters lead to the conclusion that empirical evidence on the valuation of children's environmental health is limited. While experience from the valuation of adults' environmental health provides valuable insights on how to evaluate children's health, a number of specific questions need to be further examined and addressed in order to obtain reliable estimates of health benefits for children. Methodological and data issues are of particular importance and the main conclusions from the present volume are summarised in the concluding chapter. Key policy implications are developed and paths for further research are considered.

The impacts of environment on health have been at the core of economic valuation for the last twenty years. The focus of much of existing research has been on working-age adults. However, in the past few years there has been increased emphasis on valuation of impacts for the elderly. Even more recently, the focus has shifted to children. This is due in part to a widespread perception that children are particularly vulnerable to the impacts of environmental degradation and/or pollution. In addition, valuing such impacts raises a number of methodological concerns, distinct from valuation of impacts for other parts of the population. However, epidemiological and economic evidence remains still rather limited. As such, in order to reduce environmental risks to children, a better understanding of the major threats, challenges and opportunities that exist in the valuation of children's environmental health impacts is required.

Methodological Issues

As noted above, empirical evidence on the valuation of children's environmental health is limited. While experience from the valuation of adults' environmental health provides valuable insights on how to evaluate children's health, a number of specific questions need to be further examined and addressed in order to obtain reliable estimates of health benefits for children. Methodological and data issues are of particular importance and the main conclusions from the present volume are summarised in what follows.

There is little information on environment-related health impacts that are unique to children, such as foetal loss and developmental disorders. A few particularly important health endpoints have been identified. However, estimates of a large number of health outcomes relative either to mortality or morbidity are not available. More data are necessary, and more particularly, data on specific health endpoints comparable to those for adults, such as chronic morbidity risk and asthma morbidity. For instance, taking into account the latency/delay between exposure and illnesses for specific impact areas for children is key to an understanding of the long term effects of environment degradation on children's health. The lack of such data precludes an evaluation of the health impacts of existing environment-related health policies. Therefore, priority should be given to the collection and assessment of epidemiological data to implement valuation studies to provide efficient policy advice.

Improved epidemiological data of this sort is not, however, sufficient. An important conclusion from the previous chapters is that children differ from adults not only in terms of risk, but also in terms of valuation. Children are neither little adults nor little consumers. Ignoring those differences could lead to biased estimates of health benefits associated with a reduction of environmental risk and therefore to inefficient policies. As an example, according to empirical economic studies estimating WTP to reduce health risks, values associated with mortality and morbidity risk reductions differ greatly for adults. Not surprisingly, according to Dickie and Gerking (2005), empirical evidence has highlighted large discrepancies between WTP to reduce mortality risks and WTP to reduce morbidity risks for children: mortality risk reductions for children are more valued than morbidity risk reduction for children. Morbidity and mortality risk reductions need to be estimated in a consistent way if policy makers want to be informed about the efficiency of the establishment of priorities and allocation of resources between these components from the health field. In order to be able to correctly compare children and adults values of health benefits, estimates should be obtained from a consistent valuation approach.

The literature on the valuation of adults' health is extensive. Given risk differences between adults and children, whether it be in terms of environmental exposure or in terms of dose-response, we can reasonably expect large disparities in estimates of health benefits between adults and children. However, precisely how great these disparities are is an issue which is only now being addressed by economists in a systematic manner. The reasons for this lacuna are not hard to find. The valuation of children's health poses unique challenges to economists.

Perhaps most significantly, methodological uncertainty is of great importance. The most striking distinction in this regard is the difference in the choice of the measure of health outcomes. Most fundamentally, different techniques can be used to estimate the health benefits from a risk reduction in terms of different types of health measures – such as WTP and QALY measures – which are incommensurable. WTP measures appear as good measures of a change in social welfare since they are more theoretically founded than QALYs and they provide estimates that are commensurable with cost figures. The choice of the measure of the health outcome is, of course, associated with the choice of valuation technique.

However, even within individual methodological frameworks, health outcomes can be measured differently. For instance, when valuing health benefits associated with a risk reduction in an economic framework, different measures may be used, whether for mortality risk reduction or morbidity risk reduction. WTP values are commonly preferred over COI values because they take account of all costs borne by the individual, while COI values do not take into account intangible costs, which may be rather substantial depending upon the health impact in question. Moreover, COI values may vary significantly between countries since they depend on the structure of the health system in place, while WTP values are rather consistent in OECD countries. Furthermore, WTP estimates can be used to derive two types of policy-relevant measures: VSL or VOLY. Recent studies seem to indicate that VSL is relevant for acute deaths and for latent deaths while VOLY is relevant for chronic health effects[2].

While the present volume reports on interesting work presently being conducted in this area, the validity of different methodologies to derive values in the specific context of children's environmental health needs to be systematically evaluated in order to help policymakers design efficient environment and health policies aimed at reducing health risks for children. The methodology adopted to derive such values should be chosen on the basis of its theoretical validity. However, many of these methodologies are based on considerations which are methodologically problematic for children. Many of the authors in the present volume argue that WTP is the most appropriate measure and that well-conducted contingent valuation surveys provide the most promising means of obtaining values of WTP to reduce health risks experienced by children. Stated preference (SP) techniques, which include the contingent valuation method, are preferable to revealed preference (RP) methods because of their greater flexibility in comparison with RP techniques. They can be used in contexts in which real behaviour patterns cannot be observed or in which there is no market for the good in question. Moreover, they allow for the measurement of that which is of interest – the preferences for WTP, since they measure a loss in utility, while RP methods measure a loss in money.

The choice of the perspective of the respondent is a major concern when valuing children's health. The WTP for environmental health risk reductions cannot be directly elicited from children because of children's limited cognitive abilities with respect to the expression of well-ordered preferences, and little or no control over the resources

which allow these preferences to be made effective. As such, it is necessary to rely on proxies to elicit their preferences. Commonsense suggests choosing their parents. However, such a perspective violates one of the central assumptions made by the economic theory of the consumer – each agent is the best judge of its own preferences. How can we be certain that parents are truly reflecting the underlying preferences of their children?

In addition, the use of the parental perspective may raise additional difficulties, such as the incorporation of altruism (paternalistic and non-paternalistic) in the WTP derived. Indeed, existing empirical results suggest that parents may value their children's health more highly than their own. Asking parents about their WTP to reduce a risk to their children also shifts the context of valuation from the individual level to a household level valuation context. Indeed, the need to value environmental health impacts for children has brought to the fore the need to see all valuation studies in the context of the household. An individual WTP for a given environmental good (or bad) which is non-excludable at the household level and/or for which there are important intra-household externalities necessitates viewing the individual respondent as a household member. If not assessed appropriately the WTP estimated for environmental health impacts for adults may include the WTP for a risk reduction in their own health, as well as other household members. A number of chapters in the present volume have emphasised the need for the application of an appropriate household allocation model.

When credible values are lacking, practitioners may be tempted to propose transferring values for adults to children in order to provide figures to policy makers. In the case of children's environmental health valuation, where so few studies are available, benefits transfer may be particularly hazardous. One possibility would consist in inferring the marginal rate of substitution (MRS), defined as the ratio of adults' values for their own health and adults' values for their children's health, as suggested in the literature[3]. However, benefit transfer – in its crudest form through the use of a generic MRS – has no justification if the estimates to be transferred are not reliable.

Given that the MRS may vary across different health risks or different demographic groups, estimating children's health benefits as any constant multiple of adult benefit may be misleading. Similarly, transferring estimates for adults to children on a 1-to-1 basis may lead to an underestimation of children's health benefits[4]. Arguably, it is the latter practice which is most common in practice, albeit in an unintended manner through 'sin of omission rather than commission'. Adult values are used by default in many policy proposals. The problem with the benefit transfer approach is that results may be used (or misused) for different purposes than those for which they were originally envisaged. For example, WTP values may be estimated by transferring results from studies or other effects or of other population groups, sometimes by using a "context" factor in order to take into account the difference in the contexts of valuation.

Policy Implications

Public decision makers require estimates of the effects of policy interventions on social welfare in order to implement efficient policies or programmes. To quantify the health benefits of environmental policies, estimates of the reduced probability of illness or death are generally required. For that purpose, economic valuation has become a

central tool, and studies have stressed the need for a better understanding of how to value the environmental health risks faced by children. However, we need to better understand the major threats, challenges and opportunities that exist in the field of children's health and the environment.

The paucity of research in this area, and the conflicting results from that which is available, leaves little guidance for policy makers on how to value health risks to children. Due to the lack of empirical research on VSL, most economic analyses rely on adult VSL for children's health effects. However, in the absence of reliable estimates of children's health, inappropriate policy decisions could be undertaken. On the one hand, ignoring risk differences between adults and children could lead to setting wrong standards for environmental policies, concerning for example the maximum allowable level of air pollution concentrations. On the other hand, ignoring the valuation differences between adults and children could lead to wrong policy priorities being set within the health and environment fields, which, in the long run, could generate an important social welfare loss.

Policymakers have been forced to make decisions and set priorities on the basis of very limited evidence and limited information. As noted above, children are different from adults, and the values associated with environmental health impacts are likely to differ between the two groups. However, assessment of these differences is in its infancy. This raises a question on the validity of the policy strategies/actions/instruments/targets currently in place: do they reflect the differences between adults and children? Are they (still) appropriate? In increasing scale of policy scope, three related 'policy failures' can be identified:

- Standards that are set in many countries for specific environmental impacts (i.e. air pollution concentrations) are based on their impacts on adults, which are often quite different from those for children. Proper valuation of impacts on children would result in standards which are different, often (but not always) more stringent.

- Policy priorities across different environmental health impact areas are based on adult responses, and so are often inappropriate for children. In such cases, governments are not allocating investments so as to avoid loss of lives or ill-health in an optimal manner.

- The allocation of resources between the environmental (ex ante) and the health (ex post) public policy fields may be imbalanced – with too much focus on 'cleaning up' the health impacts generated by environmental problems, rather than on preventing the environmental problems in the first place.

While limited, existing evidence seems to indicate that the resources devoted toward children's health are too low. This misallocation may arise from the lack of data and empirical evidence (as previously mentioned), resulting in an underestimation of the value of benefits associated with improved environmental conditions. More specifically, social preferences for reducing mortality risks related to morbidity risks should be better reflected in cost-benefit analyses and policy measures than they are at present. However, misallocation of priorities and resources may also arise from the lack of co-ordination between the environment and health public policy spheres. While this issue touches upon more general issues of public policy co-ordination, in the context of the subject matter of the present volume, differences in the valuation methodologies applied in the two spheres is clearly a contributing factor.

In order to obtain credible estimates in both valuation fields it would, of course, be helpful to harmonise the valuation methods applied. If based upon state-of-the-art theoretical and empirical findings, this would constitute a major input in the valuation of environment-related health risks for children. Indeed, the growing concern for children's health-related issues has encouraged the implementation of a large number of studies in the United States as well as in Europe, most of them funded by government or public agencies (such as the United States Environmental Protection Agency[5], the European Commission, etc.) and important international organisations.

For example, in Europe, the Pan European Programme (THE PEP)[6], gathering research groups in five European countries (Austria, France, Malta, the Netherlands, Sweden and Switzerland), has been carried out in order to assess the transport-related health impacts and their costs and benefits, with a special emphasis on children. The objective is to contribute to the development of WHO-Guidelines for the economic valuation of transport related health effects. In the United States, the Environment Protection Agency has funded a number of empirical studies related the valuation of environmental health risks to children. Examples include undertaking surveys to measure the WTP to avoid asthma incidence or to avoid skin cancer for oneself, children and the population as a whole, as well as work on the transfer of adults' values to children's values. A number of new empirical projects related to children's health focus on latency issues, supporting the importance and relevance of this issue on the valuation of children's health.

While there are specific children's environmental health concerns in individual countries, there are also key global risk factors. A good example is asthma which represents the health impact that has been mostly considered in epidemiological studies and that concerns a great number of OECD Member countries, as well as non member countries. The WHO has implemented cost-effectiveness analyses of interventions that address environmental risk factors. But concerted international co-operation is essential to co-ordinate the resources and needs of different countries. The challenges facing the international research and policy community in this area are significant, but so are the potential returns.

All these projects are promising and will certainly contribute a great deal to a better understanding of the general principles which need to be applied in order to correctly value the benefits associated with a reduction of environmental health risks experienced by children. However, the literature on the valuation of adults' health highlights risk and valuation differences between countries, social and ethnic groups. Given the lack of available data and the methodological complexities involved, valuation of children's environmental health impacts is likely to be even more fraught with difficulties. More comparative economic studies carried out in different countries would contribute a great deal to the generation of more credible values. More ambitiously, the application of a multi-disciplinary approach (gathering economists, epidemiologists, sociologists, psychologists, etc.) may be necessary in order to obtain sound estimates.

Notes

1 OECD Environment Directorate, National Policies Division. The views expressed in this chapter are those of the authors and do not necessarily reflect those of the OECD.

2 For empirical evidence, see Markandya et al. (2004) and Chilton et al. (2004). For further details, see Pearce et al., (2005).

3 For further details, see Dickie and Gerking (2005).

4 According to limited empirical evidence, WTP values for children are at least greater than those for adults. In this context, transferring adult values to children would lead to an underestimation of health benefits. For further details, see Agee and Crocker (2005).

5 See also US EPA (2003).

6 The main outcomes and conclusions of THE PEP are covered in the synthesis brochure (see THE PEP, 2004).

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Economic Valuation of Environmental Health Risks to Children

The relationship between environment and children's health has been the subject of increasing interest these last ten years. For instance, many OECD member countries are reporting asthma epidemics exacerbated by air pollution: in the United States nearly 1 in 13 school-age children (approximately 4.8 million) has asthma, and the rate is increasing more rapidly in school-age children than in any other group. The importance of this issue has resulted in a growing number of epidemiological studies aiming at better understanding and better characterising the relationship between environmental pollution and the health of children.

However, in many respects, the valuation of children's health strongly differs from the valuation of adults' health and constitutes a real challenge for analysts as well as for decision-makers. Consequently, this book proposes an in depth analysis of the main methodological difficulties associated with estimating the social value of a reduction in risk to children. Questions such as how to elicit children's preferences, what valuation methodology and benefit measure to choose, how to discount benefits to children's health, and how to account for economic uncertainties in this specific context of economic valuation will be systematically examined in order to define key policy implications and to pave the way for further research.

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