

Preliminary: Comments welcome

## **Valuing Morbidity in Environmental Benefit-Cost Analysis**

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### **ABSTRACT**

For benefit-cost analysis of policies with respect to environmental and natural resources, economic researchers typically require monetized values of households' willingness to pay for reductions in risks to human life and health. I briefly recap some of the main issues in valuing reductions in the risk of death that account for our considerably smaller literature on valuing reductions in morbidity risks. An important distinction is the issue of valuation in "illness space" versus valuation in "illness attribute space." I compare the requirements for environmental benefit-cost analysis with the limitations of the standard approaches taken in cost-effectiveness analysis in health economics, and highlight some areas that are ripe for further research.

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## Contents

1. Introduction.....	3
2. Sudden death data but not much illness data .....	5
2.1 Mortality focus.....	5
2.1 Data deficiencies.....	7
3. Illness space versus illness-attribute space .....	8
3.1 WTP to reduce morbidity measured in “illness space” .....	9
3.1.1 Reduced morbidity via <i>treatment</i> for those already sick .....	10
3.1.2 Reduced morbidity via <i>prevention</i> of illness .....	11
3.1.3 WTP differentials for broad categories of morbidity.....	12
3.1.4 The curse of dimensionality.....	13
3.2 Measuring the quantity of morbidity in “illness <i>attribute</i> space” .....	14
3.2.1 Health economists’ tools for quantifying morbidity in one dimension .....	15
3.2.2 QALYs and benefit-cost analysis .....	18
3.2.3 Different definitions of “value” .....	19
3.2.4 Atheoretic morbidity valuation: acceptable cost per QALY .....	21
3.3 Utility-theoretic WTP in “illness <i>attribute</i> space”: illness profiles .....	22
4. Directions for future research .....	25
4.1 WTP as a function of <i>expected</i> morbidity attributes.....	25
4.2 Choice scenarios that mimic environmental policy choices .....	26
4.2 Reduced morbidity as a public good.....	27
4.3 State of the art methods in design and analysis .....	28
5. Conclusions.....	28

## 1. Introduction

Environmental legislation, such as the Clean Air Act in the U.S., often stipulates that regulations must protect both human health and ecosystems. In benefit-cost analysis of such regulations, the dominant measured component of benefits has been reductions in human mortality risks. Human health benefits are easier to assess than benefits from ecosystem protection because ecosystems involve a multitude of species. Mortality reduction benefits have also been easier to address than related morbidity (illness) reduction benefits because of the vast numbers of illness profiles—time patterns of symptoms and outcomes—attributable at least probabilistically to environmental contaminants. Deaths, abstracting from prior morbidity, have been a more homogeneous commodity to try to value.

In practice, cost-of-illness methods are commonly used to measure the benefits of morbidity reductions. These methods are a placeholder strategy that cannot fully capture the non-market cost of illness, including “pain and suffering.” As Richardson et al. (2013) reiterate in their brief review of cost-of-illness and other methods, the U.S. Environmental Protection Agency acknowledges that “many important morbidity effects are poorly studied from the WTP perspective.” In fact, the U.S. EPA has identified the valuation of reduced morbidity as the greatest long-term research need of the Agency (see U.S. EPA (2005)).

Section 2 of this review will examine some of the main reasons why we do not yet have a full complement of empirically estimated willingness-to-pay values for avoided human morbidity for use in benefit-cost analysis of environmental policies. One reason has been our intense focus on market-based evidence from labor market wage-risk studies about tradeoffs between money and the risk of sudden accidental death in the current period. This emphasis on sudden deaths has had the advantage of eliminating any distortions in mortality risk reduction benefits that could be attributed to pre-mortality morbidity. By design, however, these methods intentionally exclude morbidity reduction benefits.

Another reason for our limited inventory of morbidity reduction benefits estimates is that few environmental illnesses are reportable, so revealed-preference (RP) data are scarce. Stated-preference (SP) data are necessary when actual market choices are not observed. SP data have been especially relevant when it is important to account for WTP to reduce the risk of prospective illness profiles that involve potentially long latencies before symptoms appear. SP

studies are difficult to do well, and are harder to defend than RP studies. Thus, even compared to mortality risk reductions, it has been harder to fund and harder to publish the research needed to produce robust estimates of morbidity reduction benefits for benefit-cost analysis of public policies. Environmental economists are of course no strangers to the controversy over whether SP demand information is reliable. For more than two decades, the views of researchers on opposite sides of the litigation over the magnitude of the economic damages caused by the 1989 Exxon Valdez oil spill colored the debate about whether valid WTP information could be gleaned from SP surveys.

Section 3 will inventory an assortment of studies that attempt to measure WTP estimates for specific types of illness. One might think that the field of health economics would have provided large numbers of estimates of the benefits of morbidity risk reductions. For example, the pharmacoeconomics community should be, in principle, intensely interested in market research concerning patients' WTP for treatments for a variety of illnesses. However, an aversion to monetization of health states, held by many health economists, restricts morbidity valuation in the health field. Health economists tend to measure morbidity in healthy-time equivalents, rather than dollar equivalents. This orthodoxy in health economics does not preclude cost-effectiveness analysis (CEA) for allocations of a fixed hospital budget among alternative healthcare treatments. Unfortunately, however, its rejection of monetization renders this body of research of little value for environmental benefit-cost analyses.

Section 3 also points out that environmental economists can (and should) take advantage of a dominant theme in health economics: the "decontextualization" of illnesses. Health economists have recognized the value of utility-theoretic methods for converting the infinite dimensions of possible health states into a one-dimensional index based on a smaller set of "spanning" illness attributes. If a small set of illness attributes can capture all of the most salient dimensions of any given illness, the dimensionality of the morbidity-valuation problem can be drastically reduced. Rather than seeking one-size-fits-all estimates for morbidity reduction benefits (analogous to our obsession with finding a single true value for a statistical life), environmental economists should aspire to develop a "one *model* fits all" formula for generalized morbidity reduction benefits. Bespoke estimates (i.e. made-to-measure studies) for specific types of morbidity reduction benefits can be justified when the policy stakes are especially high. However, benefits transfer methods are often the only practical approach for run-of-the-mill

regulatory analyses. There is a huge need for encompassing WTP models that can accommodate the vast heterogeneity in illness profiles related to environmental exposures.

Section 4 identifies some important directions for future research on the valuation of reductions in morbidity risks, and Section 5 concludes.

## **2. Sudden accidental death data, but not much illness data**

With improved life-saving technologies, the valuation of morbidity has become increasingly important. According to Davies et al. (2007), for example, a trend of increased survival with cardiovascular disease has actually caused an increase in the *prevalence* of cardiovascular disease in many high-income countries, even though the *incidence* of these diseases is falling over time. Fewer sudden deaths from cardiovascular disease unfortunately mean that more individuals will be living with post-heart-attack or post-stroke morbidity prior to their eventual deaths from these or other causes. We need to know more about the tradeoffs people are willing to make between reductions in compromised health states (whether via prevention or via treatment) and other social goals.

Expanding upon the introduction, a number of important factors have conspired to limit the quantity and quality of available research concerning measurement of the social benefits of reductions in illness (morbidity) in a way that is useful for benefit-cost analysis.

### **2.1 Mortality focus**

First, research on the economics of environmental health has focused on society's willingness to incur the costs of reducing risks to human *life* (premature *mortality*). A large literature focuses on individual WTP for a given small risk reduction in mortality risk, aggregated across enough people so that the cumulative risk reduction equals 1.0, or a "statistical life" (VSL). The aggregate WTP for this statistical life has been called the "value of a statistical life," although this has proven to be a particularly confusing and upsetting term for non-specialists, as explained in Cameron (2010). A thorough review by Cropper et al. (2011) of VSL research to date is included in a prior volume of this journal.<sup>1</sup>

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<sup>1</sup> Some of the most frequently cited reviews and meta-analyses include Mrozek and Taylor (2002), Viscusi and Aldy (2003), Kochi et al. (2006), and Bellavance et al. (2009). More recently, Dekker et al. (2011) estimate a Bayesian meta-model that reveals systematic differences in VSL estimates by the risk context, a source of systematic variation that probably afflicts WTP estimates for morbidity risk reductions as well. Doucouliagos et al. (2012) emphasize

There has been an implicit, and sometimes explicit, simplifying assumption in the environmental health valuation literature that “a death is a death” and reductions in mortality risks due to environmental causes should be valued the same as reductions in mortality risks due to other causes, although this is really an empirical question.<sup>2</sup> Short of relatively sudden death from a heart attack, stroke, or accident, all deaths involve some period of pre-mortality morbidity with different characteristics, and it seems unavoidable that people will associate different amounts of disutility with (eventual) deaths from different causes. But relatively little data on preferences for mortality risk reductions has been derived in specifically environmental contexts, so it has been important to proceed as though the value of avoided mortality is the same across all contexts. If willingness to pay for mortality risk reductions is *independent* of the cause of death, preferences for reduced mortality risk in various labor-market contexts or other non-environmental contexts can be readily transferred to environmental contexts. Modern labor-market wage-risk models explain wages as a function of actuarial fatality risks across different industries and occupations, where the health risk in question is typically “sudden accidental death in the current period.” In these data, minimal morbidity is involved. This strategy does avoid biases in the values of avoided mortality that would stem from different patterns of pre-mortality morbidity, but it is obviously unhelpful to the task of estimating values of avoided morbidity.

Importantly, most environmental risks do *not* typically result in sudden death in the current period. Instead, environmental risks often cumulate over extended periods of exposure, resulting in illnesses such as respiratory disease or heart disease or different types of cancers, sometimes with long latencies after the period of exposure. To the extent that people perceive a difference between sudden death and death at some point in the distant future—perhaps after a long period of reasonably good health, but then a long period of illness with either moderate or severe symptoms or disability levels—it is important to consider people’s willingness to bear the

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corrections for publication biases and the availability of worker’s compensation programs. A survey by Viscusi (2012) itemizes a number of remaining challenges concerning VSL measurement.

<sup>2</sup> If willingness to pay to reduce mortality risks depended *only* upon the number of expected lost-life years involved, we would see roughly identical WTP estimates for all deaths at the same age. In terms simply of lost life-years, it may be the case that “dead is dead,” although it is possible that people are willing to pay more to increase their chances of staying alive long enough to experience major life events, such as a child’s graduation or wedding, for example, or to otherwise discharge their responsibilities for child-rearing, one of the issues explored in Cameron et al. (2010a).

costs of reducing the risks of adverse health outcomes that may be much more complex than simply sudden accidental death in the current period.

## 2.1 Data deficiencies

There is a paucity of appropriate revealed-preference data for studying the value of morbidity reductions. Deaths and their causes must be reported, but we have much less information about illnesses. Mandatory reporting of infectious diseases by clinicians in the U.S. varies by jurisdiction. All U.S. states participate in a national morbidity reporting system and report either aggregate or case-specific data for roughly 60 infectious diseases and related conditions to the Centers for Disease Control (CDC) in Atlanta, GA.<sup>3</sup> Unfortunately for environmental health researchers, however, few environmental pollutants are classed as infectious. Although pollution may disrupt ecosystems or compromise the immune systems of organisms to a point that infectious agents thrive, outbreaks of infection are less directly linked to chronic or episodic pollution. Air pollution more commonly affects respiration and cardiovascular systems. Water and soil pollution may be toxic or carcinogenic or teratogenic. These health problems are less likely to be immediately and unambiguously connected to pollution from a specific source. Furthermore, a health insurance system that excludes coverage for pre-existing conditions exacerbates under-reporting of chronic conditions that might be related to environmental exposures.

Wage-risk estimates of WTP for any type of health-risk reductions are also, by definition, representative only of workers. Other constituencies affected by environmental problems (notably children and the elderly) are not in the labor force, so wage-risk approaches cannot measure their preferences. This creates a potentially serious mismatch between the population at risk for environmentally related health risks and the population for which we have revealed-preference data on tradeoffs willingly made between health states and money.

Environmental health risks can be very much different from occupational health risks. Furthermore, even in wage-risk mortality studies the *type* of death is likely to differ systematically across industries, occupations and accidents.<sup>4</sup> Deaths due to burns, falls, crushing

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<sup>3</sup> The National Notifiable Diseases Surveillance System (NNDSS) is described at <http://wwwn.cdc.gov/nndss/>. The complete list of notifiable diseases at the national level as of 2010 is included in the document available at <http://www.cdc.gov/mmwr/PDF/wk/mm5953.pdf>.

<sup>4</sup> Some recent evidence of latent heterogeneity, even within a wage-risk framework, is illustrated in Kniesner et al. (2010) and numerous other researchers have explored the systematic effects of observed heterogeneity. Scotton and

injuries, workplace homicide, etc., may involve different amounts and/or types of pre-mortality morbidity (i.e. suffering prior to death). The data are relatively deeper for fatal job-related injuries, permitting wage-risk analyses, but reporting requirements for injuries are not as stringent and the great heterogeneity in types of injuries renders them harder to value.

Workplace accidents may involve systematically different types of *morbidity* that typical environmental health hazards. If WTP for a particular type of mortality risk reduction actually carries along an implicit differential that reflects the type and duration of morbidity that precedes this death, WTP to reduce pre-mortality morbidity might account for some of the observed differences in VSL estimates across different RP wage-risk studies and across RP wage-risk and SP studies of other types of health risks.

Stated preference studies can be used when revealed preference data are unavailable, but health economists may not yet be as far along the learning curve as environmental economists have come. Ozdemir and Johnson (2013) find less consistency among health economists concerning quality judgments about SP research and the suitability of different types of studies for policy analysis.

### **3. Illness space versus illness-attribute space**

There are two basic alternative approaches to morbidity valuation. The first approach we will call “WTP in illness space.” These studies consider specific named illnesses, and sometimes just one stylized or unspecified illness profile for that type of illness, and undertake to measure carefully people’s WTP to avoid or reduce the risk of contracting this particular illness. The second approach we will call “WTP in illness *attribute* space.” This literature is less well populated. However, it has important connections to the standard approaches taken by health economists to de-contextualize the infinite variety of possible illnesses by describing each one in terms of its levels of a much smaller number of common attributes.

In health economics, the standardization of heterogeneous health states using the idea of “quality adjusted life-years” (QALYs, to be discussed later) is analogous to the idea in the

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Taylor (2011), for example, establish that compensating wage differentials for workplace deaths differ for homicides and accidents, so the cause of death can matter even among different types of sudden deaths. Schaffner and Spengler (2010) use wages across job changes to reveal that cross-sectional samples involve likely unobserved heterogeneity biases that produce over-estimates of the VSL. A recent state-of-the-art panel-data wage-risk study is described in Kniesner et al. (2012), a paper which also includes many of the key citations in the wage-risk VSL literature to that point.

market research literature of the distinction between “product/brand space” and “attribute space.” A market may offer an overwhelming number of differentiated products or brands, for example, but each of these products might be summarized by its levels of a much smaller number of attributes. Utility levels may be determined by bundles of attributes, rather than by products or brands and the marginal utility per unit of each attribute may be sufficient to explain choices. Here, the “products/brands” are different named illnesses, like heart disease or diabetes. A much more parsimonious and general model of health preferences is possible if each specific named illness can be captured by a smaller set of generic spanning attributes.

Just what attributes should be included in this smaller spanning set is an important research question. For example, there seems to be a persistent sense in policy circles that “cancer” versus “noncancer” may be an important attribute of any illness. This particular attribute may contribute a systematic increment in WTP to reduce the risk of any type of cancer, independent of the other basic illness attributes in the small set of generic attributes intended to capture most of the important differences across illnesses.<sup>5</sup>

### **3.1 WTP to reduce morbidity measured in “illness space”**

As the morbidity valuation literature began to develop, the initial forays sought to develop WTP estimates for the avoidance of specific individual types of illness. Using specially tailored studies, it is in principle possible to develop a different WTP estimate for each specific illness. I will enumerate a variety of such studies in the following sections on treatment and prevention. There can be as many WTP estimates as there are types of illnesses, and even more if we differentiate each illness by its severity, duration, and delays in onset, by the characteristics of its victims, and by the characteristics of the individuals being asked to bear the costs of prevention.<sup>6</sup>

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<sup>5</sup> If the name of an illness evokes additional unmeasured or implicit attributes, beyond just the minimal set of health-state attributes used in a health assessment survey, this could be considered analogous to the so-called “brand effect” in the marketing literature, e.g. Swait and Erdem (2007) or Eckert et al. (2012).

<sup>6</sup> As soon as research on the valuation of health risk reductions departs from the “sudden death in the current period” as the sole type of health risk in question, the issue of pre-mortality morbidity becomes relevant (i.e. the amount of time spent being sick or disabled prior to death). Bosworth et al. (2009) demonstrate that when individuals consider descriptions of public policies that reduce both illnesses and deaths in their communities, willingness to pay for these policies varies systematically with both the number of illnesses avoided and the number of deaths avoided. However, when the same sorts of policies are described only in terms of the number of deaths they prevent, willingness to pay to prevent deaths is greater, suggesting that these individuals automatically impute some amount of pre-mortality illness when illness information is omitted.

### 3.1.1 Reduced morbidity via *treatment* for those already sick

Willingness to pay for treatments for specific ailments, understandably, is a topic of great interest in the pharmacoeconomics literature. There have been increasing numbers of valuation studies designed to determine the market potential of particular pharmaceutical products or treatments for specific conditions. However, these studies focus on willingness to pay for treatment by patients who are already afflicted by the illness in question. For example, Iskedjian et al. (2009) assess WTP for relief from the pain of multiple sclerosis. Seidler et al. (2012) consider WTP for treatments and medications for skin diseases.

Recently, researchers in Taiwan and Korea seem to be more willing than researchers elsewhere to explore WTP measures for treatment of existing illnesses, especially cancer. Stated preference methods are used by Lang (2010) to measure WTP for lung cancer treatments and by Lang et al. (2012) to assess the WTP of cervical cancer patients to achieve a complete remission of the disease, using health-related quality of life (HRQL) as an explanatory variable. Oh et al. (2012) measure the WTP for treatment by breast cancer patients, citing the need for Koreans to “better evaluate treatment in the coming era of personalized medicine.” WTP for a hypothetical new treatment that cures prostate cancer without side effects is measured by Li et al. (2012).

Marti (2012) and Servan-Mori et al. (2012) use discrete choice experiments to measure WTP for smoking cessation medications. Smoking cessation is generally sought as a means to reduce the subject’s own health risks, so perhaps these values might transfer to private demands for environmental health risk reductions.<sup>7</sup>

Two asthma studies are highly relevant to environmental health risks, where reducing the exacerbation of existing illnesses is one goal of environmental regulations analogous to “treatment.” Blomquist et al. (2011) survey two groups about a hypothetical asthma therapy, including a convenience sample of parents whose children currently suffered from asthma, and Kentucky households from the general population. The parent sample is used to measure WTP for reductions in children’s asthma risks. Brandt et al. (2012) administer a survey about WTP to reduce a child’s asthma morbidity, also using a sample of parents whose children currently have asthma symptoms. Valuation scenarios include both the frequency of asthma episodes and the

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<sup>7</sup> WTP estimates for morbidity values have also been generated in a number of other contexts that may have less relevance to environmental health risk scenarios. For example, Suh et al. (2011) have considered osteoporosis treatments to prevent fractures in Korea, but neither osteoporosis (a silent disease), nor the resulting fractures, are understood to be a common result of exposures to environmental contaminants.

psychosocial stress associated with these episodes.<sup>8</sup> However, the estimated values from these two studies are specifically for asthma. Findings may be readily transferable to reductions in asthma morbidity from environmental regulations, but not to other types of environmentally induced morbidity.

### **3.1.2 Reduced morbidity via *prevention* of illness**

While many valuation exercises in health care contexts pertain to circumstances where the consumer has already contracted the illness in question and is seeking relief, this context does not perfectly match the usual environmental health risk reduction scenario where we need to assess willingness to pay to reduce the risk of getting the disease in the first place. In environmental policy analysis, we often require prospective estimates of the anticipated benefits of prevention of morbidity (although some benefits may accrue in the form of reductions in the exacerbation of existing illnesses, and this could be viewed as isomorphic with treatment).

Milligan et al. (2010) take advantage of an experimental module in the 2002 module of the Health and Retirement Survey (HRS). In this case, respondents were asked if they were willing and able to pay a given dollar amount per month (out-of-pocket, or in the form of additional health insurance premiums) for a new drug that could completely prevent cancer and had no side effects, although this intervention may not have been completely plausible.

WTP for cardiovascular prevention programs is assessed by Jacobs et al. (2011), although this respondents in this study were implicitly asked to value a bundle that included not just the health benefits of the program, but also the disutility of the substantial time requirements for participating the intervention and their subjective perceptions of the program's effectiveness. A similar problem may afflict the study of WTP to prevent influenza by Johnston et al. (2010), where respondents' dislike of vaccinations and disagreement with national influenza vaccination recommendations were associated with lower WTP for prevention.

Using a set of forced-choice discrete choice experiments, Prosser et al. (2013) also elicit values for avoided influenza episodes. These episodes were described as afflicting a hypothetical family member of specified age, or the respondent him or herself. Respondents consider an episode described by duration in days, days lost from usual activities, symptoms

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<sup>8</sup> The hypothetical intervention is not described as curing asthma and does not induce an unmeasured bias against medications. Likewise, the intervention does not offer other non-asthma-related benefits that might also confound the estimates.

(present/absent), and time willingly traded at the end of the respondent's own life. The main finding in this study pertains to a roughly U-shaped profile in WTP according to the age of the patient, with greater WTP for the very young and the very old. But these authors point out that a "gold standard" method for valuing temporary health states for economic evaluations has not yet been identified.

There are selected estimates of people's willingness to pay to avoid specific types of acute non-fatal health effects, for example gastrointestinal illness, as studied by Viscusi et al. (2012). There is also a very detailed study of WTP to reduce morbidity from drinking water contamination. Adamowicz et al. (2011) address the problem of morbidity and mortality risk tradeoffs in municipal water systems. Pathogens such as E. coli, cryptosporidium and giardia often threaten municipal water supplies. Chlorine compounds are often used as one of the less expensive means to combat these pathogens, but chlorine leads to the formation of trihalomethanes (THMs) that have been linked to bladder cancers. Tap water is described to survey respondents as a commodity that can be described by three attributes: mortality risks (cancer and microbial), morbidity risks (cancer and microbial) and cost to the household.

### **3.1.3 WTP differentials for broad categories of morbidity**

There has been a recurring debate in policy circles about whether it is appropriate to incorporate a "cancer premium" into VSL estimates when the health risk in question involves some type of cancer. The sense that there should be a "cancer premium" probably stems from people's greater dread of death from cancer than from other causes. This dread is likely due to the expectation that the morbidity that precedes a cancer death can be particularly difficult, especially if the cancer is treated aggressively. A cancer premium would be a type of "brand effect."

Bosworth et al. (2009) model choices among hypothetical *public* policies to prevent community-level illnesses and avoid deaths. The utility coefficients on the terms in avoided illnesses and avoided deaths are allowed to differ according to a wide range of illness types. For none of these coefficients, however, is it possible to reject the hypothesis that the underlying parameter is identical across illness types. These results suggest that for reductions in risks to *public* health, rather than *personal* health, no cancer premium is indicated. Our findings are different in the case of private risk reductions, however. In Cameron et al. (2010b), we distinguish between five different types of cancers—breast cancer, prostate cancer, colon cancer,

lung cancer, and serious skin cancer—and find that WTP differs systematically among different types of cancers as well as between cancers and other illnesses, including heart disease, heart attacks, respiratory disease, strokes, diabetes, Alzheimer’s disease and traffic accidents.

In contrast, Alberini and Scasny (2011) implement a stated preference survey for a respondents in Italy and in the Czech Republic. Their subjects were asked to choose between costly interventions to reduce *mortality* risks that differed in terms of their nature as private goods or a public goods, the length of time before the reduction in the probability of dying would begin, and the cause of death (where the causes of death were limited to cancer, road traffic accidents, or respiratory illnesses). These different labels imply different types of morbidity, although the pattern or severity of the morbidity was not made explicit in the choice sets. These authors find a “cancer premium” that is statistically significant for adults in both samples, noting that this is “consistent with policy analysis practice within the European Commission, which applies a 50% cancer premium, and in the UK.”

WTP estimates specifically for reductions in injuries have also been sought in a number of settings. Anything other than a very minor injury is likely to involve a period of morbidity. Estimates of the value of a statistical non-fatal injury are included in a wage-risk survey in Mexico city by Hammitt and Ibarra (2006). These authors find that non-fatal injury rates tend to be collinear with fatality rates, consistent with the earlier observations of Viscusi and Aldy (2003). In a study of similar vintage, Hultkrantz et al. (2006) deal with the collinearity problem by calculating the average value of a statistical serious injury based on “death-risk equivalents.”

More recently, Hensher et al. (2009) address the value of reductions in traffic injury risks using a stated-preference survey with discrete choice experiments involving alternative travel routes. Each route in a choice set is described by speed limits, speed cameras, travel time measures, running costs, and tolls, as well as the number of deaths per year and the number of severe permanent injuries per year, the number of injuries requiring hospitalization per year, and the number of minor injuries per year. They a utility function that is linear in annual rates of death and three types of injuries, so that WTP can be estimated for injuries of each level of severity and permanence.

### **3.1.4 The curse of dimensionality**

Given the potentially infinite number of specific illnesses and illness profiles, not to mention the potential for heterogeneity across consumers in WTP to reduce any one of these

types of morbidity, there is considerable need for “decontextualized” or “generic” WTP estimates based on illness attributes. Dimensionality can be reduced if each illness can be represented by a different combination of levels for a common set of shared attributes. To this end, we will digress to consider the dominant tradition in the health economics literature, where decontextualization is paramount. Much progress has been made on the characterization of illnesses in attribute space in this literature, but these results are unfortunately not directly suited to benefit-cost analysis.

### **3.2 Measuring the quantity of morbidity in “illness *attribute space*”**

In the health economics literature, there is a long tradition of efforts to reduce dramatically the dimensionality of the space of all possible illnesses. Health economists have a much stronger tradition than environmental economists in their efforts to standardize morbidity for so-called “health technology assessment” (HTA). Unfortunately, these researchers often have a preoccupation with equity concerns (sometimes at the expense of efficiency) and thus an aversion to monetization, which is unfortunately crucial for benefit-cost analysis of environmental policies. **But efficiency is important if we are to allocate society’s resources in a way that maximizes the total value available for redistribution. Failure to emphasize efficiency can easily lead to lower well-being for those we might believe we are helping by our attentions to equity.** A brief primer on the most popular methods for standardization of the quantity of morbidity is appropriate at this point.

For the question about how to allocate scarce hospital resources for treatment, a typical policy or management scenario in health economics, there is no uncertainty about the baseline health state: health is already compromised. There may be uncertainty about whether a proposed treatment will restore full health, or just something between full health and the current health state. Without treatment, there may be some probability of death, or some outcome between death and the current compromised health state. Purchase of the treatment option presumably improves the odds of better outcomes and reduces the odds of worse outcomes, relative to the status quo.

Where cost-effectiveness analysis is the prevailing methodology for determining the best allocation of a fixed healthcare budget, the dominant paradigm involves standardization of all kinds of health states into a common univariate physical metric known as a quality-adjusted life year (QALY). There are many different approaches to this endeavor. In the QALY literature,

the goal is to reduce any arbitrary high-dimensional current health state to a one-dimensional metric that can be compared and aggregated across different illnesses. This is the “quality-adjusting” portion of the QALY exercise. The second part of the task is to combine this one-dimensional measures of the nature/severity of a particular health state with the amount of time in that health state to produce the “life-years” part of the calculation.

### **3.2.1 Health economists’ tools for quantifying morbidity in one dimension**

#### ***Visual analog scale (VAS)***

Many health-rating “instruments” are available. One (proprietary) approach to QALYs has been promulgated by a set of researchers called the EuroQol Group, whose instrument is described at <http://www.euroqol.org>. This is an update to the EQ-5D survey instrument described in Brooks (1996) and Dolan (1997). The instrument first elicits self-reported ratings of health-related quality of life on five dimensions: mobility (“in walking about”), self-care (“washing or dressing myself”), usual activities (e.g. work, study, housework, family or leisure activities), pain/discomfort, and anxiety/depression (“anxious or depressed”). The newest version offers five possible ratings options on each dimension. A “unique health state” is then defined by a set of five digits between 1 and 5 (e.g. “12413”). This allows for 3125 different health states between “11111” and “55555.” Sets of indicator variables relative to the base category for each of these five dimensions are created for use as regressors. As a dependent variable for the regression, the standard EuroQol survey next uses a vertical scale, marked from 0 to 100 with every fifth level labeled, known as a visual analog scale (VAS). The top of the scale is marked as “The best health you can imagine,” and the bottom of the scale is marked as “The worst health you can imagine.” The elicitation asks the respondent to indicate how good or bad their current health is on the day of the survey.

The researcher then regresses the respondent’s subjective VAS level on the five sets of indicators (dummy variables) that capture the same person’s ratings on the five distinct health state attributes. The omitted category is typically the “1” level on each attribute (no problem), so a health state of “11111” is normalized as 1.0 on the VAS scale, or “full health”. The coefficients in this regression are variously called “index values,” “QALY weights,” “preference weights,” “preference-based values,” “tariffs,” or “utilities.” If we assume that all relevant features of any illness can be captured by the five symptom types of the EQ-5D, then the five ratings for any

arbitrary illness can be plugged into the estimated regression equation to produce a fitted value of the dependent variable (i.e. a prediction of the expected self-rating of subjective health in that state).

### ***Standard gamble (SG)***

In the “standard gamble (SG) approach, respondents are asked to choose between remaining in a compromised health state for a given length of time and accepting a medical intervention that has (a) a chance of restoring them to full health, but also (b) a chance of killing them. Brazier et al. (2002) is a popular citation. The chance,  $p$ , of the best outcome occurring is varied until the subject is just indifferent between the certain outcome (staying in the compromised health state) and uncertain outcome (gambling on a return to full health versus death). We might assume that the subject is comparing utility from the first alternative (with certainty) against *expected* utility from the gamble across the best and worst outcomes.

If one is willing to assign a cardinal utility value of 1 to the best outcome and 0 to the worst outcome, then the parameter  $p$  reveals utility, on this cardinal utility scale, associated with the “certain” health outcome. If  $p$  is one, the “certain” health state is valued identically to full health. If  $p$  is closer to zero, so that  $(1-p)$  approaches one, the “certain” health state is valued similarly to death (or in some studies, to a state worse than death). This method also produces a “utility” index on a scale from zero to one for decontextualized health states. However, heterogeneity in risk preferences will influence the results from this method, and while expected utility is the dominant paradigm, it is not the only model of choice under uncertainty. Many economists, of course, also balk at the notion of cardinal utility, since modern consumer theory requires only ordinal utility comparisons.

### ***Time trade-off (TTO)***

Other methods have also been used to elicit information from research subjects (patients, members of the general population, or medical experts) about utility-preserving tradeoffs willingly made among portfolios of symptoms. One of these methods has been the “time trade off” (TTO) approach where, for example, subjects may be told to imagine that they could choose to live ten years in their current health state or give up some life-years at the end of their life to live a shorter number of years in full health. They are asked to indicate how much time in full health would be equivalent to ten years in their current state, and the ratio of this shorter number

of full-health years (say, 7 years) to the alternative 10 years in the current health state produces a TTO score of 0.7. This method thus produces an index on a scale of zero to one. To continue, five years in the current health state would then be interpreted as  $0.7 \times (5 \text{ years}) = 3.5$  QALYs. This method relies implicitly on individual time preferences.

### ***Discrete choice experiments (DCE)***

A review by de Bekker-Grob et al. (2012) covers the expanding use of discrete choice experiments in the health literature since about 1990 (known as conjoint choice experiments or stated choice methods in the marketing, transportation, and environmental economics literatures). However, health economists unfortunately tend to use years in full health as a non-monetary numeraire good rather than net income (other consumption) as would be necessary for monetization.

In a recent example, Lancsar et al. (2011) use DCEs to calculate “distributional weights” for QALYs, but they hold net income implicitly constant in their choice scenarios, precluding estimation of a marginal utility of net income. The two alternatives in each choice scenario treat health problems (for *other* people, who differ in their characteristics). Utility is modeled as linear in the logarithms of age at onset, age at death without treatment, quality-of-life without treatment, and QALYs gained from treatment. However, QALYs are “estimated regressors” in the choice model, calculated separately, rather than having the weights on their component illness attributes estimated simultaneously with the other utility parameters in the model. While nonlinear forms are entertained (up to cubic in each argument), there are no interaction terms.

Bansback et al. (2012a) and Bansback et al. (2012b) ask respondents whether they would “prefer Life A or Life B, or are they the same?” Their survey describes each “life” according to a different set of EuroQol ratings (expressed in words), and the duration in that health state is described as one of 10, 7, 4, or 1 year, followed by death. They use a specification for the systematic portion of utility that forces fitted utility to be proportional to the time spent in the given state. The fitted model neatly permits the researcher to solve for the number of years in full health (rather than the difference in income) that would achieve the same utility as ten years in a compromised health state. However, the marginal utility of an extra period in a given health state depends upon the attributes of that health state, but not upon time in that state. The inherent limitations of linear specifications are also noted in the brief critique by Johnson (2009).

In a 2012 dissertation, Norman (2012) uses a survey with conjoint choice sets involving three alternatives that include “State 1,” “State 2,” and “Immediate death” to measure people’s willingness to make trade-offs between quality of life and survival, as required for QALY construction. The two health states are described in terms of six health attributes (i.e. those used in the so-called SF-6D instrument—physical functioning, role limitation, social functioning, pain, mental health and vitality) and a duration for this health state. These choice experiments are thus specifically designed to estimate time trade-off (TTO) standardizations of sets of health state attributes, but within a structural conjoint choice estimation framework, rather than the usual reduced-form TTO questions, with very thorough empirical analysis. Importantly, the design of this experiment allows relaxation and testing of the restriction that utility is linear with respect to time in a health state: the marginal utility of time need not be constant. But again, there is no difference in net income across alternatives, so these mixtures of illness attributes cannot be monetized through WTP calculations.<sup>9</sup>

### 3.2.2 QALYs and benefit-cost analysis

These four basic QALY-type methods outlined above certainly measure something, **but what they measure is not directly useful for benefit-cost analysis or efficiency assessment when it comes to allocating society’s scarce resources across health-care interventions and other good things.** Any of the available variations on the standard QALY methods do indeed represent possible formulas to combine the multiple dimensions of different health states into a single index. These various approaches share the laudable goal to “decontextualize” a wide range of heterogeneous health states by converting them into levels of a unit-free one-dimensional metric. Unfortunately, however, many QALY-based estimates of health tradeoffs are not automatically compatible with the formal theory of demand that underlies models of consumer behavior in economics.

Under some strong assumptions, it is possible that the quantities of health improvement produced by different allocations of a budget for treatments for a variety of afflictions could be

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<sup>9</sup> Even WTP-capable DCE exercises typically impose the assumption (often untested) that the marginal utility of net income is constant and that utility is additively separable in net income. This makes the denominator in any marginal or total WTP calculation a simple scalar, independent of the level of net income or any other attributes of the alternatives. However, preferences often display diminishing marginal utility with increasing amounts of net income, just as they do with respect to other arguments. When the denominator in an MRS calculation is not a constant, however, it is not possible to derive a fixed tradeoff willingly made under all circumstances.

directly compared. Bleichrodt and Quiggin (1999) derive the conditions under which cost-effectiveness analysis based on QALYs can be consistent with benefit-cost analysis. It is necessary that (i.) the lifetime utility function over consumption and health status be additive over time; (ii.) the one-period utility functions can be multiplicatively decomposed into a utility function over consumption and a utility function over health status; and (iii.) the utility of consumption is constant over time. Empirical evidence, however, as in Viney and Savage (2005), tends to suggest that these restrictive conditions do not hold. Thus we need to conclude that aggregation of physical health benefits via QALY-type measures is typically not consistent with rigorous utility-theoretic principles. Nevertheless, QALY measures constitute the prevailing orthodoxy in health technology assessment settings, a fact that is somewhat discouraging to Johnson (2009).

The question might be raised as to why pharmaceutical companies do not avidly pursue measurement of consumers' WTP for drugs to treat specific types of morbidity by directly funding more WTP studies. Perhaps the demand for such research would be greater if consumers, rather than their care providers, directly chose their medications. In direct-to-consumer advertising of prescription medications, prices seem never to be mentioned, and manufacturers emphasize comparisons across medications in terms of effectiveness and side effects. Health insurance covers the costs of expensive medications in many cases, blunting both the consumer's and the physician's perceptions of the price attribute. Perhaps consumers' price inelasticity is highly desirable from the pharmaceutical companies, and company profits are likely to be greater if attention is diverted from the price attribute for alternative medications. Health insurance companies may have the greatest incentives to understand the price elasticity of demand for different drugs or medical treatments. With the implementation of the Affordable Care Act (Obamacare) in the U.S., we may see an increase in the demand for reliable WTP information to assess public policy with respect to payments for different types of medical treatments.

### **3.2.3 Different definitions of "value"**

In much of the health economics literature, "values" are commonly denominated in terms of equivalent time in full health, rather than dollars. Environmental economists just need to get used to the idea that the notion of health "valuation" in the health economics literature has a different meaning than health "valuation" in environmental economics. Semantically, what

environmental economists consider to be “valuation” is often referred to as “monetization” in health economics.<sup>10</sup>

To environmental economists accustomed to benefit-cost analysis, it can be difficult to understand why many health economists so diligently avoid “monetization” of health states. In some cases, this is due to an ethical aversion to monetizing health, perhaps an artifact of a deontological perspective. People may be willing to give up money for improvements in their own health, but unwilling to accept money in exchange for decreases in their own health (or we may be unwilling to invite them to do so). At issue is sometimes the Kaldor-Hicks compensation step required for true Pareto improvements. Compensation is possible with money. However, it may be impossible or inappropriate with health, since ex post interpersonal transfers of health are not feasible.

There may also be an argument that everyone is, in principle, endowed with an equal amount of time, but not an equal income, so time might be a more equitable numeraire. Finally, budgets for treatment may be viewed as essentially exogenous. The only role of decision-makers in health-oriented contexts may be to allocate a fixed healthcare budget across competing treatments, perhaps provided at no individual expense to patients. Then the size of the budget is not an issue and neither are the opportunity costs of its use for healthcare as opposed to other good things. Thus cost-effectiveness in terms of QALYs, rather than the broader maximization of net social benefits, is an adequate criterion.

It is not clear whether all healthcare *practitioners* naturally reject WTP assessments, however. In a study about treatment of ovarian cancer, for example, Longo (1999) reports on an interesting comparison of pharmacoeconomic cost-utility (CU) analysis and a willingness-to-pay approach. He reports that two of the pharmacy managers in his study “...understood, and preferred, the CU data. The others, who had no education or training on CU principles, preferred the WTP data. All managers understood the outputs from WTP studies.”

For benefit-cost analysis of proposed policies in environmental economics, measurement of the benefits from prospective morbidity reductions requires conversion of the expected

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<sup>10</sup> The spectrum of value measures is documented by the journal *Value in Health*, published since 1998 by the International Society for Pharmacoeconomics and Outcomes Research and indexed by Web of Science since 2002. This journal specifically encourages submissions of papers “on the development and use of various types of instruments to express the value of health care, including health ‘utility’ assessments, discrete choice experiments/conjoint analyses and assessments of individuals’ willingness-to-pay.” A Web of Science search for 2012, however, reveals 3,809 indexed items for Value in Health in that year, but only nineteen of these remain when one limits the search to items that mention “willingness to pay” or “WTP.”

reductions in *physical* symptoms into a monetized compensating or equivalent variation in terms of other goods and services (other consumption, or net income). These other goods and services are typically measured at current prices in terms of the amount of income an individual would be willing to swap for a reduction in a portfolio of symptoms associated with a given illness. While monetization may be distasteful to some people, it is undeniable that people regularly demonstrate a willingness to forgo other consumption to improve their odds of avoiding ill health. WTP (rather than willingness to accept compensation, WTA) is of course the preferred approach to monetization when the proposed policy will compel people (taxpayers, workers, investors, and/or consumers) to bear the costs of implementing an environmental policy that will protect health.

### **3.2.4 Atheoretic morbidity valuation: acceptable cost per QALY**

In cost-effectiveness analysis, medical treatments are often ranked in terms of their costs per QALY. The question of acceptable levels of cost per QALY (for broader social decision-making purposes) has been addressed by researchers who have explored the possibility of measuring “WTP for a QALY.” King et al. (2005) ask subjects, directly, to identify the most they would be willing to pay to purchase a cure for all of their current health problems and symptoms with a single payment. They use a variety of measures to calculate the number of QALYs being purchased. However, the preferences embodied in the QALY-calculating process are independent from the preferences underlying the WTP portion of the model, rather than being estimated simultaneously. This literature is also burdened by an inclination to assume that WTP/QALY should be constant, but there is no a priori reason to expect that WTP per QALY should be constant, even if the marginal utility from an additional QALY unit is constant by construction. If nothing else, the marginal utility of an additional unit of net income will change with the level of income and can differ dramatically across people, rendering WTP/QALY nonconstant.<sup>11</sup>

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<sup>11</sup> Gyrd-Hansen and Kjaer (2012) provide a more-recent take on the notion of WTP for a QALY. They point out that WTP measures normalize the utility of a health state on the marginal utility of income, whereas QALY measures normalize on the marginal utility of time in full health as the numeraire (if a TTO method is used), and on the marginal utility of the risk of death (if an SG method is used). Thus a constant WTP/QALY would require that the two marginal utilities forming the numeraires in each case would have to be linearly related.

### 3.3 Utility-theoretic WTP in “illness *attribute* space”: illness profiles

The extensive efforts in health economics to reduce heterogeneous illnesses from near-infinite-dimensional illness space to a much smaller-dimensional illness attribute space points the way to a potentially valuable line of inquiry for environmental economists. Now that we have explored the problem of WTP for an array of specific individual illnesses that may be caused by poor environmental quality, it may be time to think more carefully about decontextualizing our WTP estimates to make our empirical findings more broadly applicable to a wide variety of illnesses, provided these illnesses can be captured by a smaller set of illness attributes.

DCEs have gained ground in the health economics literature as a more theoretically justified approach to converting heterogeneous health states into a continuous univariate (utility) scale. But this body of research is less helpful to environmental benefit-cost analysis than it could be, because health-economics DCEs eschew using net income or cost as one attribute of the alternatives between which respondents are asked to choose. This omission is supremely frustrating for environmental economists who must attempt benefit-cost analyses. Without a conforming estimate of the marginal utility of net income, it is simply not possible to monetize differences in health status by calculating the marginal rate of substitution between health status and money that yields the appropriate measure of WTP. **Without WTP measures, we cannot pursue *efficient* allocations of society’s resources available for health-risk reductions, and allocative inefficiency can lead to lost opportunities to raise overall social well-being.**<sup>12</sup>

Even in CEA applications, however, omission of net income in a DCE imposes an implicit assumption of separability in preferences over income and health states. Hugonnier et al. (2013) remind us that in the absence of encompassing models, separability between health models and financial models cannot be verified and thus cannot be taken for granted. In rigorously utility-theoretic specifications with stated-preference discrete-choice data where it is possible to estimate WTP, one major concern is that morbidity and co-morbidity can affect the marginal utility of “other consumption,” as measured by net income.<sup>13</sup>

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<sup>12</sup> Income does make a brief appearance when Pickard et al. (2013) compare TTO scores across individuals who suffer from six different chronic conditions. They include four income categories among the controls in their atheoretic TTO regressions. Intriguingly, the indicator for income of “\$75,000 or more” bears an individually statistically significant coefficient as a determinant of people’s TTOs, but there is no discussion of this finding in the paper itself, and this study does not invoke a random-utility type of estimating specification.

<sup>13</sup> In unpublished work, DeShazo and Cameron (2005) find that current same-illness morbidity and other-illness co-morbidity have statistically significant effects on the marginal utility of other consumption, and same-illness morbidity increases the disutility of a discounted lost life-year. The individual’s subjective risks of prospectively

In an extensive project spanning the last decade, summarized in Cameron and DeShazo (2013) and related papers, we have sought to reconceptualize morbidity-related conjoint choice scenarios posed to respondents in an effort to reflect better the types of health risks relevant for environmental policymaking. Our choice scenarios offer respondents the opportunity to purchase an intervention that will reduce their chance of suffering a *future profile* of illness. Each choice scenario describes two different interventions, each of which reduces the individual's *risk* of suffering a specified illness or injury with a particular time profile at a specified annual *cost*, plus a status quo (no-purchase) alternative that involves no risk reduction and no cost. Each targeted health threat is described in terms of the individual's likely age at onset, the duration of the illness (if any), time spent in remission (if any), and the individual's age at death in relation to the life expectancy that they would enjoy if they did not contract this illness. In addition to this specific time profile for the illness in question, the health threat is further described by a name of the illness, as well as the nature of the treatments (hospitalization, surgery) and the mix of time spent with moderate or severe pain/disability.<sup>14</sup>

In this research, it would perhaps have been ideal to describe each illness in terms of one of the usual lists of illness attributes, such as the EQ-5D or one of the other alternatives. However, it is necessary in these choice sets to accommodate many more attributes than just those that describe the nature of an illness in the usual QALY framework.<sup>15</sup> The most important attributes to be considered in this study concern (1) the cost of the risk reduction, (2) the size of the risk reduction that the intervention would provide, and (3) the time profile of the illness being targeted. Crucially, and in contrast to QALY-type research, the time profile for each illness includes a latency period, before any symptoms would appear. There is a spell of illness (unless the illness is "sudden death"), but each profile can also potentially include a spell of recovery/remission (for non-fatal morbidity) and perhaps a spell of lost life-years if the affliction leads to premature mortality. Given these required attributes (i.e. cost, risk reduction, and the

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developing the same illness and other illnesses tend to affect the marginal disutility of sick-years and lost life-years, but not the marginal utility of net income.

<sup>14</sup> Our use of illness profiles was inspired, in part, by an unpublished paper by van Houtven and Smith (1998), designed to measure WTP to avoid the infertility consequences of endocrine disruptors using a stated-preference survey experimented with time profiles of infertility risk. Survey respondents were shown infertility risk age/time profiles without and with an intervention. Unfortunately, test subjects' difficulties with graphical material led us to forsake graphical illness profiles and substitute verbal descriptions.

<sup>15</sup> Discrete choice experiments must not overly tax the cognitive capacity of research subjects, so the number of attributes in a choice set cannot be so large as to force respondents to resort to simplifying heuristics. See Cameron and DeShazo (2010)

partitioning of the individual's nominal remaining life into four distinct time spells of different durations), we already had six attributes associated with each alternative. Thus we had to be stingy in our characterization of health status during each one of these spells.<sup>16</sup>

The fact that each respondent is *not* currently suffering from each of the health threats in question means that there is a *risk* of this illness whether or not the individual chooses the costly risk-reducing intervention. Our scenarios abstract from reality by assuming that the intervention does not change the severity or duration of the illness, should the individual get sick. Instead, the intervention merely changes the *probability* of experiencing the identical illness profile.<sup>17</sup>

Our choice sets were designed with random combinations of illness attributes, risk reductions, and costs. Formal blocked experimental designs are impractical because the range of eligible illness profiles that can be offered to a given respondent is dictated by that individual's gender and current age. We acquire age and gender information for each subject in advance of the survey and generate five choice sets for each person, excluding only those combinations of illness names and profiles that are clearly implausible, such as sudden death from diabetes, or recovery from Alzheimers. The mix of attributes for each alternative is therefore orthogonal to everything except the individual's age and gender. Given that illness profiles are determined by the respondent's current age, however, we are careful to control extensively for age heterogeneity in the marginal utility parameters we estimate.

The random assignment of risks, costs, and illness profiles and attributes means that we can be confident that omitted variables bias is minimized in models that do not include all possible attributes of each illness profile. In Cameron and DeShazo (2013), for example, we do not control for the names of the illnesses. In a separate manuscript, Cameron et al. (2010b), we generalize to allow the marginal (dis)utilities of sick-time, recovered time and lost life-years to vary systematically with the label assigned to the illness.

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<sup>16</sup> We could not accommodate a full set of EQ-5D-type attributes, but the individual's health status during their time in each spell is implied by the name of the illness as well the minimal characterization of symptoms and treatments. The nature of the recovered/remission state is also revealed by our analysis to be viewed as worse than the pre-illness status quo health state.

<sup>17</sup> Choice scenarios including different time profiles, or different symptoms and treatments, for the illness in question (with and without the risk-reducing intervention) would have necessitated roughly twice as many descriptive attributes, which we judged would exceed the cognitive capacity of too many respondents. Ways to describe changes the expected *time profiles* of illness as a result of risk reductions await future research.

## 4. Directions for future research

Decontextualized WTP estimates for illnesses described in terms of generic attributes will allow us to “fill in the blanks” in the menu of morbidity benefits estimates when there is no existing study that provides estimates of WTP for a given specific environmental illness. There will still be occasional needs, of course, for in-depth studies of specific illnesses, rather than mere benefits-function transfers. However, models that encompass a wide variety of illnesses are also necessary to permit us to *test* whether WTP amounts differ by type of illness. This cannot be established from independent analyses for different illnesses.

### 4.1 WTP as a function of *expected* morbidity attributes

For benefit-cost analysis of proposed environmental policies, useful measures of the value of morbidity risk reductions should be derived *prospectively*. We need to understand what types of costs different groups in society are willing to incur, *ex ante*, to reduce the risk of future illness. But this raises the question of the extent to which anticipated disutility may fail to match *ex post* disutility among people who are currently experiencing the illnesses in question. When people are misinformed about a key determinant of their demand for something, there is sometimes a “libertarian paternalism” argument for giving them what they would prefer if they knew the facts, rather than going along with their preferences despite their misinformation (Thaler and Sunstein (2003)).

Collective willingness to pay for prospective environmental health risk reductions will hinge on heterogeneous subjective (as opposed to objective) risk magnitudes and the degree of individual risk aversion across the exposed population. Perception of small risks is difficult to model. WTP will also depend on heterogeneous subjective perceptions of the likely latency of the health problem (as opposed to objective scientific estimates) and variations in individual time preferences or discount rates across this population. Potential victims will rely on their own accumulated knowledge about a particular illness (perhaps among family members or acquaintances) to infer the expected time profile of symptoms and effects on life expectancy, as well as the likely variance in time profiles for the illness in question.

## 4.2 Choice scenarios that mimic environmental policy choices

Despite the econometric sophistication of state-of-the-art DCE studies in health economics, such as Norman (2012), the data collected in these studies are not really adequate for the problem of valuing morbidity reductions from environmental protection. For example:

1. The hypothetical choice scenario includes no plausible intervention that involves private *costs*, as would be the case with an environmental policy (net income is implicitly the same across alternatives);
2. Respondents are given no information on the baseline *risk* of experiencing each health state, and the intervention does not involve a specific risk reduction;
3. The adverse health states are to be experienced by the individual him- or herself for the specified period of time, but no *latency* period before the onset of symptoms is specified, so these health states are not plausible future possibilities, merely hypothetical current health states;
4. The adverse health states should not all be fatal illnesses, since chronic non-fatal illnesses are also relevant to environmental policy choices;
5. The status quo is not included as an option; there is simply a “forced choice” between two adverse health states and immediate death.

The decision context for which QALY measures are derived typically concerns decisions that need to be made to allocate healthcare resources among people who are already sick. This means that there is no reason to consider the *risk* of acquiring the illness possibly at some time in the distant future, since the probability of illness is 100% for each case in question. With respect to uncertainty in the QALY literature, the standard gamble (SG) approach involves uncertainty about whether the treatment will restore the individual to full health or kill them, but there is no uncertainty about whether the individual will suffer the illness for which the treatment is being considered. Thus risk preferences are not part of the landscape in the health economics setting in the same way they enter into the environmental economics health-risk reduction setting. There is also no reason to worry about disease latency in most QALY scenarios, for example, since each case is someone who is either actually or hypothetically sick now. This means that our understanding of individual time preferences may be much less crucial in the health economics cost-effectiveness context than in the environmental benefit-cost context. Time preferences with respect to future health and future income remain an important area for research.

It is likely to be difficult to divorce a given morbidity reduction benefit from the other features of an environmental policy that is designed to deliver these benefits. The distributional consequences of any realistic policy will influence people's willingness to pay for that policy, so that it may be difficult to isolate a de-contextualized value for environmental morbidity reductions that is transferable across policies. In Cai et al. (2010), for example, we find that differences in the respondent's understanding of who would benefit from an environmental policy, as well as differences in the respondent's understanding of how the costs would be borne, produced sizeable differences in WTP for the environmental intervention.

## **4.2 Reduced morbidity as a public good**

Most research concerning the value of mortality risk reductions emphasizes individuals' willingness to pay to reduce their own personal mortality risks. However, environmental policy typically involves risk reductions in the form of public goods, rather than private goods. These public goods are often created by unfunded mandates (regulations), where there is sometimes relatively little overlap between the beneficiaries of the policy and those who will be called upon to pay its costs.

In the presence of impure altruism, environmental policy must also consider people's willingness to forgo other consumption to reduce the risk of morbidity, or to prevent the exacerbation of morbidity, for other people, not just themselves. In a generic healthcare context, Bosworth et al. (2009) use discrete choice stated preference experiments to consider public health policies to *prevent* illnesses and avoid premature deaths. WTP for publicly funded *treatment* policies that benefit other people is considered in Hurley and Mentzakis (2013) and Bosworth et al. (2013). Hurley and Mentzakis consider hypothetical charitable contributions (WTP) for treatments of individuals who vary in their relatedness to the respondent, the communicability of their condition, their location, the severity of their condition, the medical necessity of the treatment, but the specific type of illness is unfortunately not part of the choice scenarios. Bosworth et al. quantify the benefits in terms of increased recoveries and avoided premature deaths from randomly designated types of illness stemming from randomly designated causes. WTP varies by type of illness and the affected population (including the characteristics of the beneficiaries). WTP also varies hugely by the respondent's subjective self-interest in the

treatment in question and depends on individual discount rates and the time commitment represented by the policy option.

### **4.3 Specialized WTP estimates for vulnerable populations**

Environmental economists have long struggled with the question of how to estimate the value of reductions in morbidity risks experienced by children, especially since most children do not themselves directly choose between health risk reductions and other consumption. These decisions are made for them by parents or guardians when private choices are involved. How should this complication be reflected in social decision-making with respect to children's morbidity risks? If these morbidity risk reductions are public goods, how do we feel about achieving morbidity risk reductions through prevention versus treatment?

Related questions may concern private choices about morbidity risks by people who are already sick with other illnesses. Are people more or less willing to pay for incremental morbidity risk reductions if they are already, themselves, experiencing prior morbidity from the same or other causes? What about WTP for morbidity risk reductions for other people who are already sick, through the provision of health risk reductions as public goods, when paternalistic altruism may be part of the story?

### **4.4 State of the art methods in design and analysis**

Certainly, as DCEs are used to adapt QALY-type research to new contexts that are more relevant to nonmarket valuation of morbidity reductions due to environmental policies, researchers will need to be attentive to the evolving consensus about best practices. Resources are available to bring new researchers up to speed quickly in several relevant areas, such as the checklist provided by Bridges et al. (2011), the review of good experimental design in Johnson et al. (2013), or the discussion of appropriate analyses to conduct, as in Hauber et al. (in progress, 2013).

## **5. Conclusions**

As has been the case for mortality risks valuation, there is an understandable desire by the policy-making community for one-size-fits-all off-the-shelf estimates of the values of specific types of reduced morbidity risks. The task of benefits estimation would be far simpler if health risk reduction benefits were strictly proportional to the size of the risk reduction and if the

benefit from a given-sized risk reduction was independent of the attributes of the risk and the characteristics of the affected populations. We know that WTP to reduce *mortality* risks, for example, can differ systematically with a subject's age, income, current health status, health expectations, and the type, latency, and prognosis associated with the health risk. It is likely that WTP to reduce *morbidity* risks is likewise systematically heterogeneous. WTP to reduce morbidity risks will likely vary as well with an individual's past experience with the ailment in question (among family members or acquaintances) and with the individual's subjective risk of that illness, based on family history and their own health habits relative to what they understand about best practices to minimize risk. Heterogeneous preferences must certainly be acknowledged.

For environmental regulations, it would be nice to have a formula that will produce a single WTP amount for reductions in the risks of each of a long list of illnesses such as lung cancer, bronchitis, asthma, bladder cancer, skin cancer, heart disease, and so on. It would be nice if the cause of each type illness risk was irrelevant. Then the same illness when resulting from non-environmental causes would produce the same WTP for avoidance as for each illness that science tells us can be caused (or exacerbated) by air pollution, water pollution, soil contamination, damage to the ozone layer, or climate change.

This desire for decontextualized benefits estimates certainly accounts for the appeal of QALY-type methods for environmental morbidity valuation. For environmental benefit-cost analysis, however, more attention needs to be paid to baseline risks and risk reductions, and to time profiles of future health states, since environmental policies tend merely to reduce the *probability* of illness at some time in the future. Individual risk preferences, time preferences, and faith in future of medical ingenuity will come into play for morbidity risks that have long or variable latencies. Other features of environmental policies, such as their distributional consequences (in terms of benefits, or in terms of costs) will also influence people's preferences across policy alternatives.

There is much promise in exploration of decontextualized human morbidity reduction benefits. Early environmental policies were "no-brainers," where even just crude measures of the human mortality reduction benefits were more than adequate to dominate the social costs of the proposed regulations. As we continue to implement more regulations that internalize environmental externalities, however, the marginal costs of regulation will continue to rise and

the marginal benefits will continue to fall. It will become necessary to document more components of these marginal benefits. Unfortunately, we must also remember that environmental policy preferences will involve more considerations than merely their human health effects. There is much left to study if we seek to rely on evidence-based regulation to improve social welfare.

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