Assigning Values to Life: Comparing Methods for Valuing Health Risks. By Fred Kuchler and Elise Golan. Food and Rural Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 784.

Abstract

We examine five approaches economists and health policy analysts have developed for evaluating policy affecting health and safety: cost-of-illness, willingness-to-pay, cost-effectiveness analysis, risk-risk analysis, and health-health analysis. We examine the theoretical basis and empirical application of each approach and investigate the influence that assumptions embedded in each approach have on policy guidance. We reach four principal conclusions. First, the approaches are not interchangeable: they measure different things. Even estimates using the same approach are often not comparable because, in practice, there is little consistency in the application of any of the approaches. Second, the usefulness of each approach depends on the unit of account. The philosophical decision to eschew the monetization of health costs or benefits constrains the ability of the approach to rank policy options and to gauge the social desirability of policy. Third, all of the approaches except risk-risk analysis and one variation of cost-effectiveness analysis incorporate the effects of income and circumstance. As a result, policy guidance could be influenced by the distribution of income. Fourth, the theory and practice of willingness-to-pay estimation are in opposition. While it is now common practice for regulatory agencies to adopt the willingness-to-pay approach for estimating health and safety benefits, they do so by assuming away the importance of individual preferences. We build on these four conclusions to suggest the appropriate use of each approach.

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Executive Summary

The resources to eliminate even a small portion of the hazards to life and health do not exist and policymakers must choose which hazard-control programs to fund. The most efficient use of resources is best gauged by comparing the costs and benefits of potential programs. However, where markets do not exist, or are incomplete, it is difficult to accurately gauge the costs and benefits of program choices. This report examines the major approaches economists and health policy analysts have developed for evaluating the benefits and costs of policy affecting health and safety: cost-of-illness, willingness-to-pay, cost-effectiveness analysis, risk-risk analysis, and health-health analysis.

One of the first problems analysts must confront when deciding how to gauge the costs and benefits of potential policy is what unit of measurement to use: dollars or physical units. The primary advantage of using a dollar scale is that it provides both a measure of net benefits and a complete ranking of expenditure alternatives. The philosophical decision to eschew the monetization of health costs or benefits constrains the ability of the approach to rank policy options and to gauge the social desirability of policy. Only the cost-of-illness and willingness-to-pay approaches use dollars to measure both costs and benefits.

Another problem analysts face when measuring the costs and benefits of health and safety intervention is determining what should be counted as a cost. Economists think of costs as consequences of choice and scarcity. Where goods are not scarce (more than what everyone might want) or where alternatives do not exist, choices have no cost. This observation leads to two important conclusions relevant to measuring costs and benefits. First, the range of choices and the perspective of the choicemaker will both have an impact on "cost." Second, "costs" could differ depending on whether they are measured before or after the policy change in question.

The different notions of cost and the various ways in which health and safety benefits and costs can be measured lead to substantial differences among the five major approaches. As a result, the approaches are not interchangeable and there are circumstances where one would be more appropriate than another.

The *cost-of-illness* (COI) approach tallies the dollars spent on medical expenses and the dollars of employment compensation that are forgone as a result of illnesses, accidents, or premature deaths. COI estimates frequently have served as a measure of the monetized benefits of government programs that promote health and reduce the number of premature deaths, illnesses, or injuries (the value of program benefits are the costs that are not incurred). Evaluation:

● Its theoretical legitimacy hinges on the assumption that national income is a valid measure of societal welfare. Many economists have challenged this assumption and most reject national income as a welfare measure.

● It equates the value of a life with forgone wages. Thus, higher paid members of society will be assigned higher values of life.

● It is not always a good measure of disease severity. Cost-of-illness estimates are influenced by a number of factors other than disease severity, including the current distribution of income, education, and employment skills, technological constraints to disease treatment, sick-leave policies, and health insurance systems (both private and public). As a result, cost-of-illness estimates often move in the opposite direction from disease severity measures.

● It is often characterized as the most practical of the valuation methods: data on direct medical cost and human capital costs are seemingly easy to collect. However, direct medical expenses are often difficult to assess accurately because of the intricacies of insurance arrangements; and human capital costs are equally difficult to ascertain because of the various forms of compensation that are available to employees.

● It is not a reliable lower bound estimate of willingness to pay.

● Despite its weakness as a measure of welfare or disease severity, it does provide a measure of the economic impact of illness. It provides an accounting of the dollars spent on medical expenses and the wage dollars that are forgone as a result of illness or premature death. Such an accounting is useful to economists and policymakers interested in gauging the magnitude of the economic flows resulting from government programs that improve public health.

The **willingness-to-pay** (WTP) approach measures the resources individuals are willing and able to give up for a reduction in the probability of encountering a hazard that will compromise their health. It assigns dollar values to life and health. Evaluation:

● It reflects individual preferences for risk reduction where the demand for risk reduction is derived from *ex ante*, or expected health benefits. These quantities exist only *ex ante*, at the moment of choice. They are not equivalent to realized damages.

● It reflects the observation that individual preferences are unique and individual demands for risk reduction vary. However, because health and safety are normal goods, some of the variance in willingness-to-pay estimates will be explained by income differences rather than preferences. So, just as in cost-of-illness analysis, income and circumstance could play a role in determining the size of willingness-to-pay estimates. When benefits are calculated as willingness-to-pay, policies may be guided away from programs that save poorer lives and toward programs that save more affluent lives.

● With WTP, individual preferences are aggregated and the Kaldor-Hicks potential compensation criterion is used to determine the social desirability of proposed policy. This approach entails an efficiency-first, equity-second rationale. The Kaldor-Hicks criterion has been criticized on the grounds that as long as compensation remains potential, social welfare is not maximized.

This criticism could be particularly serious in the case of policy concerning mortality. If efficient policy results in deaths, equity cannot be redressed through *ex post* redistribution schemes: it is impossible to redistribute between those who are alive and those who are dead.

● Empirical estimates of it have proved sensitive to the characteristics of the study population, the level of risk, and the type of risk. Willingness-to-pay results from one study are therefore not necessarily applicable across studies. Nevertheless, in practice, regulatory agencies that have adopted the willingness-to-pay approach have generally adopted a single value for lives saved where the value has been derived from compensating wage studies. Agencies apply their selected value to every health risk, regardless of the population likely to receive program benefits, the type of risk that might be mitigated, or the level of risk mitigated.

● Its valuations represent a consistent and faithful application of the principles of applied welfare economics. WTP measures provide the best estimate of individual welfare available to economists. While there is little reason to challenge WTP from a theoretical perspective, estimation raises practical problems because it depends on individual and idiosyncratic utility functions. With additional studies analysts may be able to estimate the demand for risk reduction throughout the population for a variety of different risks.

When analysts use ***cost-effectiveness analysis*** they attempt to measure benefits without assigning dollar values to life and health. Cost-effectiveness analysis is a comparison of costs with the number of physical benefits. The ratio of dollar costs to physical benefits is the cost per physical benefit. The program with the lowest cost per benefit is the most cost-effective. Evaluation:

● When analysts know anything about preferences for risk reduction and about the distribution of health and safety program benefits, rankings derived from cost-effectiveness analysis are likely to diverge from those derived from the willingness-to-pay approach.

● As it measures costs and benefits in different units of account, it is not intended to yield a net benefits estimate. Thus, the measures do not show whether any program is worthwhile. It is up to the decisionmaker to decide whether any program is worth the price.

● Only programs with identical health outcomes can be ranked using cost-effectiveness estimates.

● Results usually cannot be compared across cost-effectiveness studies as three distinct types of calculations are called "cost-effectiveness." Each type of calculation satisfies different goals. Two variants of cost-effectiveness analysis are subject to the influence of income and circumstance. Policy guidance in these variations will be influenced in the same way as it is with cost-of-illness and willingness-to-pay.

● Cost-effectiveness analysis may help minimize costs when an irrevocable decision has been made to take an action, but no decision has been made about technique or method.

● Of the three variants of cost-effectiveness analysis in common use, the simplest, the ratio of program costs to a count of health benefits, may be the most useful (this is the variant that is not influenced by income). This variant of cost effectiveness may serve as a coarse filter, helping to screen out programs that more complex analyses would also show are not worthwhile. However, this use of cost-effectiveness has no theoretical appeal. It is not an individual welfare measure and does not fully account for costs avoided by programs.

With risk-risk analysis and health-health analysis, analysts compare program costs and benefits without monetizing either benefits or costs. A *risk-risk analysis* enumerates the risks that are reduced and risks that are inadvertently increased by government health and safety policy. Both the desirable and undesirable risk changes are denominated in physical terms, though each could be denominated in different physical units. Evaluation:

● Estimates of benefits and costs are not influenced by resource scarcity and net benefits are not calculated. As a result, risk-risk analysis does not distinguish between expensive programs that offer few benefits and programs that dramatically reduce health risks at little expense. It is up to the decision-maker to decide whether the benefits are worth the costs.

● It can only rank programs for which benefit and costs are measured in the same physical units.

● Risk-risk analysis is most useful in cases of all-or-nothing decisions. That is, only one program is offered and the decisionmaker must decide either to go forward with the program or to accept the status quo. When there are more options, risk-risk analysis shifts most of the burden of analysis to the decisionmaker.

Health-health analysis evaluates policies by comparing a count of deaths prevented with a count of deaths induced by transferring income from individuals to the government in order to finance government health and safety programs. This approach is built on two observations. First, risk reduction is a normal good, purchases of which increase with increasing income and decline when income falls. Second, government programs, even those that directly serve public health, have to be financed. Money for those programs has to come from individuals, and, thus paying for programs reduces individuals' ability to purchase risk reduction privately. Evaluation:

● It tallies benefits and costs in the same unit of account (lives), meaning that analysts can rank programs and calculate net benefits.

● Because income and mortality rates vary inversely, income effects in health-health analysis have an influence opposite to that of cost-of-illness or willingness-to-pay. Policies are guided toward programs that save poorer lives and away from those that save more affluent lives.

● It is restricted in its usefulness because it is applicable only to policy influencing mortality, not morbidity.

● Health-health analysis is an appropriate technique for comparing costs and benefits when analysts want to highlight both policy efficiency (net benefits) and the distribution of health (the extent to which one subpopulation might benefit at the expense of another). However, until the relationships between income and morbidity are better understood, health-health analysis can address questions only where benefits are denominated in the number of lives saved. Further, because analysts who use health-health analysis must translate dollars (income) into health, it may be easier to simply use standard cost-benefit analysis.

Assigning Values to Life

Comparing Methods
for Valuing Health Risks

Fred Kuchler and Elise Golan

Introduction

Foodborne disease caused by microbial pathogens in food is a serious public health problem in the United States. Each year there are between 6 and 33 million cases of disease caused by pathogens such as *E. coli* O157:H7 and *Salmonella*, and as many as 9,000 people may die from these illnesses. Recent highly publicized outbreaks of foodborne illness and recalls of potentially contaminated foods have raised public concern, and have led the Federal Government to undertake a number of programs to reduce the risk to public health from microbial pathogens in the food supply. The key issue from an economic perspective is how to measure the potential benefits and costs of efforts to reduce human health risk.

In this report, we examine five approaches that have been developed by economists and health policy analysts for evaluating policy affecting health and safety: cost-of-illness, willingness-to-pay, cost-effectiveness analysis, risk-risk analysis, and health-health analysis. Our goals are to determine exactly what analysts measure when they use each approach, determine the appropriate use for each approach, and most important, examine the influence that specific assumptions embedded in the various approaches have on policy recommendations. We consider a number of questions during our investigation.

● Whose costs and benefits are we measuring? Whose goals are we trying to satisfy?

● How is the problem of resource scarcity reflected in calculations? Can we rank programs? Can we calculate net benefits, determining whether any program is worthwhile?

● Is it feasible to measure what we intend to measure?

The answers to these questions help to reveal the strengths and weaknesses of the five approaches. They reveal the type of information that each approach provides to policymakers.

In the first section, "Why Must Costs and Benefits Influence Health and Safety Choices?" we discuss the importance of using consistent measures of costs and benefits in evaluating government policies to reduce health and safety risks. We argue that if government policy were guided by consistent comparisons of program costs and benefits, health benefits would be larger and costs would be smaller. In "How Do We Measure Costs and Benefits for Health and Safety Intervention? An Introduction to the Methodologies," we present a brief description of the various ways costs and benefits might be compared. We list and describe the basic attributes of different methods, depending on whether health and safety benefits are assigned dollar values. In "Cost-of-Illness Approach," we describe the cost-of-illness method for assigning value. In "Willingness-to-Pay

Approach," we describe the willingness-to-pay method and compare the various methods for estimating willingness-to-pay. In "COI and WTP—Is There a Middle Ground?" we compare the cost-of-illness and willingness-to-pay methods and examine the common assumption that cost-of-illness estimates are a lower bound to willingness-to-pay estimates. In "Refraining from Assigning Values to Life and Health: Cost-Effectiveness Analysis," we discuss cost-effectiveness analysis and show the limitations to using analyses that fail to monetize health benefits. Surprisingly, in many cases this method does require assigning values to life and health and those values are exactly equal to forgone income. In "Eliminating Dollars from Cost-Benefit Comparisons—Risk-Risk and Health-Health Analysis," we show which of the desirable characteristics of conventional cost-benefit analysis can be maintained when neither costs nor benefits are monetized.

Why Must Costs and Benefits Influence Health and Safety Choices?

It is impossible to protect everyone from every threat to their health and safety. The resources to eliminate even a small portion of all hazards do not exist. Viscusi (1996) states:

> The need for economic balancing is inevitable in a world of constrained resources. Suppose that we were to devote the entire U.S. gross domestic product to the prevention of fatal accidents. Even then, we would be only able to spend $55 million per fatality...That expenditure would leave literally nothing for other goods, such as other risks or environmental pollution, let alone basics like food, housing and medical care. (p. 120)

The physical inability to eliminate all hazards means that some hazards will never be eliminated and some risks will always persist. There is no way to avoid choosing to mitigate some hazards and choosing to accept the risks of all others. How should society select which hazards to control?

Many Federal decisions regarding health and safety are made on the basis of risk standards. Regulatory agencies must take action to reduce any risk exceeding standards.[1] Under risk standards, decisionmakers (the regulatory agencies) cannot discriminate on the basis of cost among risks they might address. Hazards that are very expensive to rectify are accorded the same priority as those that are less expensive. If regulators were allowed to consider cost, they might make somewhat different choices and a larger number of deaths, illnesses, or injuries might be prevented at lesser cost.

Viscusi and Hamilton (1996) claimed that much of the resources of government agencies charged with

protecting public health is used to reduce small risks at great expense while more substantial and more easily mitigated risks persist. They characterized this outcome as a "90:10 phenomenon." Namely, society spends 90 percent of its resources to achieve the last 10 percent of risk-reduction benefits. When the 90:10 phenomenon characterizes the outcome of risk mitigation choices, more deaths, illnesses, and injuries are likely than when expenditures all produce similar risk reductions. The 90:10 phenomenon is an outcome entirely consistent with decision making based on risk standards.

To illustrate the 90:10 phenomenon, Viscusi and Hamilton examined the cost of cleaning Superfund toxic waste sites and the likely number of cancers prevented by doing so.[2] They found that cost per cancer avoided was "staggering" (p. 58). At only one site the cost per cancer avoided was $5 million or less. At six sites, the cost ranged from $5 million to $100 million per cancer avoided. At 18 sites, the cost ranged from $100 million to $1 billion. At two sites, no cancers were prevented, and costs were therefore infinite. Most (67 sites) fell into the range Viscusi and Hamilton denoted as over $1 billion.

An earlier and more encyclopedic view of health and safety interventions (Morrall, 1986) showed that the variance of cost per life saved for health and safety regulations is large. The National Highway Traffic Safety Administration's 1967 rule on steering column protection was estimated to save 1,300 lives annually at a cost of $100 per life saved. At the other end of the scale, the Occupational Health and Safety Administration's 1985 formaldehyde regulation was estimated to save 0.010 life annually at a cost of $72 billion per life saved, in 1984 dollars. The upper end of the distribution has not gone away. Many small risks now can be mitigated only with enormous expenditures. (See, for example, updated information

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[1] For example, the three Delaney Clauses in the Federal Food, Drug, and Cosmetic Act all require zero risk by demanding zero exposure to carcinogens. The Food Quality Protection Act of 1996 eliminated the applicability of the Delaney Clause to pesticides, instead requiring that risk levels be so small they can be considered negligible. Of course, standards can be set at any level of risk.

[2] EPA's Superfund risk assessments are based on extremely conservative assumptions, and do not reveal what likely risks are. See Lichtenberg (1991) for a discussion of the relation between likely risks and conservatively estimated risks.

in Lutter and Morrall (1994) in Viscusi (1996), and in Tengs et al. (1995).) The tabulation by Tengs et al. shows that the upper end of the distribution has extended in recent years. The cost per life saved varied over 11 orders of magnitude among government interventions.

When the public sector controls risks where the cost per life saved is denominated in hundreds of billions of dollars, there may not be resources available to address a risk that can be controlled at a lower (more cost-effective) price. The practical importance of failing to address the relatively large risks that can be controlled at relatively modest expense is that regulatory compliance costs (which operate like any other production cost) or government expenditures (financed through taxes) may be many orders of magnitude higher than they would be for a different bundle of regulations and the same overall level of risk reduction. In a follow-up study, Tengs and Graham (1996) showed that with some simple rules for allocating costs among life-saving interventions (expanding those that are most cost-effective and contracting others), the number of lives saved could be more than double the current number. Alternatively, the current number of lives saved could be maintained at a savings of $31 billion per year, in 1993 dollars.[3]

Tengs and Graham based their calculations on a decision rule that prevents as many deaths as resources permit. In effect, their rule selects hazards to mitigate by comparing costs and benefits (cost-benefit analysis) and choosing to finance those programs that maximize benefits net of costs (net benefits). This decision rule overcomes the problems inherent in decision making based on risk standards. As a practical matter, their decision rule first selects those hazards that are both relatively risky for many people and inexpensive to fix. Last on the list of corrective actions would be those hazards that pose small risks for few individuals and are relatively expensive to

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[3] Tengs and Graham noted that the Federal government is not completely flexible in its allocation of life-saving resources. They experimented with a variety of constraints on allocations among programs. With constraints, their measure of the opportunity cost of the current allocation was reduced. Their conclusion that the current allocation could be improved was not overturned by adding such constraints.

correct. The goal of protecting as many lives as resources allow can be met only by comparing costs and benefits (cost-benefit analysis), and guiding the selection of hazards to mitigate with that information.

Health and Cost-Benefit Analysis

In competitive markets, prices lead to an efficient allocation of resources and there is no efficiency argument for government intervention and therefore no need for cost-benefit analysis. In these markets, producers maximize profits by setting price equal to marginal cost, and consumers maximize utility by purchasing goods to the point where marginal utility is equal to price. This condition is duplicated for all goods and services so that throughout the economy, the marginal value of production is equal to the marginal cost. In such a system, not only do prices lead to an allocation of resources in which the value of marginal production equals the cost, but they also lead to the maximum societal welfare. If individuals choose consumption to maximize utility and if the welfare of society is the sum of individual welfare, then given correct prices, the bundle of goods actually purchased maximizes societal welfare. Or, as Little (1956) stated:

> Thus the theory of value, or price, and the theory of economic welfare were hand in glove, both being based on the utility theory of consumers' behavior.

When markets do not function correctly, prices do not indicate marginal cost. When markets are absent, there is no price signal at all. In these cases, prices do not lead to an efficient allocation of resources or to maximum societal welfare. Policymakers must find another way to achieve economic efficiency and maximize societal welfare, such as cost-benefit analysis. Chakravarty (1987) explained the need for cost-benefit analysis:

> The whole raison d'être of 'cost-benefit analysis' is the very fact that the world is imperfect and suitable corrections are called for in arriving at a proper estimate of how much net benefit accrues to society as a result of committing resources in a specified direction. (p. 690)

The Federal Office of Management and Budget (1996) lists four conditions under which markets may fail to maximize productive or allocative efficiency and therefore warrant cost-benefit analyses: externalities, natural monopolies, market power, and inadequate or asymmetric information. Cost-benefit practitioners often add public goods (goods that are nonrival in consumption and have high exclusion costs) to the list.

Health and safety fit the criteria for cost-benefit analysis because these commodities are not exchanged for money (see, for example, Fuchs and Zeckhauser, 1987, p. 263). Thus, there are no obvious or recorded prices that might be used to monetize health benefits. In addition, many of the commodities that individuals use to directly influence their own health (including legal medications, illegal drugs, tobacco, and surgery) are largely traded in markets characterized by distortions. For example, health insurance drives a wedge between prices health care buyers pay and prices health care providers receive.

Though markets for health may not exist or prices may fail to reveal the value of health, markets for risky goods exist and frequently result in efficient allocations. In many cases, consumers are aware of the risks associated with consuming goods and services and assume them voluntarily (for example, skiing is not risk free). However, consumers are often unaware of the health risks associated with some goods. In many cases, markets for risky goods are characterized by market failure in the form of asymmetric information or even missing markets. For example, consumers may be unable to distinguish on the basis of price between hamburgers contaminated with *E. coli* O157:H7 and uncontaminated hamburgers. In these cases, consumers cannot gauge the true value of the food, including its health-influencing characteristic. In these kinds of cases, cost-benefit analysis may be needed to design policies to reduce health risks.

Whether benefits and costs guide development of interventions to protect life and health depends on government decisionmakers' ability and willingness to consider such estimates. Formal demands for consideration of costs and benefits in regulatory programs began with President Nixon. Presidents Ford, Carter, Reagan, and Clinton each issued Executive Orders demanding some consideration of costs and benefits in regulatory analyses (Executive Office of the President, 1989, pp. 13-15 and Weidenbaum, 1997). Demands to balance costs and benefits have also come through the Legislative Branch. The Regulatory Flexibility Act (1980), for example, requires special attention to regulatory impacts on small businesses. Another, the Unfunded Mandates Reform Act (1995), requires Federal agencies to assess costs and benefits of regulatory actions that may result in expenditures by State, local, tribal governments, or the private sector of at least $100 million.[4]

Even with political and economic consensus that both costs and benefits ought to guide decisions, finding a consensus on the best measure for costs and benefits is daunting. Paradoxically, while market failure is the condition that makes cost-benefit analysis useful, market failure also makes cost-benefit analysis difficult to do. Layard and Glaister (1994, p. 3) stated:

> . . . the main problem in cost-benefit analysis is to arrive at adequate and consistent valuations where market prices fail in some way.

For policy that has an impact on morbidity or mortality, this task is even more daunting. To use cost-benefit analysis to evaluate policy that influences health, an economic value for life and health must be estimated. As innocuous as this observation appears, it has led to one of the most heated debates in economic theory. How can an economic value for life and health be contemplated when these possessions are invaluable? What unit should be used to measure the value of life and health?

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[4] Conversely, Federal decisions are often legally constrained to ignore costs or benefits. Van Houtven and Cropper (1996) note that ambient standard-setting cannot take costs into account under the 1970 Clean Air Act and benefits cannot be considered in effluent standards under the Clean Water Act. Despite these legal constraints, Van Houtven and Cropper showed that costs have exercised a small, but consistent, influence on health and safety intervention decisions. Statistical analysis of EPA decisions, both under laws mandating consideration of costs and benefits and under the 1970 Clean Air Act, showed that, on average, decisions were influenced by costs and benefits. After a legal decision stating that EPA improperly considered costs in emission standards for hazardous air pollutants, EPA greatly reduced (but did not eliminate) the influence of cost on its decisions.

How Do We Measure Costs and Benefits
for Health and Safety Interventions?
An Introduction to the Methodologies

What Unit of Measurement Should Be Used?

The first decision that health-policy analysts must make when measuring the costs and benefits of health and safety intervention is the unit of measurement to use. In conventional cost-benefit analyses, such as those that use willingness-to-pay or cost-of-illness estimates, both the costs and benefits of policy are measured in dollars. This means that for health policy analyses, health outcomes must be translated into dollar amounts.

Conventional cost-benefit analysis $\Longrightarrow$
$$\text{\textit{Dollar benefits minus dollar costs}} \qquad (1)$$

Analysis based on a money scale has three major advantages. First, such analysis provides a complete ranking of programs, including programs with diverse outcomes. The diverse outcomes are comparable and therefore can be ranked because costs and benefits are measured in a common unit, i.e., dollars. For example, the costs and benefits of a kidney dialysis machine can be compared with those of a nutrition program. Second, a money scale provides an evaluation of the desirability of each program. For example, if the net benefits (benefits minus costs) of the kidney machine and the nutrition program were negative (regardless of the ranking), neither would be worth the cost. A program is worth the price only if dollar benefits exceed dollar costs. Third, money is already commonly used to rank choices and convey value. It allows us to compare values and make trade-offs among all goods, whether produced in the public or private sector. We can compare the relative value of various public health programs and compare public health programs with alternative ways individuals might spend their money, like consumer goods. We can easily compare the value of programs with the value of goods and labor services that have to be used up carrying out the program.

In spite of money's advantages as a unit of analysis, analysts or policymakers may be uncomfortable with assigning dollar values when benefits are human health and safety. They may not like the idea of assigning a finite value to life and health, and they may not like the idea of using a unit of account that is itself distributed unevenly throughout the population.

Cost-effectiveness analysis is an approach that uses dollars to measure costs. However, it avoids assigning a dollar value to health benefits. Instead, benefits are left in physical terms, namely a count of the adverse health outcomes averted.

Cost-effectiveness analysis $\Longrightarrow$ $\qquad\qquad$ (2)
$$\frac{\textit{Dollar costs}}{\textit{Adverse outcomes averted}}$$

Cost-effectiveness analysis makes programs with identical types of health outcomes comparable and shows which program yields the greatest health benefit per dollar. Cost-effectiveness cannot be used to compare programs with different health outcomes because costs and benefits are measured in different units of account. The costs and benefits of a kidney machine cannot be compared with those of a nutrition program. Despite this restriction, cost-effectiveness analysis has been applied to a wide variety of health interventions. For example, Tengs et al. (1995) calculated the cost effectiveness of over 500 interventions with respect to lives saved. Cost-effectiveness estimates do not, by themselves, indicate whether any policy intervention offers positive net benefits. For example, though cost-effectiveness analysis may be able to rank a kidney dialysis machine and a nutrition program with respect to lives saved, it will not indicate whether either is worth the price.

Another approach to comparing costs and benefits uses a count of health outcomes for both costs and benefits. Health policy analysts have long recognized that many policies designed to lower particular public health risks unintentionally raise other risks (see Lave (1981) for a discussion of risk-risk analysis). For example, treating drinking water with chlorine reduces the incidence of several diseases. But exposure to chlorine raises the risk of cancer. The example indicates risk-risk analysis may yield a count of

desired health outcomes measured in different units than the undesired health outcomes caused by undertaking a health or safety program. Here, benefits would be denominated as numbers of a variety of infectious disease cases. Costs would be a count of induced cancers. With multiple programs, ranking will often not be a straightforward exercise. Calculating net benefits cannot avoid making value judgments about the relative merit of avoiding different types of illnesses.

It is possible to count health outcomes for both program benefits and costs, while maintaining the same unit of account for benefits and costs. A trade-off exists between privately purchased health-risk reductions and publicly purchased health-risk reductions. With any fall in disposable income, individuals lose some of their ability to privately purchase reductions in risk. Thus, because new regulatory compliance costs or taxes required to finance new safety programs reduce individual disposable incomes, they reduce the ability of individuals to protect themselves from health risks. As a result, adverse health outcomes occur. An analyst who knows how the costs of a government program are distributed could forecast the number of adverse health outcomes induced by the program. Lutter and Morrall (1994) argue that analysts can compare a count of the fatalities averted by public sector programs with a count of the fatalities induced by regulatory costs. They call such a comparison health-health analysis.

Health-health analysis $\Rightarrow$
Lives saved minus lives lost (3)

A primary disadvantage of health-health analysis is that it confines the tally of costs to mortality risks. A primary advantage of health-health analysis is that costs and benefits are measured in a common unit: lives. As with conventional cost-benefit analysis, net benefits can be calculated. For example, suppose program A is expected to save 18 lives and program B is expected to save 10 lives. If the two programs cost the same dollar amount, program A is ranked higher in cost-effectiveness. However, health-health analysis yields more information than cost-effectiveness. It can determine that neither is worth the cost of 20 lives (negative net benefits for both programs).

It is interesting to note that analyses of costs and benefits that are denominated in lives convey a different

type of information than those denominated in dollars. The choice of a unit of account reveals which costs and benefits are most important. For example, suppose a health program was estimated to cost $1 million and yield benefits of $5 million. With a benefit-cost ratio of five, the project appears like a good return on Federal expenditures, all else equal. A similar risk-risk ratio is likely to generate less enthusiasm. In discussing the actuarial evidence on the benefits of passenger-side airbags, Graham and Segui-Gomez (1997) state that a 5:1 ratio of deaths averted to deaths induced is unacceptable

> Overall, the best estimates are that for every five lives saved by front-right passenger airbags, a life (usually a child) is lost. We are aware of no precedent in the history of preventive medicine where a mandatory measure was sustained with such a poor ratio of lifesaving benefit to fatal risk.

That a 5:1 ratio of benefits to costs derived from conventional benefit-cost analysis would be viewed differently from a 5:1 ratio of benefits to costs derived from a risk-risk analysis shows that the unit of account does matter. A decisionmaker can rely on an efficiency argument to justify a program with positive dollar net benefits, even if program beneficiaries are different from those who bear the cost. The Graham and Segui-Gomez statement suggests that some are unwilling to make choices when lives are the unit of account. Efficiency arguments could be invoked just as they are when dollars are the unit of account. But calculating net benefits in lives makes distributional consequences obvious. It requires arguing that a life lost in one group can be offset one-for-one by a life saved in another group. The Graham and Segui-Gomez statement indicates that children's lives cannot be exchanged with adult lives, at least not at a rate near one-for-one.

Table 1 classifies the various cost-benefit approaches by unit of account. The choice of a unit of account reveals the philosophical underpinnings of the approach as well as the usefulness of the approach. Approaches that use the same unit of account for costs and benefits (willingness-to-pay, cost-of-illness, health-health analysis) are the most useful for ranking. When money is the common unit of account (willingness-to-pay and cost-of-illness), the approach has the added benefit of indicating social desirability.

Approaches that monetize benefits and costs are built on the philosophical stance that, like other commodities, health and life can be valued in economic terms for comparison with other goods that people value. Using health-health analysis, finding positively valued net benefits may be less significant than with conventional cost-benefit analysis. However, finding that a program yields a net loss of life may be powerful evidence that its costs exceed its benefits.

What Should Be Counted as a Cost?

Having chosen a unit of account, the second decision that health-policy analysts must make when measuring the costs and benefits of health and safety intervention is to determine what should be counted as a cost. Economists think of costs as consequences of choices. Without choice, there is no sense in which costs exist. Alchian (1968) defined cost of an event as the highest valued opportunity necessarily forsaken. That is, an individual incurs a cost only when forced to choose between alternative goods or courses of action. Where goods are not scarce (more than what everyone might want) or where alternatives do not exist, choices have no cost. This notion of cost is exactly how Buchanan (1987) describes opportunity cost:

> *Opportunity cost is the evaluation placed on the most highly valued of the rejected alternatives or opportunities*. It is that value that is given up or sacrificed in order to secure the higher value that selection of the chosen object embodies.

Three observations germane to the differences among approaches to valuing life and health flow from his definition of cost. First, someone must be choosing. The various approaches to comparing costs and benefits imply different choicemakers with different goals and objectives, and the analyst must, at least implicitly, determine who is choosing. Is the choicemaker a central planner intent on maximizing net national product or an individual maximizing utility?

Second, the fact that different approaches implicitly postulate different choicemakers with different goals and objectives, means that each approach will value benefits and costs uniquely. Each will tally a different set of costs and benefits as each approach tallies what its implicit choicemaker believes he or she will gain or lose.

Third, costs differ from damages. This distinction is what makes willingness-to-pay differ from other valuation approaches. Consider the example of an environmental hazard that poses a small risk of cancer to many people. Everyone might be willing to pay a small amount to reduce a small probability of contracting cancer in the distant future. The dollar value of the realized damages that actually accrue to individuals will be much different from the opportunity costs of reducing the risk. Years after the risk was mitigated, most will receive nothing. As the probability of cancer without mitigation was known to be small, most would not have contracted cancer from exposure to that particular carcinogen, mitigated or otherwise. A few will benefit enormously by avoiding a cancer. A few will pay for mitigation and get cancer anyway, unless the risk was eliminated. What individuals are willing to pay to reduce such risks may therefore bear little resemblance to the actual damages they might experience. On the other hand, when the choicemaker is a net-national-product-maximizing central planner, such as with cost-of-illness and some forms of cost-effectiveness analysis, actual damages sustained may be a good guide to program benefits. In cases where damages occur on a regular and recurring basis, costs and benefits may be precisely specified (although still difficult to measure).

Table 1—Characteristics of methods for comparing costs and benefits

Benefits {		Costs	
		Monetized	Count of health outcomes
	Monetized	Conventional cost-benefit analysis (COI and WTP)	
	Count of health outcomes	Cost-effectiveness analysis	Risk-risk analysis or health-health analysis

The different notions of cost and the various ways in which health and safety benefits and costs can be measured are the subject of the following sections. Each approach defines costs and benefits differently. Each approach is sufficiently different so that the choice of approach will influence the guidance given to policymakers.

Cost-of Illness Approach

Cost-of-illness (COI) estimates provide an accounting of the dollars spent on medical expenses and the dollars of employment compensation that are forgone as a result of illnesses, accidents, or premature deaths. Such an accounting provides useful information to economists and policymakers because it indicates the magnitude of the economic flows resulting from government programs that improve public health.

COI estimates frequently have served as a measure of the monetized benefits of government programs that promote health and reduce the number of premature deaths, illnesses, or injuries (the value of program benefits are the costs that are avoided). However, COI estimates do not provide reasonable measures of the social value of program benefits nor do they provide a consistent gauge of the severity of illness. COI measures are influenced by transitory variables such as the distribution of education, employment opportunities, income, the current state of medical technology, and the characteristics of the institutions through which medical services are bought and sold. The influence of these transitory variables and the effects of income and circumstance erode the usefulness of COI estimates as measures of social welfare or disease severity.

The Components of Cost-of-Illness

COI estimates are composed of two types of costs: direct and indirect. Direct costs are expenditures for medical goods and services such as medications, doctor visits, and hospitalization. Indirect or human capital costs are the present value of labor earnings that are forgone as a result of an adverse health outcome.[5] Specifically, indirect costs per person can be expressed as

$$Indirect\ costs = \sum_{t=0}^{\infty} \frac{P_t E_t}{(1+r)^t} \qquad (4)$$

where E_t is the individual's earnings in year t, P_t is the probability of surviving until year t, and r is an interest rate, measuring the opportunity cost of lost earnings. The discount rate, $(1 + r)^{-1}$, converts future losses into today's dollars. Direct and human capital costs are summed to yield a COI estimate.

For a particular illness, the comparative sizes of direct and indirect costs depend on the characteristics of the illness and the technologies associated with the illness. Mushkin (1979) argued that, over time, biomedical research, technological change, and new diagnostics should result in proportionally higher direct costs. She showed that from 1900-1975, direct costs did rise as a proportion of total costs: in 1900, direct costs of illness were 10 percent of total cost while in 1975 they were 25 percent of the total. Mushkin hypothesized that medical advances would serve to equate direct and indirect costs, and in fact, there are many cases where advances have raised direct costs and lowered indirect costs. For example, Calabresi and Bobbitt (1978) note that, prior to the invention of the kidney dialysis machine, kidney failure was quickly fatal. COI estimates from kidney failure prior to invention of the machine would include very low direct costs and high indirect costs. Using the machine, COI estimates would include very high direct costs (especially in the years immediately following its invention) and reduced indirect costs (as patients return to work).[6]

In cases where illness results in extensive morbidity or premature mortality, indirect costs still greatly outweigh direct costs. Experience with COI estimates for foodborne pathogens suggests that, in general, the relative share of total costs due to medical expenses is lower for pathogens that are more likely to cause deaths or disability. Extrapolations from published estimates of foodborne-illness costs (Buzby et al., 1996) indicate that in 1993, direct medical expenditures accounted for between 30 and 50 percent of

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[5]The COI approach is sometimes called the earnings-expenditure approach.

[6]Tullock (1995) argues that the current debate over the extent of government involvement in health care was precipitated by increasing ability, at increasing cost, of curing diseases.

total costs of illness for cases of *Salmonella* (non-typhoid), *Campylobacter jejuni* or *coli*, *Staphylococcus aureus, Clostridium perfringens*, and *Listeria monocytogenes*, 12 percent for *E. coli* O157:H7, and only 3 percent for cases of *Toxoplasma gondii* (Golan et al., 1998). The distribution of costs between medical and productivity loss depends on the rate of death and disability for each pathogen.

In the sections that follow, we examine and critique the theoretical basis for using the COI approach to measure costs associated with morbidity and mortality. We first examine the theoretical underpinnings of the indirect or human capital component of the COI measure and then turn to the direct cost component.

Human Capital Costs and the Wealth of Nations

The human capital approach is based on the assertion that the cost to society of adverse health outcomes is the impact that such outcomes have on national income. Robinson (1986) traces the philosophical underpinnings of the human capital approach to the economic doctrine dominant from the beginning of the 19th through the middle of the 20th centuries. According to this doctrine, the best government policy is the one that most effectively furthers the "wealth of nations," as measured by national income. The human capital approach to valuing life is consistent with this doctrine. With the human capital approach, the value of a life is measured in terms of its contribution to national income, i.e., to the wealth of the nation. The human capital approach is based on the assertion that social welfare is diminished by illness, disability, and premature death to the extent that these outcomes diminish national income.

The use of forgone earnings to measure the value of health and life therefore hinges on two assertions. First, that changes in health status are reflected in changes in earnings and national income and, second, that national income is a valid measure of social welfare. Both assertions must hold for the COI approach to provide a valid measure of change in societal well-being. The first assertion is often, but not always, true, and the second is usually false. Both are examined below.

Early proponents of the human capital approach argued that investments in health contribute to economic growth (particularly Mushkin, 1962), and this notion is reflected in many modern debates concerning investment in health and safety. It is argued that though many investments in human health and safety might appear to restrain production and national income (through, for example, restrictions on unsafe but productive production procedures), these investments ultimately augment human capital and lead to increases in both the number and quality of people in the workforce, thereby increasing national income and social welfare.

It is reasonable to assume that a healthy labor force is more productive than an unhealthy one, and empirical work has established a connection between health and ability to earn income (for example, Mullahy and Sindelar, 1995). However, health and income need not move lock-step for everyone. Harberger (1971) presents the example of a coal miner with silicosis who voluntarily quits a $7-an-hour job in the mine to take a $2-an-hour job clerking in a grocery store. Though the miner's health would improve, his earnings and his productivity as measured by the value of production would go down. Clearly, increases in health do not necessarily lead to increases in national income.

The second assertion, that national income is an accurate indicator of societal well-being, is even more problematic. As Mishan (1975) observes, there are many ways to increase output without necessarily increasing a society's welfare:

> . . . although financial journalists manage to convey the contrary impression, maximizing GNP is not an acceptable goal of economic policy. If it were, the simplest way of promoting it would be to adopt a policy of virtually unlimited immigration—accepting immigrants up to the point at which the value of their marginal product is zero. (p. 301)

Mishan continues by noting that simply tabulating income and the number of productive bodies in a society is not an accurate gauge of social welfare. If it were, then the death of someone with a negative net present value earnings stream would result in a net benefit to society. Indeed, strict adherence to a national income theory of well-being leads to the

uncomfortable conclusion that unproductive members of society detract from social welfare. Mishan rejects this "net output method" criterion because it does not incorporate the welfare of the potential victims, restricting itself to society *ex post* and ignoring society *ex ante*. Other economists have rejected the moral implications of a criterion that provides assistance only to those whose contribution to net output is positive (Devons, 1961; Ridker, 1967).

Other criticisms of national income as an indicator of societal well-being are a bit more subtle. Samuelson (1950) was one of the first to criticize national income as a welfare measure with his observation that when there are two or more individuals in society, maximizing aggregate income yields ambiguous welfare implications. However, not only does national income gloss over distributional issues in calculating welfare (the aggregation problem), it also fails to account for "non-material utilities." National income accounts only for goods and services that are bought and sold, meaning that as long as society places any value on non-market goods, services, or intangibles, social welfare measures derived with national income measures will diverge from true social welfare. For public health issues, the obvious failing of COI is its inability to account for the value of pain and suffering avoided. For example, the observation that the ex-coal miner breathes more easily after changing professions is not reflected by an increase in national income.

The list of intangibles and non-marketed goods that add to the well-being of a society is quite long, and, as a result, the correspondence between income and social well-being is not a reliable one. Frankel (1952) discusses three general circumstances in which income and well-being may diverge, and his general observations are echoed in many of the modern critiques of national income as a measure of social welfare (Usher, 1994, reproduces this list). Frankel's first observation is that income is only part of welfare and that increases in income may not lead to increases in welfare if another aspect of welfare is affected adversely in the process (examples include economic growth that results in severe environmental degradation or increases in income spurred by abusive use of child labor). Second, Frankel notes that some social problems are perceived only when a degree of prosperity is attained. He observes that the fault-lines of society, such as an inequitable distribu-

tion of access to income or unequal civil rights, might become more pronounced as income grows. Frankel's third observation is that social well-being gives meaning to economic welfare and not the other way around. Frankel argues that the nature and composition of income and economic welfare are not found outside society, but are formed and determined by the institutions, laws, customs, and beliefs of each society.

Empirical evidence supports the argument that national income is not a good gauge of well-being. Standard measures of income and wealth, including GDP, have long diverged from a wide class of measures of well-being. Miringoff, Miringoff, and Opdycke (1996) calculate an index of social health composed of indicators of infant mortality, child abuse, children in poverty, drug abuse, unemployment, homicide, and poverty among those over 65. They find that while GDP grew at a rate of 3.2 percent per year between 1970 and 1979, the social health index declined 2.6 percent per year. Though GDP and the Dow Jones have clearly exhibited long-term increases, many measures of well-being, especially for the poor, have declined.

The legitimacy of the human capital measure as an indicator of changes in welfare resulting from changes in health status hinges on the twin assertions that changes in health status are reflected in changes in national income and that national income is a valid measure of well-being. As illustrated above, earnings and national income do not always mirror health status, and national income is not a reliable gauge of social well-being. The human capital measure of the cost of illness does not measure changes in social welfare and these measures are therefore not appropriate for use in cost-benefit analysis.

Direct Costs of Illness Measure Individual Costs

The direct costs of illness, i.e., expenditures on medicines, health services, and other defensive goods and services, provide an indication of *individual* welfare loss. The welfare cost of these direct expenditures to the individual is the forgone utility resulting from the shift in expenditure patterns. To pay for the medical expenses from the illness, the individual must take money out of savings or reduce other consumption

activities thereby losing the utility of these consumption and savings activities.

However, though the amount of money spent on medical care entails an equal drop in consumption or savings for the *individual*, the same is not true at the *societal* level. Direct expenditures do not correspond to a drop in income or consumption for the economy as a whole, they simply constitute a redirection of economic activity, with some sectors of the economy actually benefiting from increased economic activity. In fact, like all defensive expenditures, medical expenditures are registered as positive additions to national income. For example, all of the defensive expenditures resulting from an outbreak of *E. coli*, such as emergency room care and kidney machines, would lead to increased economic activity in the medical services and equipment sectors of the economy. Increased output in these sectors could actually have a positive impact on national product. For example, Golan et al. (1998) found that in the case of foodborne pathogens, diverting expenditure from general goods and services to expenditure on medical goods and services, including residential care facilities, had a positive net impact on economic activity and income.

At a societal level, direct expenditures for medical care stimulate economic activity in some sectors of the economy, producing welfare gains in those sectors, and stifling economic activity and welfare in other sectors. There are gainers and losers from direct expenditures; these numbers do not correspond to a simple drop in social welfare. So, though the direct costs of illness measure individual costs, simply summing these costs does not result in an accurate measure of societal costs.

The fact that human capital costs strive to estimate societal costs while direct costs measure individual costs results in an uneasy marriage when the two are combined in COI estimates. This internal inconsistency further undermines the usefulness of COI as a measure of either societal or individual welfare.

COI as a Measure of Disease Severity

Practitioners of the COI approach tend to concede its limitations as a measure of individual welfare

changes resulting from illness or premature death but defend the approach as a straightforward measure of the economic impact of disease. However, the straightforwardness of the approach is misleading. Practitioners of COI are susceptible to the assumption that it provides a direct measure of disease severity. This is not true. Both the human capital component and the direct cost component are influenced by a number of factors besides disease severity. A number of these factors are examined below.

Most glaringly, the human capital component of the COI reflects the current distribution of earnings, which in turn reflects the current distribution of education and job skills. In other words, indirect costs are greatly influenced by socio-economic characteristics including race and sex. As a result, value-of-life estimates calculated with the human capital approach indicate values for women, minorities, and the unskilled trailing behind those of white males. Robinson (1986) quotes a study by Cooper and Brody (1976) in which they estimate the value of a college-educated white man between the ages of 25 and 29 at $475,000, a similarly aged white male high-school dropout at $248,000, and a similarly aged African-American male high-school dropout at $165,000. They value a white female high-school dropout at $140,000 and an African-American high-school dropout at $108,000. COI estimates would therefore indicate that a disease that strikes only white males is more severe than a disease that strikes only African-American males or only females, even when the incidence and symptoms of the diseases are identical.[7]

The COI approach might also indicate that illnesses in economically developed countries are more severe

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[7]Quoting the Old Testament, Berndt (1991) observes that differential valuations of human capital have been around for a long time.

   The Lord said to Moses, 'Say to the people of Israel,...your valuation of male from twenty years old up to sixty years old shall be fifty shekels of silver, according to the shekel of the sanctuary. If the person is a female, your valuation shall be thirty shekels....And if the person is sixty years old and upward, then your valuation for a male shall be fifteen shekels, and for a female ten shekels.' *The Bible*, Revised Standard Version, Leviticus 27:3-7

than similar illnesses in economically developing countries. For example, a study on the impact of global warming assigned lower dollar values to the lives of residents of lesser-developed nations than to residents of industrialized nations: the human capital approach led to values differing by an order of magnitude (cited in Pearce, 1995). Global cost-benefit analysis incorporating this valuation bias would lead to equally biased policy recommendations. That is, value choice could influence whether storm barriers are cost-effective in Bangladesh or whether nations that use relatively larger quantities of fossil fuels should plant trees to reduce CO_2 levels in the atmosphere. Differing value-of-life estimates result in recommendations favoring the most highly valued population, a fact that was not missed in recent international climate negotiations. News reports commented that these negotiations were threatened due to the unequal valuation of lives used in the background analysis (Pearce, 1995).

Direct expenditures are also influenced by the distribution of income. Health care is a normal good, and increases in income will be accompanied by increased consumption of health care. Viscusi (1994a) summarized studies estimating, at the margin, individual willingness to consume health-related services out of income. He found that the different studies and methodologies all yielded low, but decidedly positive, marginal propensities to consume health care, although, on average, results from the international studies were three times those from cross-section studies.

Because health care is a normal good, an illness that strikes low-income individuals (perhaps caused by an opportunistic microorganism attacking individuals whose health is already compromised) would cause smaller direct health expenditures than a disease that strikes randomly throughout the population, even if disease incidence and symptoms were similar. Again, COI calculations would show larger costs for the randomly striking disease than for the low-income disease. If COI were used to judge severity, an analyst would conclude that the randomly striking disease was more severe than the low-income disease.

Direct expenditures also reflect the ability of current medical techniques to treat the disease under consideration. For example, treatment of the common cold generates enormous expenditures on cold medicines

each year, while a disease like malaria may generate relatively few expenditures because there are few remedies. COI estimates for each disease might indicate that the cost of a cold is greater than that of a debilitating disease like malaria. Both direct and indirect costs would contribute to this conclusion because malaria incidence is highest in low-income countries. If a treatment for malaria is discovered, the recalculated COI would soar with purchases of the newly discovered treatment. Advances in medical science can simultaneously improve individual welfare and increase calculated COI.

A variety of factors influence earnings, health, and health-care consumption. As a result, the severity of an illness is not identical to the severity of the economic consequences of an illness. The COI of a particular disease that targets a particular population not only measures the severity of the disease, but also the population's education, skill level, income, sick-leave benefits, and insurance coverage, as well as the types of medical interventions currently available.

Is the COI Approach Ever a Useful Tool?

Though the cost-of-illness approach is not a useful tool for measuring social or individual welfare changes or for measuring disease severity, it can provide economists and policymakers with useful information. The COI approach traces the economic flows associated with an adverse health outcome. It accounts for the drop in productivity resulting from illness, accident, or premature death, and it accounts for the shift in consumer expenditure from more general consumption goods, and savings and investment, to medical goods and services. Cost-of-illness (COI) estimates provide an accounting of the dollars spent on medical expenses and the dollars of employment compensation that are forgone as a result of illnesses, accidents, or premature deaths. Such an accounting provides useful information to economists and policymakers interested in gauging the pure economic impact of government policy to reduce adverse health outcomes.

In addition, when combined with a general equilibrium analysis, such as a Social Accounting Matrix, the COI approach provides the first step in deciphering the full economic impact of illness and premature

death. For example, Golan et al. (1998) use a Social Accounting Matrix model to gauge the extent and distribution of the costs of foodborne illness due to meat and poultry. With the SAM model they trace the economic ramifications of the dollar costs of foodborne illness. They find that though the human capital costs of foodborne illness result in a general decline in economic activity, the direct costs trigger growth in the medical support industries and decline in general consumption goods and services. This redistribution of economic activity results in a redistribution of income extending past those individuals who actually contract a foodborne illness.

Any COI estimate can be disaggregated (as in the Golan et al. study) to examine the direction of the economic flows resulting from illness and premature death. If this step is taken, the COI approach can reveal not just the magnitude, but the distributional consequences of illness. COI is therefore a useful tool for gauging the extent and distribution of the costs of adverse health outcomes. It is a first step in deciphering the economic distortions triggered by illness and premature death.

Empirical Considerations

It is widely accepted in the health economics literature that the direct and indirect expenses incorporated in COI measures are relatively easy to estimate, and that therefore, despite its flaws, the COI approach is preferable to the other approaches, particularly the willingness-to-pay approach. The assumed empirical superiority of the COI approach prompted Mishan (1975) to make his much-quoted observation:

> In view of the existing quantomania, one may be forgiven for asserting that there is more to be said for rough estimates of the precise concept [willingness-to-pay] than precise estimates of economically irrelevant concepts [COI]. (p. 320)

How precise are calculated COI estimates? The alleged straightforwardness of the empirical estimation is only apparent to those who have never tried it. In reality, it is quite difficult to decipher what the direct and indirect costs associated with an illness are. There is no COI template to follow, and data are guaranteed to be insufficient and inexact.

The primary problem with empirically estimating direct costs is that the prices charged to health care consumers are usually distorted and rarely reflect true economic value. For example, the consumer price of medicine or medical services is typically much lower than the true cost. Interactions between insurance plans and the medical regulatory system yield a gap between accounting costs and economic costs throughout the medical system (Sox et al., 1988; Finkler, 1982; Hildred and Watkins, 1996). As a result, the empirical researcher could be faced with three or four prices for the same good or service. This abundance of prices makes comparisons across COI studies almost impossible.

Even if a consistent approach to determining cost is developed, it remains difficult to decipher exactly what treatments are being purchased and for whom. The standard procedure in comprehensive empirical studies of COI, is to use estimates from the Health Care Financing Administration (HCFA) on total health care expenditures as the basis for estimating specific expenditures by disease (e.g., physician services, hospital services, pharmaceuticals, medical equipment). This procedure is subject to numerous sources of error, many of which are summarized by Scitovsky (1982) in her review of the empirical literature.[8]

One of the primary difficulties that arises in estimating COI involves determining the type of medical expenditure. It is particularly difficult to disaggregate hospital payments. These expenditures typically include drugs administered on the premises plus salaries paid to health professionals and staff meaning that "professional medical services" and "drugs and medical sundries" are underestimated while "hospital services" and "nursing home services" are overestimated.

Another problem arises due to inaccuracies in hospital diagnostic data and the fact that expenses might

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[8] Most of the bias mentioned by Scitovsky stems from use of the HCFA and other specific data sets, however, since these data sets are the primary sources of information on medical expense, her observations are pertinent to any COI study (see Kenkel, 1994 for an overview of Scitovsky's critiques and other critiques of the HCFA data set).

not be attributed to the correct illness. Similarly, a number of illnesses might be grouped under one diagnostic code making it impossible to decipher individual expenses. For example, in the National Health Interview Survey, most symptoms potentially due to foodborne pathogens are coded in four general disease categories, "intestinal infections due to other organisms, not elsewhere classified," "food poisoning–unspecified," "infectious colitis, enteritis, and gastroenteritis," or "infectious diarrhea." This level of generality makes it difficult to differentiate specific illnesses such as salmonellosis from campylobacteriosis.

Another difficulty with many of the large data sets is that they typically assume the same charge for all types of physician services, when in fact a visit to a physician for a routine physical does not cost the same as a visit for cancer. Another problem concerns the treatment of multiple conditions. The convention is to allocate all expenses to the patient's primary diagnosis, a practice that leads to substantial overestimation of some expenses and underestimation of others. Scitovsky (1982) estimates that 52 percent of all hospital patients have multiple conditions.

A number of difficulties also arise in calculating the indirect costs of illness. Not only is it difficult to accurately establish the number of work-loss days through the use of survey data, but it is also a challenge to determine the cost of these days. It is difficult to account for the cost of non-paid labor (for example, human capital costs of stay-at-home parents), and it is often equally difficult to accurately estimate forgone earnings. An employee's compensation typically includes more than wages. Pension plans, health insurance, flexible hours, etc., can all contribute to compensation and should be included in an accurate measure of human capital costs. Failure to account for these benefits will result in underestimation of indirect costs, especially for wealthier income groups.

In light of the myriad of difficulties listed above, it is clear that empirical estimation of COI is not as straightforward as advertised. The empirical researcher faces a number of difficult decisions in determining direct and indirect costs and there is little chance for conformity across studies. Little about COI estimates is mechanical, and judgment and interpolation are often the analyst's principal function.

Conclusion

Since its inception in the middle of the 20th century, the cost-of-illness approach to measuring the cost of adverse health outcomes has been cast in many roles: as a direct measure of societal welfare; as a measure of individual welfare change resulting from changes in health status; and as an indicator of outcome severity. In the discussion above we have shown that the COI approach is not a valid tool for welfare analysis because it does not provide adequate estimates of individual or social welfare. We have also demonstrated that COI estimates are not reliable measure of disease severity. In addition we have illustrated some of the difficulties that arise in calculating COI.

However, despite its shortcomings for welfare analysis and as a measure of disease severity, the COI approach is still a useful economic tool. The COI approach provides an *accounting* of the dollars spent on medical expenses and the wage dollars that are forgone as a result of illness, accident, or premature death. Such an accounting provides useful information to economists and policymakers because it indicates the direction and magnitude of the economic flows resulting from health shocks to the economy.

Willingness-to-Pay Approach

An entirely different approach to assigning value to risk reduction is to estimate what risk reduction is worth to individuals whose health might benefit. With this approach, analysts estimate consumers' willingness to pay (WTP) for reductions in health risk or improvements in health. Clearly, these values may vary among individuals because preferences are idiosyncratic. In addition, such values usually differ from COI estimates, because, unlike the wealth-maximizing society in the COI approach, individuals may attach value to goods that are not marketed. These goods include intangibles such as pain and suffering.

The WTP approach reflects the observation that individual preferences are unique and individual demands for risk reduction vary. However, because health and safety are normal goods, a substantial portion of the variance in WTP estimates will be explained by income differences rather than preferences. So, just as in COI analysis, income and circumstance could play a role in determining the size of WTP estimates.

This chapter examines the theoretical basis for using the WTP approach for social welfare analysis and presents some of the most important criticisms of the approach. This discussion is followed by a review of the methods used to empirically estimate WTP values for health and life.

WTP is an *Ex Ante* Choice

When WTP is used in the evaluation of health and safety programs, it measures what individuals would be willing and able to pay for a reduction in the probability of encountering a hazard that might compromise their health. The WTP approach is, therefore, concerned with measuring *ex ante* valuations; valuations at the moment choices are made.

The WTP approach for estimating benefits of public health programs rests on the observation that individuals can and do make tradeoffs between health and other consumption goods and services. Proponents of the approach contend that even though individuals tend to place an infinite value on their own lives (and the lives of those they hold dear), they do not feel

similarly about small changes in risk. Individuals routinely and voluntarily accept many small risks in exchange for finite benefits. For example, driving a little faster than surrounding traffic may raise the risk of injury but usually results in reaching a destination sooner. Or, a person might enjoy attending a popular movie at a crowded theater, recognizing that the activity raises the risk of contracting a contagious disease. An individual might suffer actual harm as result of the decision to speed or to sit in a crowded theater and might later regret the decision. But WTP does not measure realized damages or capture the *ex post* valuation of an individual's changed health status. COI would be more appropriate for such estimates.

WTP is most appropriate for evaluating health- or life-threatening hazards that strike with some degree of randomness, so that no one could predict exactly who will actually suffer from the hazard or benefit from the prevention. Many of the hazards addressed through publicly financed health and safety programs fit this description. In these cases, health and safety programs are not targeted at specific individuals, but at reducing hazards to which many may be exposed, reducing probabilities of risk or death or illness for many. It is hard to imagine individuals voluntarily engaging in activities involving the immediate and certain death of a participant, and WTP is not intended to be a price reflective of such exchanges.

Schelling (1966) was the first to propose WTP for valuing changes in health status. He argued that applying WTP to health and life was simply a logical extension of standard welfare economic principles—principles based on consumer sovereignty:

> The gravity of decisions about life-saving can be dispelled by letting the consumer (taxpayer, lobbyist, questionnaire respondent) express himself on the comparatively unexciting subject of small increments in small risks, acting as though he has preferences even if in fact he does not. People do it for life insurance: they could do it for life-saving. (p. 161)

As expressed by Schelling, the foundation of the WTP approach is the belief that individuals are the

best judge of their own well-being, and even in matters involving life and death, individual preferences should be held sovereign.[9]

WTP and Welfare

The usefulness of WTP estimates for cost-benefit analysis depends on the validity of these estimates as welfare measures. There is little question that WTP measures provide the best estimate of *individual* welfare available to economists. In the neoclassical economics tradition, the guiding principle in determining consumer welfare is to measure a consumer's "willingness to pay." Conceptually, these amounts are the values consumers attribute to goods they purchase, or conversely, the cost of forgone consumption opportunities. They are measured as consumer surplus derived either from a Marshallian demand curve (treating the quantity demanded as a function of prices and income, while letting utility vary) or from a Hicksian demand curve (treating quantity demanded as a function of prices and a utility level, where income adjusts to maintain the utility level). It is generally recognized that the Hicksian measures are more accurate measures of consumer welfare.

When applied to changes in mortality or morbidity risk, WTP measures the change in income, coupled with the change in the risk of mortality or morbidity, that leaves the consumer's utility unchanged. The WTP approach for calculating individual welfare changes due to changes in health status strives to estimate the theoretically correct Hicksian measures. These measures are therefore the best individual welfare measures available to economists.

Despite its usefulness as a gauge of *individual* welfare, the WTP approach is clearly less successful as a measure of social welfare. One reason for this short-

coming is that, with the WTP approach, individual valuations of life and health are aggregated to arrive at society's valuation even though such an aggregation is not usually a reliable indicator of social welfare for cost-benefit analysis. It is justifiable to sum individual utilities (WTP) only if the marginal utility of income is equal across income groups, i.e., if an extra dollar of income is equally valued by a millionaire and by someone with an income hovering above the poverty line. Only if an additional dollar is equally valuable to all groups, given the prevailing income distribution, can interpersonal comparisons of utility be made. Only in this case can individual well-being measures be aggregated to provide a basis for comparing costs and benefits across groups. Though there could be cases where the marginal utility of income was equal across income groups, it is unlikely that this condition could be met in cases of even mildly unequal income distributions. In cases where the marginal utility of income is not equal, interpersonal comparisons of utility cannot be made and money loses its value as a measure of welfare. Money is transformed into a "rubber ruler" (Friedman, 1996).

To avoid the whole issue of making interpersonal comparisons of welfare and placing values on gains to one group versus costs to another, economists, starting with Pigou's treatise on welfare economics (1952), have distinguished between efficiency and equity in welfare decisions. Welfare efficiency is concerned with maximizing the sum of individuals' welfare (whether measured as some function of net national product, consumption, or intangibles) while welfare equity is concerned with the distribution of welfare. The Kaldor-Hicks compensation principle is the decision criterion used for strict individual welfare maximization. In this role, the Kaldor-Hicks criterion has been dubbed the "fundamental principle" of cost-benefit analysis (Stokey and Zeckhauser, 1978; Gramlich, 1990).

The Kaldor-Hicks criterion states that a proposed policy change is desirable on social welfare grounds if everyone's welfare can potentially improve (Kaldor, 1939 and Hicks, 1940). The Kaldor-Hicks criterion means that a program may be desirable even if it makes some worse off and others better off. That is, a program where some pay yet receive no benefits while others receive benefits without paying could be acceptable under the Kaldor-Hicks criterion. If the

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[9] Robinson (1986, p. 139) argues that the fundamental concepts represented by the WTP approach are inexorably linked to neoclassical economic philosophy: "Any conceptual strength possessed by the willingness-to-pay approach stems solely from its compatibility with the subjectivist orientation of the welfare economics of the postwar period. Analysis of the philosophical origins of the school of economics reveals that the path it took is not the only one possible, and that for some purposes others may be better."

value of the benefits generated by the program exceeded the payments, it would be possible for gainers to compensate losers. As long as there are positive net gains to society as a whole, the Kaldor-Hicks compensation principle is met. The Kaldor-Hicks criterion not only avoids the difficult question of how to compare costs and benefits accruing to different segments of the population, it also effectively avoids considering the distribution of costs and benefits at all. As succinctly put by Gramlich (1990), "Who these gainers and losers are, and how much they gain or lose are questions that simply do not matter under the Kaldor-Hicks standard" (p. 115).

The efficiency-first, equity-second approach of the Kaldor-Hicks criterion is defended on two fronts. The first defense is that any attempt to incorporate equity considerations in the welfare maximization equations, say through the introduction of weights, will result in inefficiencies. It is argued that any equity-enhancing redistribution should be achieved through lump-sum transfers after welfare maximization has taken place (Harberger, 1978). The second defense of the efficiency-first approach is that the role of economists should be restricted to enhancing efficiency and that equity considerations are best left to the political sphere (Kaldor, 1939). Others have argued that equity and efficiency must be attacked simultaneously and that lump sum transfers are mythical beasts (Layard and Glaister, 1994).

Despite the ongoing debate concerning equity and efficiency in determining social welfare from individual welfare estimates, the WTP approach vigorously applies the standard tools of neo-classical welfare economics to issues concerning health and life. At the theoretical level, the WTP approach to valuing human life is a faithful application of the principles of standard applied welfare economics: it builds up from individual valuations, it does not make interpersonal comparisons of utility, and it adopts the Kaldor-Hicks compensation criterion as its *modus operandi*.

Is Efficiency Sufficient for Health Policy?

As illustrated above, the WTP approach is a consistent application of modern applied welfare economics to policy with health ramifications. Proponents of the approach argue that if economic valuation principles

are fundamentally sound, they must be equally applicable to every commodity, including health and life.

Criticism of the WTP approach usually centers on the assertion that health and life are not like other commodities and that there is no reason to suppose that standard economic techniques are adequate for the task of valuing life and limb. Broome (1978) questioned the validity of employing standard cost-benefit techniques to matters of life and death. The debate between Broome and his detractors is mirrored in the ongoing debate in the literature concerning the validity of the WTP approach for valuing change in health status.

Broome's first criticism of valuing life based on individual preferences concerns the compensation criterion embedded in most cost-benefit analyses. Broome argued that even a compensation scheme designed to fully compensate those who would otherwise be harmed by a public decision, would be inoperable with respect to life and death decisions. He noted "no finite amount of money could compensate a person for the loss of his life, simply because money is no good to him when he is dead (p. 92)." Broome also rejected the device adopted by analysts to circumvent this problem—the practice of "veiling" the identity of the victims in statistics and probabilities. Broome argued that ignorance of the identities of the victims does not mitigate the fact that real people with names and faces will actually die and that there is no ethical reason for valuing the life of an identified stranger more or less than that of an unidentified stranger.

Furthermore, Broome argued that when people make trade-offs involving risks to life and limb, they are ignorant of the actual outcome and are therefore not accurate judges of their own best interests:

> Consider any project in which an unknown person will die. Because whoever it is does not know it will be him, because of his ignorance, he is prepared to accept a ridiculously low compensation for letting the project go forward. The government does not know who will be killed either, but it knows it will be someone, and it knows that, whoever it is, no finite amount of compensation would be adequate for him. The cost of the project must therefore be infinite, and it is only the ignorance of the per-

son destined to die that prevents his demanding an infinite compensation. It may be true that sometimes we are forced to make decisions based on imperfect knowledge if nothing better can be done. But this is one case where the problems of imperfect knowledge can easily be eliminated. If there is to be a death, we know at once that the cost, defined as the compensation required for the loss, is infinite. Any other conclusion is a deliberate and unfair use of people's ignorance. (p. 95)

Broome's critique was amply counter-critiqued (Buchanan and Faith (1979), Jones-Lee (1979), Williams (1979), and Mishan (1981)). The central element of the critique forwarded by Buchanan and Faith was that Broome included an incorrect characterization of "costs" in his calculations. In particular they argued that Broome confused costs that influence choices (costs individuals believe, *ex ante*, they will incur from a choice) with damages (cost individuals actually incur, *ex post*, from a chosen action). They argued that Broome erroneously equated costs with damages and as a result, incorrectly compared the infinite cost of loss of life with finite benefits of expenditures on general goods and services. Buchanan and Faith maintain that the costs that influence an individual's decisions are rejected alternatives:

> To say that 'costs' are infinite for the person who loses his life in the draw of a lottery in which he rationally chooses to participate is to say nothing at all about the *value* that such an individual placed on life in the moment at which the choice was made. (p. 246)

Buchanan and Faith contend that at the instant at which individuals make risky choices, the costs they perceive are those goods and services they must sacrifice to achieve small reductions in risk. Costs are therefore of finite value. For example, the cost to the driver who chooses a speed greater than the surrounding traffic is a small increase in the likelihood of injury in an accident. The cost that influences his choice is not death, but a change in risks incurred. The cost of choosing a speed consistent with surrounding traffic is arriving later than he would by driving faster. Because the driver is willing and able to trade one alternative for another, there is no question that the alternatives the driver rejects are of finite value to him.

The rest of the critiques of Broome's paper amount to reaffirmations of the central tenet of applied welfare economics, that each person knows his or her own interest best and that public decisions should be based on these private valuations. Mishan (1981) described Broome's rejoinder (1979) as an "attack on my proposal arising not from a belief that it is inconsistent with the standard procedure but that, in some sense, it is illegitimate to extend to life and limb the standard procedure that is appropriate for other goods and bads" (p. 136). Mishan contended that to be consistent, economics must apply standard valuation procedures to all goods and bads, including life and limb and that "once he [either 'the economist' or Broome] accepts that the distinctive characteristic of economic evaluation is recourse to the individual's own valuations of the change in question, he has no choice but to go along with their responses, 'paradoxical,' perverse, or otherwise" (p. 137).

Supporters of the WTP approach to valuing life and health contend that it is a logical and consistent application of the primary tenets of standard applied welfare economics and that unease with the results simply reflects an underlying unease with the foibles of human nature. Fuchs and Zeckhauser (1987) suggest that failure to apply standard economic tools to life and health is a result of myth maintenance as opposed to economic efficiency and cost containment. They contend that myths regarding the valuation of life and health persist in our society and give us comfort but that as a result of our myths, "many mechanisms of cost containment must work in the shadows" (p. 267).

As proof of their unflagging support of the right of individuals to determine the value of life-saving or health-enhancing policy, proponents of the WTP approach have often argued for policy prescriptions that appear starkly unfair in a life and death context. For example, Viscusi (1991) supports Schelling's suggestion that the fact that the Titanic carried only enough lifeboats for first-class passengers could be a logical and valid conclusion of a properly executed WTP study (though he concludes that such lifeboat contracting could not hold up in practice because once the ship started to sink it would be impossible to deny access to the lifeboats).

The reasoning behind this conclusion hinges on the conviction that preferences are adequately revealed through consumer choices. Just as spending five

times more on bubble gum reveals five times the preference for bubble gum, spending five times more on health care reveals five times the preference for the health. Likewise, the fact that lower income groups tend not to drive new cars with up-to-the-minute safety features indicates that lower income groups place a lower value on health and safety than wealthier new car drivers. Schelling (1966) clarifies this view:

> A special matter of policy is bound to arise here. If a government is to initiate programs that may save the lives of the poor or the rich, is it worth more to save the rich than to save the poor? The answer is evidently yes if the question means is it worth more to the rich to reduce the risk to their own lives than it is to the poor to reduce the risk to their own lives. Just as the rich will pay more to avoid wasting an hour in traffic or five hours on a train, it is worth more to them to reduce the risk of their own death or the death of somebody they care about. It is worth more because they are richer than the poor.   (p. 157)

The reasoning implied by statements like those above is incomplete. Interpersonal comparisons of utility of this type are invalid unless the marginal utility of income is equal between groups.[10] In actuality, there is no reason to assume that an extra dollar was of equal value to the steerage and first-class passengers on the Titanic and there is very little reason to assume that the marginal utility of income is equal for a family with an income near the poverty line and one that purchases a new car every year. Like all consumption choices, the purchasing decisions of both the steerage passengers and the drivers of rusty, old cars are constrained by income as well as by preferences. If the marginal utility of income is greater for the old car-driver than the wealthier new-car owner, then the used child seat in the back of the old car could entail a larger sacrifice and reveal a stronger preference for safety than that revealed by the new car-owner's more expensive purchase of air bags, anti-lock brakes

and impact resistant side bars. As stressed by Deaton and Muellbauer (1980), consumption decisions are conditioned by preference *and* possibility.

Though the theoretical rationale for using unweighted individual welfare valuations in cost-benefit analysis is not based on the assumption of equal marginal utility of income across socio-economic groups, the results are similarly influenced by the current distribution of preference and possibility. The theoretical linchpin of WTP studies is the Kaldor-Hicks principle. The efficiency-first, equity-second criterion embedded in the Kaldor-Hicks principle results in policy prescriptions that favor wealthier segments of society (at least initially). The efficiency-first criterion requires that the policymaker maximize the unweighted aggregation of individual valuations. Only after maximum efficiency is achieved does the policymaker address equity concerns for real social welfare maximization.

An efficiency-first criterion would indicate that safety policy be directed to those sectors of the society that place the highest value on safety. In cases where individual WTP amounts are influenced by income as well as by preference, higher income groups would most often exhibit greater safety purchases and as a result would be the beneficiaries of safety policy. A cost-benefit analysis incorporating these results would indicate that the government should target safety improvements to upper income groups with equity concerns addressed through redistributive policy after efficiency maximization.

The usual defense of the efficiency-first, equity-second approach of the Kaldor-Hicks criterion rings a bit hollow when applied to issues of life and limb. It might be reasonable to argue that equity-enhancing redistribution should be achieved through lump-sum transfers after welfare maximization has taken place for those cases where a redistribution of income would be sufficient to leave everyone as well off as before the policy change. However, in cases where policy results in a particular distribution of premature death, disability, or ill-health, it might be difficult to adequately compensate the "losers" with any amount of lump-sum transfers. Layard and Walters (1994) argue that "there is no ethical justification for the Hicks-Kaldor criterion; where compensation will not be paid there seems no alternative to interpersonal comparisons of the value of each person's gains and

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[10]In making statements of this sort, Schelling and Viscusi are most likely victims of semantics. They probably did not intend to compare "utility" when discussing comparisons of "worth."

losses" (p. 6). For policy influencing the distribution of life and death, potential compensation will always remain just potential. The Kaldor-Hicks principle could be a valid operating criterion for most goods and services, but the fact that those needing to be compensated might be dead or dying seems to invalidate the logic of the criterion for health policy: to echo Broome, it is strictly impossible to redistribute between those in this world and those in the next.

Empirical Results

In the theoretical discussion presented above, it was implicitly assumed that WTP amounts can be measured. The WTP theory was critiqued because of the efficiency-first, equity-second criterion that is adopted with an unweighted aggregation of WTP amounts. However, because WTP amounts are subjective, the task of deriving them is very difficult. The very subjectiveness that makes them so theoretically appealing is also what makes them empirically challenging. So, whether unweighted or weighted, aggregated or individual, WTP amounts are extremely difficult to estimate over a whole population.

This point was stressed by Buchanan and Faith (1979) in their observation that the value an individual places on a commodity is best measured by opportunity costs, defined as what an individual believes he is giving up by choosing one way rather than another. These individually assessed opportunity costs exist only at the moment a decision is made, and only in the mind of the choicemaker. Opportunity costs need not bear any relation to objectively measurable costs, like realized damages. Because opportunity costs are inherently subjective and unobservable, Buchanan and Faith argue that external observers, including analysts conducting a cost-benefit study, cannot discern the value an individual places on life (or, more precisely, on changes in life-threatening risk). Thus, even if benefits of a program were large enough to compensate all those made worse off, it would be impossible to do so, because appropriate compensation levels would elude measurement.[11]

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[11] The Buchanan and Faith argument that values are subjective is not specific to life and health. The same argument could be made for any commodity. Thus, one could argue that economists cannot assign value to any non-marketed commodity.

There is no way to overcome the Buchanan and Faith argument; no one can know exactly what is in the mind of another. But, public sector decisionmakers have to choose which programs to fund and which activities to regulate. Health and safety policies will be made even if decisionmakers have only incomplete knowledge of costs and benefits. Decisions will be made even if there is nothing to guide program selection toward those that are inexpensive and offer large benefits. The real question Buchanan and Faith raise for health and safety policy is whether economists can estimate the value of health benefits well enough so that the results of cost-benefits analyses serve as good guides toward efficient program selection. In practice, economists routinely assign prices to non-marketed goods through a variety of methodologies, including the contingent valuation method, the hedonic pricing method, and the travel cost method. Some of these price estimates are quite speculative while others are more certain.

One of the most straightforward methods of assigning value involves deriving a price from associated marketed commodities (having observable prices) and a set of behavioral assumptions. That is, there may be marketed commodities for which demand characteristics are arguably similar to the non-marketed commodity. For example, consider assigning a value to irrigation water in the Southwest. In some States, water or water rights may not be traded separately from land. Yet economists can confidently assign value to new irrigation water and thereby estimate benefits of a construction project that would provide irrigation water. A simple method for assigning a value to water would be to calculate the price differential for land sold with and without irrigation water, based on recent sales prices. That price differential should represent the present discounted value of profits earned through the extra productivity of irrigation water and, equivalently, the WTP for water.

The above example uses an observable characteristic of real estate sales with the assumption of profit maximization to assign a value. So far, valuing risks to life and health has proved to be more difficult than valuing other non-marketed commodities. Finding associated marketed commodities and behavioral assumptions that allow analysts to derive a price for risk reduction is not a trivial task. As a consequence, estimating the value of risk reduction requires more heroic assumptions and leads to less robust results

than estimating the value of other non-marketed commodities.

In the health economics literature, analysts have used four primary methods for empirical estimation of willingness-to-pay measures.

- The compensating-wage method
- The contingent valuation survey method
- The household production function method
- The hedonic price method

Each method provides a means of deriving Hicksian willingness-to-pay estimates for individuals making tradeoffs between risks to life and health and other consumption goods and services. Each of these methods is examined below

Compensating Wage Differentials

The dominant empirical approach to assessing WTP risk tradeoffs uses labor-market data on wage differentials for jobs with health risks. This approach assumes that workplace risks are well understood by workers and that the additional wages workers receive when they undertake more risky occupations reflect risk choices. The underpinnings of the compensating wage approach have been traced to Adam Smith and his observation that risky or otherwise unpleasant jobs will command a compensating wage differential (pp. 99-100). The compensating differential approach relies on the assumption that workers will accept exposure to some level of job-related risk in return for some level of compensation. For example, suppose jobs A and B are identical except that, on average, there is one more job-related death per year for every 10,000 workers in job A than in job B, and workers in job A earn $500 more per year than those in job B. The implied value of a statistical life revealed by the willingness of workers in job B to forgo an extra $500 per year for a 1-in-10,000 lower annual risk is calculated at $5 million (example from Fisher et al., 1989).[12]

The basic approach in the compensating-wage literature is to estimate a hedonic wage equation where wages are specified as a function of personal characteristics of the worker and characteristics of the job. Individual worker characteristics can include wealth, age, sex, education, experience, and health. These variables are particularly important as they affect the firm's demand for the individual worker, the workers' preferences, and other labor opportunities available to the worker.[13] Job characteristics that influence costs of providing particular safety levels can include the fatality risk of the job, the nonfatal risk of the job, worker compensation benefits that are payable in case of injury on the job, and annuity benefits in the event of a fatal accident. Compensating wage differential models are consistent with WTP theory in that they recognize that individuals have unique preferences over risky alternatives and that their opportunities to reduce risk vary, often depending on the marketability of their labor skills. Compensating wage differential models postulate that a large share of the differences in risk preferences are systematic, depending on objective and measurable individual characteristics.

Accurate and consistent measurement of the risk variables and worker characteristics has been a major stumbling block to empirical estimation of compensating wage premiums, especially for early studies. Ideal risk measures should reflect subjective assessments of the risks associated with each job by both workers and employers. In fact, most studies have relied on information from national data sets that typically provide information on several thousand workers and their occupations (for a through discussion of this point, see Viscusi, 1993).

Footnote 12 continued

willingness to accept is calculated. Experimental evidence has routinely shown that willingness-to-accept is greater than willingness to pay: individuals require a larger financial inducement to accept a risk than they are willing to pay to avoid a risk (Morrison (1998)). Viscusi (1993) argues that for small changes in risk, willingness to pay and willingness to accept should be the same.

[13] To include these characteristics, empirical studies must have access to micro-level data sets, something which proved problematic in the early compensating-wage literature.

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[12] In this example, emphasis is on the amount that workers are willing to forgo to reduce risk, i.e., willingness to pay is calculated. In much of the compensating wage literature emphasis is placed on the increase in compensation that workers require in order to assume more risk, i.e.,

Wage premiums observed in the market are a result of the interaction of labor supply and labor demand, as conditioned by the characteristics of the job and individual worker preferences. The willingness-to-pay or willingness-to-accept measures are the result of holding the expected utility with respect to risk and income constant for the individual worker, while varying risk levels.

There is wide variation in the empirical estimates generated by the compensating wage technique, particularly when the earlier econometric studies are included in the comparison. For non-fatal job risk, empirical studies have encountered two difficulties. The first arises in untangling premiums for non-fatal and fatal risk in those cases where the two types of risk are correlated. Failure to account for non-fatal risk leads to bias in many fatality risk studies. The second difficulty arises because of data discrepancies: there is currently no up-to-date government data base that covers both fatal and nonfatal injuries (Viscusi (1993) discusses this point). Viscusi (1993) surveys 24 labor-market studies covering diverse populations and diverse types of injuries. He finds that, in general, empirical studies find statistically significant wage premiums for job injury risk. Most of the estimates based on data for all injuries regardless of severity are clustered in the $25,000-$50,000 range, with the wage-risk trade-off tending to be greater for more severe types of injuries.

Empirical studies of fatal risk tradeoffs yield results differing by a couple orders of magnitude. A fairly wide range of results is not surprising as empirical studies have focused on different populations of workers and include different measures of risk and compensation. Fisher et al. (1989) and Viscusi (1993) review the empirical literature and both conclude that the most reliable compensating-wage studies include variables detailing worker and job characteristics. In addition, the most credible of the studies are those that have been the most successful in measuring specific job-related risk (as opposed to occupation-related risk or general categories of risk). Fisher et al. (1989) surveyed 15 compensating-wage studies. In their judgment, the most defensible empirical results lie in the $1.6 to $8.5 million range (1986 dollars), with the best estimates lying at the lower end of the range (Gegax et al., 1991 with an estimate of $1.6 million and Dillingham, 1985 with an estimate of

$2.5 million).[14] For the principal labor market studies surveyed by Viscusi (1993), implicit value of life estimates (deflated to 1990 dollars) are centered in the $3 million to $7 million range. Of the 24 studies, Viscusi places the most confidence in the estimates derived from wage equations, as the values derived from structural models are less robust. He favors results from his own studies (Viscusi, 1979), with an implicit value of life estimate of $4.1 million (deflated to 1990 dollars), and Moore and Viscusi (1988) with an estimate of $2.5-$7.3 million ($1990).[15]

Much of the criticism of the compensating-wage approach centers on its assumptions concerning the labor market. Many critics argue that the actual labor market bears little resemblance to the labor market described in compensating-wage models (see for example, Dorman, 1996). The compensating wage approach assumes that workers are fully cognizant of the extent and consequences of the on-the-job risks they face,[16] that labor markets are strictly competitive,[17] and that insurance markets are actuarially correct, with premiums and payouts matched to accurately assessed risks. In addition, compensating-wage models have difficulty consistently accounting for job characteristics that might substitute for wages in compensating for risk such as prestige, flexible hours, and a pleasant work environment.

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[14] Fisher et al. examined the Gegax et al. paper before it was a journal publication.

[15] Fisher et al., commend the Moore and Viscusi study for using data from the National Institute of Occupational Safety and Health (NIOSH) instead of Bureau of Labor Statistics data. However, they argue there are costs to using (NIOSH) data. Though the NIOSH data include a complete census of all occupational fatalities and match death risk by State with compensation in each State, NIOSH data are only disaggregated to the one-digit SIC code, meaning that fairly diverse jobs are characterized by the same level of risk.

[16] Viscusi suggests that the fact that workers are not always well informed leads to the "quit effect" (Viscusi and Moore, 1991).

[17] In the compensating-wage literature, this assumption is questioned through examining the wage-risk premiums paid to union and non-union members. Fisher et al. (1989) discuss this evidence.

Another critique of the approach lies in the observation that not all risks are the same. For example, it can be argued that not all fatality risks represent the same utility loss. That is, not just the likelihood but also the manner in which a person might die makes a difference. Equiprobable risks of dying in an industrial accident or from food poisoning may not be equally undesirable. In addition, people are usually less willing to accept involuntary risk than risk that is voluntarily assumed through, say, a wage contract. As a result, studies, such as compensating-wage studies, that measure response to voluntary risk probably underestimate society's aversion to risk that is not contracted for. Implicit value-of-life estimates are quite sensitive to the level and type of risk under consideration, and values derived with respect to one sort of risk may not be accurate measures of the value of other sorts of risk.

One of the most common criticisms of the compensating-wage approach relates to the final use of the estimates rather than to the generation of the estimates. Compensating-wage studies are primarily restricted to high-risk blue-collar males, and yet even within this restricted population, the implicit value of life estimates fluctuate wildly. Age, experience, education, sex, and most significantly, wealth should influence willingness-to-pay or willingness-to-accept. The results of one compensating wage study can hardly be compared with the results of another due to heterogeneity problems. Nevertheless, these results are often applied to the general population, a population that may have very different attitudes to risk and health than the typical high-risk blue-collar male. Many government agencies have adopted Viscusi's mid-range estimates as official policy, requiring that these estimates be used in all analyses, regardless of the type of hazard and who is at risk. The Food and Drug Administration (Food and Drug Administration, 1995) and the Consumer Product Safety Commission (Miller et al., 1997) currently use Viscusi's midpoint value of $5 million for each life saved. The Department of Transportation used a value of $2.2 million for many years (Viscusi and Hamilton, 1996), but has recently raised the value to $2.7 million.

The most striking observation that emerges from the compensating wage literature is the sensitivity of value-of-life estimates to the characteristics of the study population and to the level and type of risk. As a result, the general applicability of these estimates is questionable. "The value of life is not a universal constant, but reflects the wage-risk trade-off pertinent to the preferences of the workers in a particular sample" (Viscusi, 1993, p. 1930). At best, compensating wage studies indicate a range for implicit value-of-life measures, but caution should be exercised in making general conclusions about the value of life.

Contingent Valuation

Contingent valuation is a tool designed to allow analysts to estimate demands for goods that are not traded or only rarely traded. It is a survey method in which respondents are asked to state their preferences in hypothetical or contingent markets. The contingent-valuation method was first used to estimate the benefits of a recreation area in Maine (Davis, 1963) and continues to be widely used by environmental economists and public-good economists.

With the contingent-valuation method, analysts first draw a sample of individuals who are asked about a change in government policy governing, for example, pollution control, scenic area regulations, hunting permit allocation, or the supply of environmental amenities. Individuals usually are asked to imagine that there is a market in which they could buy such amenities. Respondents are given a detailed description of the hypothetical market and the good being evaluated. Then, they are asked the price they would pay to receive the amenity. Typically respondents do not make cash transactions, but are asked about willingness to participate in such transactions as if there were a market. Questions about the value of policy changes are hypothetical.[18]

Analysts also collect information on the demographic and socioeconomic characteristics of respondents (including age, sex, education, and income). Demographic characteristics allow analysts to draw inferences about the entire population of beneficiaries and the aggregate demand for amenities. In effect, they estimate aggregate willingness-to-pay. If analysts can show that preferences for amenities are not random, but vary systematically, conditioned by

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[18] For more complete descriptions of the contingent-valuation technique, see Mitchell and Carson (1989) or Cummings et al. (1986).

observable demographic characteristics, then they can use population information on age, sex, education, and income to forecast aggregate demand.

The measure elicited by a contingent-valuation survey is a Hicksian willingness-to-pay measure (compensating surplus), a dollar measure of preferences. It is equivalent to a change in income, coupled with a change in the amenity under study, that leaves the respondent's utility level unchanged. Contingent valuations do not constrain the range of prices that individuals may report. Thus, such estimates are consistent in spirit with economic notions of utility: preferences are idiosyncratic and choices depend entirely on subjective judgments.

A primary undesirable characteristic of contingent valuation is that it does not require cash transactions. Individuals may not truthfully tell interviewers their real demands. Individuals may not be sufficiently able to judge their own demands without the requirement of giving up something for their choices. Contingent-valuation practitioners have developed guidelines to minimize biases and errors arising due to the hypothetical nature of the method.

To minimize unsystematic errors and enhance a study's reliability, Mitchell and Carson (1989) stress that the key scenario elements must be understandable, meaningful, and plausible to respondents. They suggest three guidelines to encourage this result. First, the WTP questions must be clear and unambiguous. Second, respondents should be familiar with the commodity to be valued. Third, respondents should have had prior valuation and choice experience with respect to consumption levels of the commodity, thus increasing the likelihood that they will have well-formed values for the commodity.

To minimize systematic bias and increase a study's validity, potential response biases must be controlled. Mitchell and Carson (1989) argue that systematic biases commonly occur in contingent valuation studies for three main reasons. First, the scenario contains strong incentives for respondents to misrepresent their true WTP amounts, thus resulting in strategic or compliance bias. Second, the scenario contains implied value cues that help determine WTP amounts. Third, there is misspecification (or misperception) of the scenario. There is no objective test to detect systematic bias, making it incumbent on the researcher to demonstrate that bias has been minimized.[19]

The issue for contingent-valuation studies involving health is whether these studies can comply with the above guidelines, or whether the special nature of the commodity "health" makes compliance unlikely. Whether or not a health-risk contingent valuation study is reliable and valid will depend not only on the design of the survey, but also on the exact nature of the health risk being assessed. Health-risk studies on mild illnesses that affect everyone sooner or later have a greater chance of being understandable, meaningful, and plausible than studies on severe, rare diseases. Ensuring that respondents are rational and knowledgeable will be more difficult for some health-risks than others. Even if the guidelines for reliability and validity have been reasonably met, a fairly standard rule of thumb places the accuracy of contingent-valuation estimates in the range of plus or minus 50 percent (Cummings et al., 1986). Contingent-valuation estimates should be interpreted in light of this accuracy range.

The use of contingent-valuation surveys to gauge the value of health and life is linked with the environmental literature in a large number of studies valuing health and environmental quality.[20] These types of contingent-valuation studies typically result in estimates of the per-day value of reducing specific, less severe symptoms such as coughing, sneezing, or throat or sinus problems. The comparability across studies tends to be limited because they pertain to diverse symptoms and differ in their reporting of marginal versus average values and median versus mean bids. In their review of contingent valuation studies evaluating less severe symptoms, Kenkel et al. (1994) find that once they control for differences in reporting, contingent-valuation estimates are relatively consistent. This observation bolsters the con-

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[19] Kenneth Arrow and Robert Solow co-chaired a Contingent Valuation Panel that delivered a widely quoted critique of that approach in its analysis of natural resource damage assessments under the Oil Pollution Act of 1990. The Panel produced guidelines to improve the reliability of any CV study (Federal Register, Vol. 58, No. 10).

[20] For a review of this literature see Kenkel et al., 1994.

clusion that in the case of less severe illnesses, contingent-valuation surveys are reasonably able to follow the guidelines for reliability and validity.

For severe health symptoms, the use of the contingent-valuation technique is more questionable. In these cases, respondents are probably not adequately familiar with most life-threatening illnesses, nor are they likely to be experienced in deciphering probabilities related to severe health risks. Nevertheless, because serious illness has an impact on both the probability of death and on the quality of life, the contingent-valuation technique may be the approach that is best suited to measuring serious illness. The hypothetical nature of this approach could prove valuable in deciphering the effect of quality and quantity of life on value estimates. To this end, Fabian et al. (1994) developed an approach that prepares respondents to think carefully about the probabilities of serious illness. Questions progress from those dealing with simple life-experience situations to more complicated situations involving various probabilities of serious illness and death.

The Fabian et al. approach yields life-path scenarios that are combined with probability analysis to determine one's willingness to pay to reduce the risk of undesirable scenarios. Despite the complexity of the approach and the length of the questionnaire, the validity and reliability of the results are not assured. Fabian et al. (1994) highlight two areas of concern: the inability of respondents to discriminate between one risk and another, and the sensitivity of results on the amount of information provided to the respondent. These concerns are compounded in market experiments in which risk and probability information are not carefully detailed.

Contingent-valuation studies that specifically examine willingness-to-pay for changes in life-threatening risk are among some of the earliest applications of the approach (Acton, 1973 and Jones-Lee, 1976), and as such are subject to some start-up errors. As a result, Fisher et al. (1989) focus their review of this literature on two fairly recent additions: a study by Jones-Lee et al. (1985) and one by Gegax et al. (1991).[21] Fisher et al. praise both of these earlier studies for focusing on risks that are familiar to the

survey respondents and for each study's attention to creating surveys with realistic and well-defined scenarios and payment mechanisms. The Jones-Lee et al. study examined individuals' willingness-to-pay for reducing the risk of serious motor vehicle accidents in Great Britain. Their results yield value-of-life estimates between $1.6 and $4.4 million (1986 dollars). Gegax et al. examined willingness to pay for reductions in job-related risks. Their value-of-life measures ranged from $2.4 million to $3.3 million per statistical life (compared with a $1.6-million estimate from their wage-risk analysis). Again, as in the case with compensating-wage studies, the results are sensitive to the types of risk under analysis.

In some cases, contingent markets might lead to more reliable estimates of willingness-to-pay than do prices from active markets. Contingent-valuation studies may be able to eliminate biases resulting from the physician-agent relationship, insurance arrangements, and irrationality in the face of severe disease (Golan and Shechter, 1993). Viscusi (1993) argues that contingent-valuation studies may be able to avoid some of the other shortcomings of market-generated estimates in that contingent-valuation studies estimate more than one value along the respondent's constant expected utility locus while wage-based studies measure only one point. Contingent-valuation studies are able to elicit more than just a point tradeoff; they estimate a respondent's utility function. The contingent-valuation approach can therefore avoid some of the heterogeneity problems inherent in labor-based estimates by making the parameters of the utility function dependent on worker characteristics. Such an approach explicitly models a value-of-life estimate as a function of income level and nonmarginal changes in risk. Another advantage of the contingent-valuation technique is that it is not constrained by circumstance: it can investigate issues for which there are no market data, and it can circumvent income constraints to derive estimates that more truly reflect preferences and not income. Of course, these strengths could prove to be weaknesses if the process does not measure real decisions regarding scarce resources. Though the contingent-valuation approach has been used extensively in the natural resources and environmental literature for the past 20 years, the technique is only slowly being applied to health-risk questions. However, recent successes in creating valid and reliable surveys could bolster research using this approach. Early skepticism regarding the application

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[21] See footnote 12.

of the contingent-valuation method to the special commodity "health" seems to be giving way to the realization that the method could prove useful in exploring health-risk tradeoffs that are obscured in market data.

Contingent valuation of food safety overcomes the problem that food is not marketed by risk levels (say, probabilities of inducing cancer) and that it is therefore difficult to assign a value to risk reduction. Contingent valuation overcomes this problem by providing survey respondents with assessments of health risk. Valuation of food safety in experimental markets attempts to go one step further—placing the good in a market-like situation where money changes hands.

Application of experimental valuation to food safety is relatively new (Hayes et al., 1995, and Fox et al., 1995). Experimenters have used auction mechanisms to establish a market-like setting under controlled conditions. Whether experimental markets elicit truthful revelations of preferences is an open question. On one hand, participants make monetary payments for goods they consume, suggesting participants are aware of the opportunity cost of their bidding behavior. On the other hand, the experimental market is still artificial and contrived; participants bid with money experimenters give them. Thus, it is not entirely clear that the opportunity cost participants incur by bidding exactly equals the cost they would realize if there were a real market for safety. For a more thorough review of this literature see Buzby et al., 1998.

Household Health Production

The household health-production function method for measuring WTP is built on the observation that households continually make decisions involving the allocation of income and time between health-enhancing goods and activities and other goods and activities. In addition to *ex post* health-care consumption items, like prescription medicines and surgeries, *ex ante* or preventive items like diet, exercise, work and leisure choices also affect health status. The household health-production approach recognizes that health is not simply an exogenous variable, but that individuals can and do make decisions attempting to influence their own health status. By maximiz-

ing a utility function that explicitly includes health expenditures, subject to an income-time budget constraint that accounts for productivity losses due to ill health, theorists using the household health-production approach are able to solve for the willingness-to-pay for health.

Grossman (1972) first modeled the trade-off between health-enhancing activities and income and leisure. Grossman's health-production model incorporates two distinct roles for good health in household demand. First, good health is a "capital" stock. Investments in health capital determine the amount of time that can be devoted to producing and consuming.[22] Second, good health is a fundamental commodity. In this distinction, Grossman adopts a conceptual separation between commodities (fundamental objects of choice) and market goods (Becker, 1965; Lancaster, 1966; Muth, 1969). Fundamental commodities, like good health and peace of mind, are not purchased but instead are produced by the individual. Purchased goods and services and the individual's time also are inputs used to produce fundamental commodities. The Grossman model incorporates these two distinct roles for health (health capital and fundamental commodity), and as a result, health is demanded by consumers in the model for two reasons: as a fundamental consumption commodity that enters directly in the utility function, and as an investment commodity determining the total amount of time available for market and non-market activities. Maximization of the Grossman model results in a WTP amount for the value of healthy time that further mirrors the two roles of good health. This WTP amount is the sum of two elements: the monetary value of the direct increase in utility associated with better health and the increased labor earnings due to better health. A primary criticism of the Grossman model is that it succeeds in endogenizing good health to such as extent that individuals in the model are able to choose their length of life.

Berger et al. (1994) develop a model that shows relations among a production function, COI, and WTP. This model includes health in three roles, as a variable in the utility function, as a determinant in the

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[22] This is an extension of the human-capital model developed by Becker, 1964, and Ben-Porath, 1967.

probability of survival for the current period, and as part of the income constraint. It considers traditional cost-of-illness measures (medical expenditures and income losses) and preventive expenditures (goods and time) where cost-of-illness is a function of health characteristics, and health is a function of preventive expenditures and an exogenous shift variable (such as environmental quality). Risk is incorporated into the model through the specification of a probability density function for health. This probability density function determines the likelihood of a particular health status (given preventive expenditures and the state of the world), which in turn determines the probability of survival for the period. Through their health-production function, Berger et al. are able to solve for an individual's *ex ante* WTP for an improvement in health status. They demonstrate that WTP for combined morbidity and mortality risks is not the sum of the WTP for each individual type of risk.

Examples of health-production functions that have been empirically estimated include Cropper's (1981) study of air pollution and work-loss days; Gerking and Stanley's (1986) study of ozone reduction and morbidity; and Dickie and Gerking's (1991) study of health attributes, private goods, and air quality (see Clemmer et al., 1994, for a review of these studies). The WTP amounts generated with these studies range from $0.73 for the reduction of symptoms to $176 for a work-loss day. This variability in WTP estimates illustrates the difficulty in consistent application of the household production approach and the difficulty in comparing estimates across studies.

A complete model of health behavior that endogenizes health investment should mirror the choices people make concerning health and consumption and leisure. However, a fundamental difficulty with the health-production approach is that even at a theoretical level, it is difficult to identify all the elements that contribute to the production and maintenance of good health (Harrington and Portney, 1987; Atkinson and Crocker, 1992). Empirical measurement of these elements, once identified, is also a difficult task requiring the quantification of non-marketed and often intangible goods. In addition, the econometric estimation of health-production functions is problematic (Harrington and Portney, 1987). Mullahy and Portney (1990) highlight the difficulties of empirical estimation in cases where health inputs, not just health, are endogenous. Bockstael and McConnell

(1983) demonstrate that the household health production function may be unable to easily estimate the value of non-marginal changes. As a result of all these difficulties, the household production approach is subject to serious measurement error and is restricted in its application. Berger et al. (1994) conclude that "the health production function approach to estimating WTP may be of limited usefulness" (p. 34).

Hedonic Approach— Other Market Evidence

The health-production approach incorporates the observation that many goods and services contribute to health status. The hedonic approach extends this through the observation that often only specific characteristics of a good or service contribute to health, with other characteristics serving other functions. The final price of a good or service will reflect the desirability of all its characteristics or attributes. For example, the attributes of a house include size, comfort, and location, and the price of the house will reflect all three attributes. If the attributes of the house include characteristics that affect health such as location in a polluted neighborhood or access to the purest water in the country, the price of the house should reflect the value of these health-influencing attributes. With the hedonic method, the value of each attribute of a good or service is calculated, and the WTP for each attribute, including health-related attributes is estimated.

Market studies evaluating the health risk tradeoff implicit with the purchase or use of a variety of goods and services have been accomplished. Viscusi's 1993 survey of the empirical literature includes seven value-of-life studies estimating the implicit health risk tradeoff in decisions regarding highway speed, seat belts, smoke detectors, smoking, car purchases, and property values. Viscusi (1993) argues that non-labor market studies are less direct and probably less reliable than labor market studies (compensating-wage studies), because they do not observe either the risk facing the individual or the monetary value of the attribute. Furthermore, Viscusi contends that these studies:

> . . . provide a lower bound on the value of life, but will not provide information about the consumer's total willingness to pay for safety,

because with such discrete decisions consumers are not pushed to the point where the marginal cost of greater safety equals its marginal valuation. (p. 1936)

The implicit value-of-life estimates included in the Viscusi survey center around $1 million, a number that is quite low in comparison with other value-of-life measures.

Fisher et al. (1989) include four consumer market studies in their survey. The results of these studies are much lower than those generated by other willingness-to-pay estimation methods, with value-of-life measures ranging from $.24 to $1.4 million (1986 dollars). Fisher et al. center these estimates at about $.55 million. They believe the estimates are low because the assumptions in these studies lead to an incomplete accounting of WTP. For example, the assumption that the time spent buckling up is the only cost of putting on a seat belt leads to understatements of the implicit value of life. Many people feel uncomfortable wearing seatbelts. If this discomfort were included in the estimates, both the cost of wearing seatbelts and the implicit value of life would be higher.

Another vein of the literature using the hedonic method involves linking property values and the value of health. In this literature, investigators estimate what individuals would be willing to pay for improvements in health by observing property values in neighborhoods with varying levels of air pollution. Everything else equal, property values in neighborhoods with lower levels of air pollution should be higher than property values in more polluted neighborhoods. In cases where air pollution can be linked to adverse health effects (real or potential), differences in property values can be used to estimate health values.[23] Klemmer et al. (1994), survey the literature on hedonic pricing of housing characteristics and report the results of empirical studies estimating the value of reductions in air pollution and studies estimating the elasticities of demand for clean air. None of these studies explicitly estimate the value of health. These studies indicate that clean air (and hence the health

benefits associated with clean air) is a normal good with a demand that is relatively inelastic, though negatively related to price. Though these results are rather innocuous, Klemmer et al. harshly criticize the approach taken in many of these studies and advocate caution in interpreting these estimates. In particular, they argue that studies that depend on the approach developed by Rosen (1974) suffer from inadequate exogenous price variation. Therefore the benefit estimates obtained from these studies are not very reliable. In addition, Klemmer et al. question Rosen's handling of the identification problem and simultaneity in an implicit market analysis.

In general, the hedonic methodology has yet to be refined for valuing health attributes associated with market goods. The value-of-life estimates resulting from this methodology are much lower than those estimated by other techniques. This discrepancy should be explored before these values are used in other contexts.

Conclusion

The WTP approach reflects individual preferences for risk reduction where the demand for risk reduction is derived from *ex ante*, or expected health benefits. WTP reflects the value of benefits to those whose lives are improved by policies, and the value should represent complete compensation for those who might be harmed. These quantities exist only *ex ante*, at the moment of choice. They are not equivalent to realized damages.

The WTP approach reflects the observation that individual preferences are unique, and individual demands for risk reduction vary. However, because health and safety are normal goods, some of the variance in WTP estimates will be explained by income differences rather than preferences. So, just as in COI analysis, income and circumstance could play a role in determining the size of WTP estimates.

In practice, regulatory agencies that have adopted WTP have generally adopted a single value for lives saved where the value has been derived from compensating-wage studies. Agencies apply their selected value to every health risk, regardless of the population likely to receive program benefits, the type of risk that might be mitigated, or the level of risk miti-

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[23] Many contingent valuation studies also exploit this relationship.

gated. This practice not only undermines the theoretical validity of the WTP approach but also flies in the face of empirical evidence. The most striking conclusion that emerges from the literature on empirical estimation of WTP is the sensitivity of value-of-life estimates to the characteristics of the study population, the level of risk, and the type of risk. Different populations faced with different risks will place a different value on life and health. There is no universal value that can be used in every situation.

Using the contingent-valuation method for valuing health and safety allows researchers to develop a more thorough mapping of risks and preferences. But, the method relies on consumers' claims about what they would be willing to buy in an imaginary market; consumers do not have to give up anything to respond to analysts' questions. Many economists remain skeptical about applying contingent-valuation techniques to health valuation. However, recently, some have argued that the method could prove useful in exploring health risk tradeoffs that are obscured in market data. For example, Kenkel et al. (1994) portray contingent valuation as the only method for untangling morbidity and mortality issues. In some cases, contingent markets might lead to more reliable results than actual markets because contingent markets are able to eliminate biases resulting from the physician-agent relationship, insurance arrangements, and irrationality in the face of severe disease.

It is possible that with additional studies, analysts will be able to estimate the demand for risk reduction throughout the population (and to separate preferences from income constraints). At that time, analysts will be faced with exactly the same problem facing those using COI. There will be a range of values that vary demographically. Cost-benefit analysts using WTP estimates will then be back in the awkward position of assigning different values to different individuals.

COI and WTP—Is There a Middle Ground?

The cost-of-illness and willingness-to-pay approaches to valuing life and health are built on two very different theoretical foundations and depend on very different data sources for empirical estimation. Each approach has its own strengths and weaknesses. The COI approach provides a measure of social costs. However, estimation is not an exercise that follows a template; data limitations demand an analyst's judgment. Thus, following the approach is neither easy nor obvious. Further, COI is not built on modern principles of applied welfare economics. The WTP approach is a strict measure of individual well-being and is derived from neoclassical welfare theory. However, as consumer risk preferences usually do not leave a clear behavioral trail, analysts have to be creative to estimate WTP. WTP amounts do not provide a straightforward measure of social cost. There have been a number of attempts to develop hybrid measures using the strengths of each approach.

In this chapter, we examine three areas of the health-valuation literature that concern bridging the distance between the COI and WTP approaches. In the first section, we examine efforts to approximate the theoretically correct WTP approach with COI measures. Next, we discuss efforts to "individualize" the COI approach. In the third section, we discuss attempts to add a social component to the WTP approach.

COI as an Approximation of WTP

The COI approach was conceived as a societal, not individual, measure of the costs of illness and premature death. Many economists have examined the usefulness of individual COI estimates in approximating individual WTP, based on the incorrect assumption that estimating COI is straightforward. Though numerous studies have found instances in which COI approximates WTP, the assumptions embedded in these studies are implausible.

In his petition for the WTP approach, Schelling (1966) was one of the first to argue that WTP differs from COI.

There is no reason to suppose that what a man would pay to eliminate some specific probability, P, of his own death is more than, less than, or equal to, P times his discounted expected earnings. In fact there is no reason to suppose that a man's future earnings, discounted in any pertinent fashion, bear any particular relation to what he would pay to reduce some likelihood of his own death. . . . But discounted lifetime earnings are relevant only in the way that they are relevant to ordinary decision about consumption, saving, quitting a job or buying a house. They are part of the income and wealth data that go into the decisions. Their connection is a functional one, not an accounting one.

(pp. 149-150)

In general, the theoretical literature supports Schelling's conclusion: illness and premature death cause changes in individual welfare that go beyond the direct or indirect costs of illness.

Individual welfare change associated with adverse health outcomes (i.e., WTP) is typically decomposed into four elements: 1) lost wages,[24] 2) medical expenses, 3) the dollar value of the disutility of illness, and 4) the impact of preventive expenditures. COI measures the first two elements but fails to capture the second two. The COI approach is not a good approximation of WTP precisely because it does not measure pain and suffering or the value of preventive behavior. In fact, a number of studies find that COI and WTP measures converge only in models that fail to include terms describing the utility of health (disutility of illness) or the influence of preventive expenditures (Linnerooth, 1979; Rosen, 1981; Berger et al., 1994; and Kenkel, 1994).

Linnerooth (1979) reviews and critiques four models that examine the relationship between COI and WTP. Two of the models included in her review establish

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[24] In cases of premature death, this term drops out of the calculations of WTP unless a bequeath motive is specified.

an exact correlation between COI and WTP (Conely, 1976; and Usher, 1971), while the other two conclude that no such correlation exists (Jones-Lee, 1974; and Cook and Graham, 1975). Linnerooth finds that the results of the different models critically depend on the specification of the objective function and particularly on the specification of "consumption." When the objective function is univariate, with utility depending only on lifetime consumption activities entailing a monetary exchange (and no bequest utility), then a direct, one-to-one relationship is established between income (human capital) and WTP. Linnerooth demonstrates that the studies conducted by Conley (1976) and Usher (1971) both depend on such a specification of the objective function in order to establish a correlation between the value of human life and human-capital measures. In both of these models, the value of life can be calculated from data on personal consumption (given assumptions with respect to the form of an individual's consumption utility). In fact, in Usher's model the value of life differs from lifetime earnings only to the extent of diminishing marginal utility of lifetime consumption.

Linnerooth demonstrates that when the objective function is expanded to include non-material consumption activities, the one-to-one relationship between human capital and consumption dissolves, and it is impossible to establish a strict correlation between COI and WTP. The other two models included in the Linnerooth review (Jones-Lee, 1974; and Cook and Graham, 1975) use the state-preference approach (where the states are "alive" and "dead") to derive the relationship between human capital and WTP. Both models break the wealth/consumption/-utility link. Both models include bequest utility and both examine the utility of life with wealth as opposed to the utility of wealth (consumption). These studies assume that the utility of lifetime consumption is only a lower bound to the utility of living. As a result, lifetime earnings are a lower bound to WTP measures of reduced risk of death.

Linnerooth's general conclusions about the relationship between COI and WTP are presented quite clearly at the end of her review,

> The conclusion of this review is that there are no theoretical grounds for establishing an empirically useful relationship between the value, in the form of Hicksian compensating variations in

wealth, of current period changes in a person's risk of death and his lifetime earnings. The significance of this conclusion to the cost-benefit analyst is that there is no testable relationship between the willingness-to-pay and the human-capital approaches to placing a value on the loss of human life.   (p. 71)

In a study following that of Linnerooth, Rosen (1981) develops a simple model with WTP for risk reduction defined as a function of consumption, income, leisure, and the probability of surviving the period. He finds that whether or not WTP exceeds income (i.e., human capital costs) depends on whether or not the utility of death exceeds the utility of zero consumption. Rosen finds this result "arcane and metaphysical" and concludes that theoretical analysis cannot establish an operational connection between human capital and risk valuation (p. 243).

Berger et al. (1994) develop the relations among a health-production function, COI, and WTP. This model includes health in three roles: as a variable in the utility function; as a determinant in the probability and quality of survival in the current period; and as part of the income constraint (the appendix provides a more detailed description of this model). Berger et al. are able to solve for an individual's *ex ante* WTP for an improvement in health status. They find that WTP collapses to COI only under four untenable assumptions: 1) defensive expenditures are nonexistent or unchanging, 2) utility is not enhanced by health, 3) there is no possibility that an illness is fatal, and 4) the value of consumption is equal to the utility of the value of consumption. Berger et al. conclude that "there are no plausible assumptions that can be made to simplify the WTP measure to COI" (p. 37).[25]

The conclusion of the theoretical literature examining the use of the COI approach to approximate WTP measures is that no amount of mathematical or theoretical manipulation changes the fact that there is simply no theoretical justification for equating indi-

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[25] Harrington and Portney (1987) succeed in reducing willingness to pay for a reduction in morbidity to the cost of illness measure under the assumptions that there are no preventive expenditures and that health does not enter the utility function directly.

vidual welfare with medical expenses and forgone earnings. As long as individuals place any value on nonmarket goods, services or intangibles, income and consumption measures will diverge from true welfare measures, and COI measures will diverge from WTP measures.

COI as a Lower Bound to WTP

Though there are no plausible conditions under which COI approximates WTP, there are some conditions under which COI estimates serve as a lower bound to WTP estimates.

Berger et al. (1994) find that, given a positive WTP amount, COI understates the cost of illness for three primary reasons. First, the COI approach neglects savings in preventive expenditures. An individual's WTP for an improvement in a particular health risk is conditioned by the existence of defensive or preventive alternatives. For example, an individual might not be willing to pay a high price for cleaning regional ground water supplies if relatively inexpensive water filters are sufficient to minimize the risk of illness. Conversely, an improvement in ground water quality could lead to reductions in expenditures in water filters. The value of the reduction in water-filter costs would be reflected in the WTP for improvements in groundwater quality. However, the value of the reduction in preventive expenditures is not captured in COI amounts. COI amounts are therefore lower than WTP amounts when preventive expenditures exist.

The second reason COI is probably a lower bound to WTP is that COI measures do not incorporate the direct value of health. COI measures do not include any amounts reflecting the enjoyment of good health or the pain and suffering associated with ill health and premature death.

The third reason that COI is a lower bound to WTP is that while COI measures dollars (which are used to purchase consumption items), WTP measures the utility of consumption purchased with dollars. In general, the value of the utility of consumption is greater than the value of consumption (Kenkel, 1994), so the consumption utility lost due to the expenses associated with illness or death outweighs the expenses themselves. Because WTP amounts reflect the utility of

consumption, they will be greater than COI amounts which reflect only consumption expenditures.

Other theoretical studies support the conclusion that COI estimates are a lower bound to WTP estimates (Jones-Lee, 1974; and Cook and Graham, 1975), as does the overwhelming evidence in the empirical literature (Loehman et al., 1979; Blomquist, 1981; and Rowe and Chestnut, 1984). However, though both the theoretical and empirical literature indicate that COI is a lower bound to WTP, neither suggests that COI amounts are good predictors of WTP amounts. Kenkel et al. (1994) conclude their comparison of COI and WTP measures by observing that in general, WTP exceeds COI, "although there does not appear to be any strong tendency for the two to move together" (p. 100). Changes in COI amounts do not necessarily indicate similar changes in WTP. Studies that rely on COI amounts should not use changes in these amounts to predict similar changes in true individual welfare. A comparison of COI amounts should not be used to compare true individual welfare.

COI Is a Lower Bound of WTP
Only When Restricted
to Individual Costs

All the evidence supporting the hypothesis that COI is a lower bound to WTP is based on a restricted COI measure. COI measures are a lower bound to WTP measures only if COI amounts are restricted to individual costs. COI studies that adhere to the theoretical underpinnings of the approach and measure social costs could feasibly result in COI amounts that surpass an aggregation of individual WTP amounts. If individual valuations do not incorporate social costs and benefits, then COI amounts could be larger than WTP amounts.

There are many cases involving health in which individual and social costs diverge. Most notably, public and private insurance arrangements introduce a wedge between the price the individual pays and the true cost of medical goods and services. Paid sick leave could also lead to differences in individual and social valuations of the cost of illness. Pure altruism could also enter into social costs estimates differently than in private estimates. If COI estimates include a wider array of social costs than individual WTP esti-

mates, then there is no basis for concluding that COI is a lower bound to WTP.

Thus, when analysts compare social costs with health benefits, there are no assurances that COI is a lower bound to WTP.

> At present, direct comparisons of these individual willingness-to-pay estimates and the aggregate cost of illness estimates cannot be made
> (Kenkel, 1994, p. 43).

The "Individualization" of COI

Many of the early applications of the COI approach focused on insuring that COI estimates were undiluted measures of social costs, and these applications were diligent in weeding out purely individual costs. In the early literature, researchers typically calculated COI net of consumption, arguing that consumption represented individual welfare and that the real loss to society from an individual's morbidity and mortality were the net earnings lost to society. Reflecting this reasoning, the National Safety Council's accident costs were computed net of consumption until 1984 (Miller, 1986).

As a rule, consumption is no longer netted out of COI estimates, though most COI studies have continued to pursue a social perspective. Typically, COI estimates have included earnings gross of taxes to reflect the loss to society of forgone earnings, and non-labor income is usually not included in COI estimates, the rationale being that non-labor income would not be lost to society even with the death of the individual. Though most COI studies retain a societal perspective, recent theoretical preference for individual willingness-to-pay valuations has led to attempts to calculate "individualized" COI measures.

One of the most widely cited studies that added an individual element to the COI approach was conducted by Landefeld and Seskin (1982). They individualized their human capital calculations by computing earnings net of taxes, including non-labor income, using an individual, rather than a social, discount rate and including a risk aversion factor. Landefeld and Seskin's COI estimates more closely approximate WTP measures than traditional COI estimates,

although such measures still do not incorporate preventive expenditures or the utility value of health.

The "Socialization" of WTP

The WTP approach is a purely individual measure of the costs of illness and premature death. However, most evaluations of costs and benefits for public policy involve social costs, and there have been a number of attempts to systematically introduce social considerations into WTP estimates.

Bailey (1980) adjusted individual WTP by including costs borne outside the family of a fatality victim, such as future direct taxes on labor and future indirect business taxes on labor that would be lost to society due to an individual's premature death. Arthur (1981) expanded the WTP approach to include economic transfers across society and make WTP estimates actuarial, as in the COI approach. Arthur includes a net social burden term in his WTP formulation so that individual enjoyment of extra life years is offset by consumption costs to society.[26]

There would seem to be a danger of double accounting in any attempt to include an externally defined social cost term in a WTP framework. Many costs that do not bear directly on the individual enter the WTP decision process. In making personal decisions, individuals certainly consider the well-being of their family and friends, and in many cases, the well-being of complete strangers or future generations. The distinction between social and individual is often blurred in individual cost-benefit calculations, meaning that some of the consumption terms introduced in efforts to "socialize" WTP have already been included in the calculation.

WTP represents pure welfare measures because the individual incorporates all relevant costs and benefits to choose the highest valued alternatives. To retain

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[26] Arthur's "social consumption equivalent" function is the basis for statistical value-of-life estimates calculated by Miller (1986) and Miller, Calhoun, and Arthur (1989) and is therefore incorporated in cost-benefit analyses conducted by a number of government agencies (e.g., Federal Highway Administration, Consumer Product Safety Commission).

its theoretical validity, social considerations should be introduced directly into the individual's utility-maximization decision and not simply added on as a correctional term.

Is There a Middle Ground? Some Conclusions

In general, any attempt to find a middle ground between WTP and COI seems to reduce, not improve, the theoretical justification of either approach. Efforts to mimic WTP estimates with COI seem especially ill conceived. Individualized COI estimates are, at best, poor substitutes for WTP estimates, and, in the processes of becoming poor substitutes, they lose many of their good qualities. Individualized COI estimates lose their transparency, their value in economic accounting, and their theoretical foundation as welfare measures. The COI approach has no theoretical basis as an individual welfare measure. Conversely, socialized WTP measures that supplement individual valuations with social consumption costs could result in measures that actually overstate true social costs.

Refraining from Assigning Values to Life and Health— Cost-Effectiveness Analysis

In conventional cost-benefit analysis, all benefits are assigned a dollar value. But, as noted in the introduction, an analyst or policymaker may be uncomfortable with assigning dollar values when benefits are human health and safety. In this case, cost-effectiveness analysis may look attractive. With cost-effectiveness analysis, analysts do not assign a dollar value to health benefits. Instead, benefits are simply a count of the adverse outcomes averted. Benefits are left in physical terms and not monetized.

Cost-effectiveness analysis is a comparison of costs with the number of physical benefits. The ratio of dollar costs to physical benefits is the cost per physical benefit. The program with the lowest cost per benefit is the most cost-effective. When comparisons are made between programs having identical types of benefits, cost-effectiveness analysis yields a cardinal ordering of alternatives. Numerical summary measures show which intervention is most and least cost-effective. For example, to study the effects of intervention strategies on heart disease, analysts can compare costs and the number of strokes averted by different programs. The program with the lowest cost-per-stroke-averted is the stroke-prevention program that is most cost-effective in the sense that dollars-per-stroke is minimized. The difference between minimum cost-effectiveness and cost-effectiveness of a particular program measures the sacrifice in efficiency associated with the program.

In this section, we show that conclusions drawn from cost-effectiveness analyses share many undesirable characteristics with conclusions drawn from conventional cost-benefit analyses, using COI or WTP to estimate benefits, but do not share many of the desirable characteristics. In particular, when analysts base their policy recommendations on cost-effectiveness analysis, their analyses will usually be subject to the influence of income and circumstance, just as with cost-benefit analysis. However, unlike cost-benefit analysis, they will give up the ability to rank diverse programs and to show whether net benefits are positive or negative. Only by luck will program rankings match those derived from cost-benefit analysis.

Background

Cost-effectiveness analysis has been used extensively to evaluate the desirability of medical technologies (Hildred and Watkins, 1996). In medical decision-making, cost-effectiveness analyses are carried out more frequently than conventional cost-benefit analyses. Elixhauser et al. (1993) indicate that about two-thirds of analyses of health-related technologies, services, and programs are cost-effectiveness analyses.

Mushkin (1979, pp. 19-20) recommends cost-effectiveness analysis over cost-benefit analysis when it is difficult to assign a price to health benefits. Garber et al. (1996, p. 28) state that it is the difficulty of carrying out cost-benefit analyses (largely the task of assigning values to health outcomes) and the discomfort associated with assigning monetary values to health outcomes that has led to rejection of cost-benefit analysis. Haddix and Shaffer (1996, p. 104) report that the public health community initially embraced cost-effectiveness over cost-benefit analysis because the former was less burdensome and less complex to execute.

There are very specific conditions under which cost-effectiveness analysis is especially useful. If an irrevocable decision has been made to take an action to prevent an adverse outcome, but no decision has been made about technique or method of action, cost-effectiveness analysis can help minimize costs. Folland, Goodman, and Stano (1993, pp. 638-9) note that cost-effectiveness analysis has been frequently applied by the Department of Defense. There, objectives can be quantified in terms like the ability to deploy forces, and analysts often are assigned goals of finding the most efficient means of achieving specified objectives. A private sector health care administrator or a government official responsible for some aspect of public health may face similar situations. A health care administrator may be compelled to offer a particular health care service. A government official may be compelled to put in place a program to reduce some particular health risk. Still, each may have the latitude to choose among programs that accomplish the mandated goal. Each can strive to receive more

benefits per dollar rather than less. Cost-effectiveness analysis may assist in making such choices.

Inability To Rank Diverse Programs and To Determine Whether Net Benefits are Positive or Negative

Cost-effectiveness cannot be used to rank options when program outcomes differ. For example, cost-effectiveness does not offer a way to compare the costs and benefits of a program that provides kidney dialysis with those provided by a nutrition program. A cost-effectiveness analysis of each would yield two calculations: the cost for treating individuals whose kidneys have failed and the cost of averting a particular diet-related illness. The benefits of blood purification cannot be compared with the benefits of a more healthful diet. When health outcomes differ, program benefits are measured in different units of account and are not comparable. This situation differs from WTP or COI where both benefits and costs of all options are denominated in dollars, and programs with diverse types of health benefits can be ranked.

In addition, cost-effectiveness estimates do not, by themselves, suggest whether any of the examined programs meet the test of efficiency. Because cost-effectiveness analysis measures costs and benefits in different units, no concept of net benefits emerges. Consider, for example, two programs that could avert *Salmonella* infections. Suppose one program costs $1,000 per infection averted and the other $2,000. The cost-effectiveness calculations indicate that the first program offers the greater benefit per dollar. But, it does not reveal whether the program is actually worth the price.

A cost-benefit analysis using WTP or COI as benefits could reveal whether the most cost-effective program costs more than it is worth. Where benefits are monetized, calculating net benefits is easily accomplished (by subtracting costs from benefits), and the sign and magnitude of that calculated value indicates how desirable the program is. But cost-effectiveness analysis does not provide any means of judging whether a program offers positive net benefits. Finding the most cost-effective program is simply a different activity from evaluating benefits using WTP or COI.

Three Variants of Cost-Effectiveness Analysis

Different decisionmakers have different goals and methods for carrying out cost-effectiveness analyses. These differences are not always obvious to those who use cost-effectiveness calculations to make comparisons among programs, and consistency across studies is a problem for cost-effectiveness analysis and for interpretation of results. Gold et al. (1996) note the variety of decisionmakers implicit in cost-effectiveness analyses.

> The imprecision attached to the term "cost-effective" stems also from the variety of masters the concept serves. Purchasers of health care use the term to convey a careful assessment of the relative value of different health care services; producers of health care technologies and programs use the idea to support marketing claims; advocates for particular illnesses or constituencies use the term to garner resource investments.   (p. xvii)

The characteristics of cost-effectiveness analysis will differ markedly depending on who the decisionmaker is and what the objectives are. Where analysts address societal problems using cost-effectiveness analysis, they tally a wider class of dollar costs than when choicemakers have a narrower focus, say that of health care institutions and third-party payers (Torrance et al., 1996, pp. 60-61). Activities that count as costs will differ, and the way in which health benefits are tabulated will differ, depending on which goal analysts (at least implicitly) embrace.

At least three variants of cost-effectiveness analysis can be distinguished, depending on the decisionmaker and goals. The first variant of cost-effectiveness analysis entails the ratio of program costs to a count of health benefits. In this type of analysis, costs are outlays for program administration. Benefits are typically the number of adverse outcomes averted, like cancers averted or premature fatalities avoided. From the perspective of satisfying individual preferences or of maximizing aggregate income, such measures are likely to be incomplete and of limited value in making public health decisions. The information would be useful, however, for a financial officer attempting to satisfy a policy goal at minimum budget exposure.

The Superfund site calculations carried out by Viscusi and Hamilton (1996) are examples of the first variant of cost-effectiveness analysis. They calculated cost-effectiveness by dividing *clean-up costs* by cancers averted. Their methods were sufficient to draw attention to the extraordinary costs per benefit that had been incurred. But such calculations do not suggest a means of allocating funds among public health and safety programs that would satisfy individual preferences or maximize aggregate income.

Selecting the most cost-effective program, measured with the first variant of cost-effectiveness, leads to choices that differ from those made by self-interested individuals. Cost-effectiveness tabulates health benefits as a count. This method is egalitarian in that everyone's benefits count equally, regardless of income. However, individual preferences for health benefits vary, and treating everyone alike eliminates the influence of preferences as well as income. Clearly, this is not an individual welfare measure.

The first cost-effectiveness variant is also unlikely to satisfy the objective of maximizing aggregate income. Cost-of-illness is a better tool to satisfy that goal. That is, selecting projects that maximize the difference between cost-of-illness that might be averted and mitigation costs, maximizes aggregate income. This calculation of net benefits is composed of dollar-denominated additions to income and dollar-denominated subtractions from income. Cost-effectiveness fails to maximize income because government expenditures directed toward mitigating a health hazard are only a part of dollar-denominated net benefits.

The only decisionmaker for whom this cost-effectiveness matters is one that attempts to avert the maximum number of adverse health outcomes at minimum budget exposure. Budget exposure is important to questions of government accounting and finance. But it is clearly not equivalent to aggregate income or to individual welfare.

The second variant of cost-effectiveness analysis involves replacing program costs with net costs, where net costs are the direct program costs minus the reductions in cost-of-illness resulting from each program. Haddix and Shaffer (1996) detail methods for the second cost-effectiveness variant, measuring societal costs and benefits (pp. 109-127). For questions with a societal perspective, they argue for com-

paring net costs with a count of adverse health outcomes averted.[27]

$$Cost\ effectiveness = \frac{Net\ cost}{Total\ adverse\ health\ outcomes\ averted} \quad (5)$$

Jones-Lee (1994) describes net costs as capital costs minus other benefits. Haddix and Shaffer treat net costs of carrying out a program as program costs minus the change in the cost-of-illness. That is, if a program reduces risks and COI falls, the reduction in COI is attributed to the program. In that case, the real costs imposed on society by financing the program are not as large as the direct expenses for the program. To find the real cost to society, Haddix and Shaffer suggest that analysts subtract the reduction in COI attributed to the program from the direct financing costs of the program.[28]

$$Net\ cost = Cost_{Program}$$
$$- Reduction\ in\ cost\ of\ illness \quad (6)$$

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[27] Haddix and Shaffer define the ratio of net cost to total adverse health outcomes averted as "average CE ratio," noting that incremental costs of various levels of programs can also be calculated. The average and incremental estimates allow decisionmakers to find an optimum level for the most cost-effective program. The importance of the incremental calculation can be seen in an often-cited cost-effectiveness study by Neuhauser and Lewicki (1975). They studied a colon cancer screening protocol. The protocol consisted of six sequential stool tests for occult blood with follow-up testing for positive results. Neuhauser and Lewicki showed that incremental cost per detected cancer increased an order of magnitude with each sequential test, reaching over $47 million for the last test (not accounting for inflation). The importance of program scale was not so well revealed by the average cost-effectiveness.

[28] Clearly, both Jones-Lee and Haddix and Shaffer describe programs financed by the public sector. An entirely different conception of costs, including regulatory compliance costs, must accompany an analysis of regulatory changes intended to protect public health.

As COI consists of direct and indirect costs, analysts have to calculate changes in both types of costs.

$$\text{Reduction in cost of illness} = \qquad (7)$$
$$\text{Direct medical expenses averted}$$
$$+ \text{Value of productivity losses averted}$$

Haddix and Shaffer define direct costs as the costs of diagnosis and treatment associated with cases of the health problem averted, as well as the cost of unintended side effects of treatments. For indirect costs they recommend calculating productivity losses (human capital costs). In this variant of cost-effectiveness analysis, analysts assign values to people equal to their productivity. As a result, these cost-effectiveness estimates functionally depend on income and circumstance. Thus, everything else equal, a program that benefits only men will be more cost-effective than a program benefitting women because men's wages are generally higher than women's wages.[29]

Garber et al. (1996, p. 51 footnote 11) note that calculating cost effectiveness by subtracting the change in COI from program costs is identical to a cost-benefit analysis in which COI serves as program benefits. From a purely mechanical perspective, exactly the same quantities are calculated as would be in a cost-benefit analysis in which the change in the COI represents benefits. With cost-benefit analysis, net benefits could be calculated as the change in COI minus the program costs. Net benefits would be, in this case, exactly what Haddix and Shaffer describe as net costs, after accounting for sign differences. The principal difference between the two calculations is that cost-effectiveness analysis divides net cost (or net benefits) by a count of adverse outcomes averted. This last calculation means that cost-effectiveness is a per capita measure rather than a total. In this case, cost-effectiveness analysis appears neither less complex nor less burdensome to carry out than a cost-benefit analysis.

Like COI, the implicit goal of the second variant of cost-effectiveness analysis is national or aggregate income maximization. This variant of cost-effectiveness analysis would be useful to an aggregate income-maximizing central planner.

The third variant of cost-effectiveness analysis is described by Garber et al. (1996). They suggest that program costs ought to include individual opportunity costs, such as the value individuals place on time lost to morbidity. With this variant, instead of counting adverse outcomes averted, analysts tabulate annual program-induced health changes over an individual's lifetime. Each of the annual changes is expressed on a zero-to-one scale, with zero representing no change in health over a year and one representing an added year of life in robust health. Intermediate health increments are valued in the 0-1 interval, converting all benefits to a common unit of account, the Quality-Adjusted Life Year (QALY).[30] For example, a new vaccine for a quickly fatal illness would prevent some premature deaths. The benefits of making the vaccine widely available could be calculated as the discounted sum of life years added. On the other hand, a palliative treatment might not add any years of life, but make years of illness more pleasant. The years of improved well-being could be evaluated as the fractional equivalent of a year of good health. The discounted sum of these fractions can be counted as QALYs. Adding all individual's QALYs yields a measure of program benefits. This variant of cost-effectiveness analysis is often called cost-utility analysis

QALYs translate all health consequences into a common unit of account for health benefits. Dividing program costs by QALYs yields a price per QALY. Thus, quite diverse programs can be ranked. However, as benefits and costs are in different units of account, no net benefit concept emerges. Like the other cost-effectiveness variants, this version does not suggest whether any program is worthwhile.

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[29] Examining the period 1967 through 1984, Berndt (1991) observed that median weekly earnings of females were about 62 percent of those of males. The ratio has been rising, and in 1996 reached 75 percent. The ratio of earnings of blacks to whites was 76 percent in 1996 (calculated from statistics in U.S. Dept. of Labor, Bureau of Labor Statistics, *Employment and Earnings*, Jan. 1997, p. 204).

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[30] Gold et al. (1996) examine a variety of ways of revealing these relative utility levels.

This variant of cost effectiveness analysis offers additional information when program benefits are primarily improvements in the quality of life, rather than in its quantity. That is, it offers a quantitative measure, a count, of a subjective quality variable. However, when program benefits are entirely reductions in premature death, program benefits are identical for everyone. Each fatal illness averted represents a fixed number of life years added. As each life year counts as 1.0, regardless of who accrues the life year, the QALY count would be a multiple of the number of illnesses averted. The multiplier would be the number of life years saved by the vaccine. In this case, a cost-effectiveness estimate would be equivalent to a multiple of the first variant of cost effectiveness.

When programs affect only quality of life, leaving expected life spans unchanged, program ranking derived from a QALY count will be guided by income and circumstance just like the second variant, in which the choicemaker is a net national product-maximizing central planner. If the opportunity cost of morbidity is not counted in QALYs, such costs are counted in the numerator, evaluated at current wages. Garber et al. (1996, p. 41) observed that this practice raises the now familiar fairness question.

> To the degree that wages reflect opportunity cost, the time of persons in demographic groups that tend to have lower-paying occupations would be valued less. It remains controversial whether it is ethically acceptable, for example, to value the time of women less than that of men in CEAs [cost-effectiveness analyses], although this is the implication of the theory.

Income and Circumstance Influence Cost-Effectiveness Analysis

The surprising feature of cost-effectiveness analysis is that when analysts attempt to make their calculations relevant to public health decisions, either accounting for individual preferences (variant 3) or accounting for social costs (variant 2), policy guidance will be influenced by income and circumstance. All else equal, programs that offer benefits for the well-to-do will show greater cost-effectiveness than programs offering identical health benefits to the poor. In this regard, policy guidance offered by an

analyst using cost-effectiveness is no different from guidance derived from conventional cost-benefit analysis where all benefits are monetized.

Cost-Effectiveness Analysis Does Not Measure Welfare

Using cost-effectiveness analysis, it is possible to have income and circumstance influence program choices without necessarily satisfying individual preferences. A simple example using the second variant of cost-effectiveness analysis shows that the ranking of programs from cost-effectiveness analysis may be entirely different from cost-benefit analysis based on WTP.[31] Suppose there is an environmental contaminant that causes cancer, and that everyone is equally exposed and susceptible to that cancer. Everyone faces exactly the same lifetime probability of contracting that cancer. Treatment costs are identical for everyone. Consider two potential programs that could eliminate exposure to the carcinogen, with one program benefiting only men and the other only women. That is, each program eliminates the risk for one half the population and does nothing for the other half.

The male-female wage differential means the program benefiting men will be calculated to be more cost-effective than the program benefiting women because the calculated indirect costs-of-illness prevented by the program for men would be higher than that for women. As the program costs and direct medical expenses averted are identical, net costs of the program benefiting men would be less than net costs of the program for women. With identical health benefits, the program with lower net costs would be more cost effective.

If we knew nothing about preferences, one might suspect that conventional cost-benefit analysis would point programs in the same direction as the second variant of cost-effectiveness. That men's wages exceed, on average, women's wages implies men have greater ability to pay for cancer risk reduction. If cancer risk reduction were a normal good, men's

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[31] Conversely, Phelps and Mushlin (1991) argue that cost-benefit analysis and cost-effectiveness analysis often suggest similar or identical decisions.

greater ability to pay would imply greater demand for risk reduction, or equivalently greater willingness-to-pay for risk reduction.

However, studies of risk perceptions show clear demographic differences that sometimes swamp the influence of income. Flynn et al. (1994) show men are likely to dismiss the importance of a small environmental cancer risk. Men's willingness-to-pay for such risk reduction is therefore likely to be negligible. Women's willingness-to-pay to eliminate such a risk may be positive. Clearly, the ranking that results when projects are ranked by WTP analysis depends on the distribution of benefits and individual preferences. By luck, the ranking could mirror that of cost-effectiveness analysis. However, it would be just by luck for similar rankings to occur.

Program rankings derived from cost-effectiveness analysis will be similar to rankings from WTP studies only when WTP is so constrained that it loses its ability to represent individual preferences, its reason for being. When agencies require analysts to use the same single value for value of life (say, $5 million for all people and all risks), there is little difference between cost-benefit analysis and the first variant of cost-effectiveness analysis. To see this relation, denote this single value as *WTP*. Then, the dollar-denominated benefits would be nothing more than a multiplicative transformation of the count of adverse outcomes averted.

$$Dollar\ benefits = \qquad\qquad (8)$$
$$Total\ health\ outcomes\ averted\ x\ WTP$$

In this case, a cost-benefit analysis would compare program (or compliance) costs with dollar benefits, as in equation 8. This comparison is nearly identical to calculations carried out under the first variant of cost-effectiveness analysis, which compares the count with program (or compliance) costs. As the difference between the two types of analyses is only a constant multiplicative transformation, this variant of cost-effectiveness analysis yields a program ranking identical to the ranking based on *WTP*. When analysts can estimate some of the systematic differences that exist, cost-benefit analyses may provide policy guidance that is quite different from cost-effectiveness.

The Importance of Transparency

A primary failing of cost effectiveness is that it does not convey information about net benefits. Thus, cost-effectiveness calculations can guide policymaking only if the person using the results assigns prices to life and health. Cost-effectiveness might reveal the cost of treating an individual whose kidneys have failed. But the decisionmaker has to decide whether it is worth incurring that cost. He has to compare that cost with what it is worth to him to keep the person alive. In effect, the decisionmaker has to acknowledge some reservation price, the maximum he would be willing to pay to continue the life of the individual whose kidneys have failed. An undertaken program must satisfy the condition that the decisionmaker's reservation price (the highest price he attaches to each health outcome) is greater than the cost of averting the adverse health outcome.

$$\frac{Net\ cost}{Total\ health\ outcomes\ averted} < \qquad (9)$$
$$Reservation\ price \Rightarrow Undertake\ project$$

When the decisionmaker chooses projects based on a rule relating his own subjective valuations of life and health to cost-effectiveness estimates, two entirely different sets of values are driving decisions. In calculating cost-effectiveness, analysts using variant two or three have imposed values for life and health equivalent to the value of lost productivity, usually wages paid. The decisionmaker's values are of course unique and not necessarily equivalent to earned income. However, it is the decisionmaker's reservation prices for different health outcomes that set net-benefit levels. The decisionmakers' unique values transform cost-effectiveness calculations, derived valuing lives as income, into net benefits that are either positive or negative.

Analysts' policy guidance may be greater if they know the decisionmaker's reservation prices. If they know the decisionmaker's reservation price for a cancer averted, then analysts can calculate the value to the decisionmaker of the health benefits each cancer prevention program provides. Armed with dollar values of benefits and costs, the analyst can calculate net benefits (using a consistent set of values), and thereby show which program offers greatest net benefits and

which offers positive net benefits. Given reservation prices for strokes and cancers prevented, the analyst can compare the relative cost-effectiveness of stroke and cancer prevention programs. Of course, this estimate of net benefits would be in terms of the decisionmaker's values. Such an estimate would differ from conventional cost-benefit analysis because reservation prices are based on decisionmakers' values rather than on the values of those who might benefit. Obviously, the two sets of estimates need not converge.

Conclusion

The best use for cost-effectiveness analysis may be that demonstrated by Viscusi and Hamilton (1996), using the first variant. This variant of cost-effectiveness may serve as a coarse filter, helping to screen out programs that more complex analyses would also show are not worthwhile. Cost-effectiveness analysis could reveal those programs for which benefits are dwarfed by costs. Though useful in some situations, this use of cost-effectiveness has no theoretical appeal. It is not an individual welfare measure and does not fully account for costs avoided by programs. Thus, it cannot provide information useful for satisfying individual preferences or for helping an income-maximizing central planner. Failure on both of these counts means it cannot be considered a substitute for conventional cost-benefit analysis. Cost-effectiveness is less useful than conventional cost-benefit analysis because it cannot rank all activities or address whether any is worthwhile.

The often-stated reason for using cost-effectiveness analysis is that it avoids assigning values to life and health. Clearly, there is no merit to that claim. Cost-effectiveness simply pushes the pricing problem on to the decisionmaker. In addition, analysts may implicitly assign prices when making cost-effectiveness estimates. Those prices will be influenced by income and circumstance, making policy guidance subject to the same factors that cost-effectiveness tries to avoid. Cost-effectiveness can require making all the same estimates as conventional cost-benefit analysis. So the claim that it is easier to accomplish is incorrect.

Eliminating Dollars from Cost-Benefit Comparisons—
Risk-Risk and Health-Health Analysis

The previous chapter on cost-effectiveness analysis examined methods by which analysts try to avoid assigning dollar values to health and safety benefits. In this chapter, we examine methods by which analysts compare program costs and benefits without monetizing either benefits or costs. We first examine risk-risk analysis which was the first tool put forward for such comparisons. Risk-risk analysis is useful only in making choices when options are very restricted. It usually cannot rank programs or indicate whether net benefits are positive or negative. The other technique we examine, health-health analysis, is restricted to cases of mortality. It does, however, maintain some of the desirable characteristics of methods that monetize benefits and costs: it can rank programs and measure net benefits. This method explicitly relies on income to identify health costs of programs. The influence of income and circumstance is an integral part of the analysis.

Risk-Risk Analysis Is
Not Influenced by Resource Scarcity

Health policy analysts have long recognized that many policies designed to lower particular public health risks unintentionally raise other risks. Lave (1981) argued that analysts could gauge the net health benefits of intervention by comparing the risks that government programs might reduce with the risks that these programs create. He named such a comparison risk-risk analysis. A risk-risk analysis enumerates the risks that are reduced and risks that are inadvertently increased. Both the desirable and undesirable risk changes are denominated in physical, and not dollar, terms.

Lave used the example of scrubber construction to illustrate how risk-risk analysis could be used to compare program benefits and costs. Health risks derived from pollution emitted from coal-fired electric generating plants might be reduced by installing scrubbers. But, as construction is a relatively risky occupation, building scrubbers is likely to raise the probability of injury for those involved in construction. Lave suggested that costs and benefits of government policy
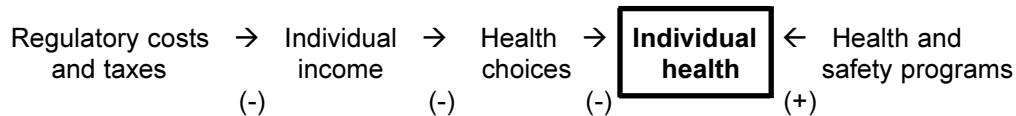
could be examined comparing the health benefits derived from improved ambient air quality with injuries incurred by scrubber construction.

As a practical matter, the health benefits and health costs included in risk-risk analysis are usually quite different. For example, suppose a water chlorination program were being evaluated on a risk-risk basis. Chlorinating water reduces exposure to a wide class of bacterial pathogens. Health benefits of chlorination consist of reduced incidence of many infectious diseases, including typhoid fever and cholera. Health costs consist of a higher risk of cancer through increased chlorine exposure. A risk-risk analysis would tally the reduction in the incidence of infectious diseases as health benefits and the increased incidence of cancer as health costs.

The notion of opportunity cost implicit in risk-risk analysis is a very small portion of opportunity cost in conventional cost-benefit analysis. In risk-risk analysis, the cost of reducing infectious diseases through chlorination is future cancer cases. The cost of carrying out the chlorination program and the cost of allowing preventable infectious diseases to persist are not tallied. Thus, risk-risk analysis does not offer distinctions between expensive programs that offer few benefits and programs that dramatically reduce health risks at little expense. Resource scarcity does not much influence benefits and costs tallied in risk-risk analysis.

As benefits and costs are usually tallied in different units, neither of which is dollar-denominated, risk-risk analysis offers no estimate of net benefits. Even if the limited opportunity cost notion implicit in risk-risk analysis were sufficient for decisionmaking, the lack of a common unit of account for benefits and costs poses problems for decisionmakers. In effect, the decisionmaker must assign prices to both benefits and costs. When a single program is at issue, say, deciding how many cancers can be tolerated to reduce waterborne diseases, the decision may be daunting. Where there are multiple programs at issue, each offering different health benefits or health

Figure 1. Causal chain linking program choices to health

Regulatory costs → Individual → Health → **Individual** ← Health and
and taxes   income   choices   **health**   safety programs
(-)   (-)   (-)   (+)

costs, the demands placed on the decisionmaker expand without bound.

Further, it would be very unusual for risk-risk analysis to offer a ranking of programs. To rank programs with risk-risk analysis, all programs that reduce a particular risk would have to induce the same set of health effects. Chlorination, for example, could be compared only with other water treatments that both control waterborne pathogens and are carcinogens. And even under such a constraint, it would be very unusual for a straightforward ranking to appear. Suppose a set of water treatments were carcinogenic and each controlled the same single pathogen. Then, analysts could tally the number of desirable health outcomes (say, a number of cholera cases reduced) and the number of induced adverse health outcomes (a number of cancers) attached to each program. If there were a program that displayed greater reductions of cholera and fewer induced cancer risks than all others, analysts could point to that program as most desirable, under a goal of reducing risks regardless of other costs. If instead, programs that most reduce risks also induce the greatest number of adverse outcomes, decisionmaking must be more complex, requiring someone to trade off cholera cases against cancers. That is, a count of desirable and undesirable health outcomes does not by itself suggest a way of trading off one for the other.

It is likely that many programs control or induce multiple health outcomes (like the large set of infectious diseases actually controlled by chlorination). In this case, an obvious best program is extremely unlikely to appear. As in the water treatment example, decisionmakers can avoid making tradeoffs only if there is a program that offers greater reductions in all infectious diseases than any other program, and that program induces fewer cancers. If the programs offer varying levels of control of each of the infectious diseases, no best choice is obvious just from the tally of diseases prevented and cancers induced. Under these conditions, analysts can construct a ranking only if they know how to trade off cholera cases against

typhoid fever cases, as well as how to trade off infectious diseases cases against cancers.

Risk-risk analysis is most useful in cases of all-or-nothing decisions. That is, only one program is offered and the decisionmaker must decide either to go forward with the program or accept the status quo. When there are more options, risk-risk analysis shifts most of the burden of analysis to the decisionmaker.

Health-Health Analysis Incorporates Resource Scarcity

Relatively new developments in economics suggest a role for analyses that do not monetize benefits or costs (Lutter and Morrall, 1994). There is a new technique by which analysts can estimate non-monetized benefits and costs that is consistent with the notion that resources are scarce.

The logic of this technique lies in two observations. First, risk reduction is a normal good, purchases of which increase with increasing income and decline when income falls. Second, government programs, even those that directly serve public health, have to be financed. Money for those programs has to come from individuals, and thus paying for programs reduces individuals' ability to purchase risk reduction privately.

The causal chain between financial costs imposed by government programs and unintended or induced adverse health effects is shown in figure 1. Negative effects proceed from left to right (eventually influencing individual health). Intended positive effects of risk reduction proceed from right to left, directly influencing individual health.

Reading from left to right, figure 1 shows that taxes reduce individual disposable incomes and constrain each individual's ability to purchase safety. A reduction in individual purchases of health-promoting goods and services will lead to increased mortality and morbidity. Reading from right to left, figure 1

indicates the direct benefits of government-sponsored health and safety programs.

Lutter and Morrall (1994) describe the small set of regulatory and judicial decisions regarding workplace safety that have been influenced by the logic in figure 1. More recently, Gramm and Dudley (1997) analyzed proposed EPA ground-level ozone standards, arguing that the economic cost of complying with the standards would result in a net increase in deaths:

> ...EPA's partial cost estimate implies an increase in mortality in the range of 50 to 700 deaths each year. If our estimate of the full costs is accurate, the financial costs of this rule could result in more than 7,000 deaths per year.
>
> (p. 18)

Lutter and Morrall argue that analysts could compare a count of fatalities averted by public-sector programs with a count of fatalities induced by regulatory costs. They named such a comparison "health-health analysis." Such analyses retain some of the desirable characteristics of conventional cost-benefit analysis. Because benefits and costs are measured in the same unit (lives), net benefits can be calculated. If we maintain the notion that positive net benefits are indicated when benefits are numerically greater than costs, net benefits are positive in the case when government health and safety programs save more people than they inadvertently kill.

Keeney provides some illustrative calculations, showing how changes in income could be used to examine regulatory costs and benefits. He postulates a negative exponential shape for the function relating income to mortality based on the observations that the poor do not live as long as the rich and that there is a limit beyond which no amount of health expenditure will reduce the mortality probability. Keeney relies on existing statistical studies measuring income and mortality, and demonstrates a relation between income and health. He calibrates his postulated functional form as in fig. 2.[32]

Figure 2

Negative exponential income-mortality function
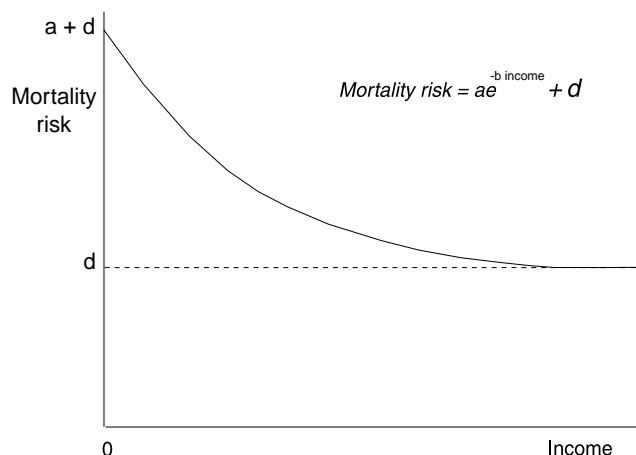

$$\text{Mortality risk} = ae^{-b\,income} + d$$

Figure 2 is an exponentially decreasing function relating income to the probability of death. The parameters a, b, and d are assumed positive. The probability of death is highest, a + d, when income is zero. Parameters a and b indicate the rate at which the probability of death diminishes with increases in income. With this function, that rate decreases as income increases. Increases in income are unable to reduce the probability of death below the level indicated by d.[33]

Lutter and Morrall (1994) show that the relation between income and mortality could be derived from a model of individual utility maximization.[34] Their model reveals a particular theoretical relation between income and mortality: the income loss nec-

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[32] Lutter and Morrall graphically presented income and mortality panel data from 101 countries. Their visual data presentation is striking confirmation of Keeney's observation.

[33] Figure 2 has a negative slope, indicating that many risk decisions could be affected by income changes and analysts do not know exactly which health effects are most important. There are cases where particular health effects could be linked to income, and in those cases the relation between income and mortality can be more complex than figure 1 indicates. For example, Ruhm (1996) empirically shows the relation among income, alcohol consumption, and automobile fatalities. As alcohol is a normal good, income reductions lead to reduced consumption and a reduced number of intoxicated drivers. Fewer alcohol-related automobile fatalities occur when income levels fall.

[34] They did not specify a particular form for the utility function. Thus, their model does not yield a particular functional form for the linkage between income and mortality.

essary to induce one premature fatality is proportional to the willingness to pay to avoid a premature statistical death.

Instead of looking for particular risks that inadvertently arise, as in risk-risk analysis, Lutter and Morrall argue that analysts should look at how programs influence individual behavior toward risk. They argue that individuals are responsible for managing risks they face. Every choice a person makes requires choosing an acceptable level of risk. Individuals make risk decisions when they choose their medical care, the neighborhoods in which they live and work, safety features built into cars and appliances, foods they eat, and a host of other goods. These risk choices affect health and safety, and like other health- and safety-enhancing goods and services, these choices tend to be influenced by income (see discussion in "Cost-of-Illness Approach"). The risk levels individuals voluntarily accept depend on how much risk reduction they can afford. When incomes rise, individuals generally purchase greater assurance of safety. When incomes fall, individuals can afford less risk reduction and life becomes more risky.[35]

Lutter and Morrall explain the relation between taxes and health risk by observing that tax and regulatory policies influence disposable income, and through income, these policies influence the way individuals manage the risks they face. That is, policies influence individuals' ability to pay for risk reduction. Thus, any government action financed by additional taxes or any government program imposing compliance costs, will be accompanied by a predictable increase in adverse health outcomes. As a result, an action intended to protect public health may reduce some risks while inducing others.

For the many people in robust good health, it would take an extraordinary income loss to reduce their health, far beyond the tax price they might face from a single new government program. It would be very unlikely for a typical tax price to influence a particular person's health. But, these observations do not diminish the importance of the relation between government expenditures and health. When we consider costs incurred in national or global markets, even price increases that appear small (or wage increases that fail, by even the slightest margin, to keep pace with inflation) may have measurable risk consequences. Consider an action that raises some consumer prices and takes only a few dollars from an individual's purchasing power. Forecasts for the survival of that particular person would not be much affected by such a small change in opportunities for risk reduction. Perhaps fatality risks might rise by a factor of one-in-a-million because of some trivial sounding change in behavior. However, with 260 million people facing similar reductions in purchasing power, and each making some trivial sounding adjustments in behavior, we could anticipate 260 deaths. (See Chapman and Hariharan (1996, p. 53) for statistical evidence showing the relation between marginal income changes and mortality.) The numerous sources of adverse health outcomes might not be identifiable, but their aggregate result would be real deaths and illnesses.

An income-mortality function of the shape Keeney described means that the health consequences of new taxes and regulatory costs may differ among consumer sub-classes. Keeney showed that all income changes are not alike: changes that vary according to demographic patterns may change aggregate mortality even when income changes are strict transfers. For example, the health consequences of income losses imposed on the relatively wealthy may be much smaller than those from losses imposed on consumers of modest means, and a transfer from one group to the other may leave aggregate income unchanged but change average mortality. Following Keeney's postulated exponentially decreasing function relating income to mortality, the incidence of program-induced mortality is regressive, with equiproportionate impacts on income causing more than proportionate adverse impacts on the poor.

Empirical Evidence Linking Income and Mortality

One of the most difficult steps in conventional cost-benefit analysis is monetizing health benefits. The counterpart in health-health analysis is the step that transforms dollar costs into lives lost. Cost-benefit

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[35] Of course there are highly risky goods and services such as skiing, sky diving, and mountain climbing that are consumed primarily by the rich.

and health-health analyses share the characteristic that they transform one variable into the unit of account of the other. For health-health analysis, the critical step is estimating the impact of income losses on mortality.

Numerous studies have offered insights into the relation between income and mortality using both macroeconomic data and individual health and income records. Most studies have produced point estimates of the relation between aggregate (or average) income and average mortality. Both Lutter and Morrall (1994) and Viscusi (1994) summarize results of statistical studies examining the relationship between income and mortality. Both establish some commonality among the studies by calculating, like Keeney (1990), an aggregate income loss per statistical death for each study. The estimates range from $1.9-$33.2 million (Nov. 1992 dollars). As Viscusi notes, "...these studies differ widely in the time period analyzed, the sample being addressed, and the other variables taken into account" (p. 8). Viscusi cites a study by Chapman and Hariharan (1994) that yields a middle-of-the-range estimate of a $13.3-million drop in income yielding a statistical death. The Lutter and Morrall list includes several studies with estimates similar to those of Chapman and Hariharan.

An analysis limited to deriving impacts based on relations among averages may conceal distributional effects. More precise information about who incurs dollar losses will result in better estimates of the number of induced fatalities. Without accounting for incidence, estimates could fail to describe some large adverse effect on a particular subpopulation. More recent work has accounted for major demographic differences in estimating the functional relation between income and mortality. Chapman and Hariharan (1996) carried out a longitudinal study of men initially aged 45-59, accounting for initial health status and some genetic factors influencing longevity. They found that the drop in income that induces a death in the lowest income quintile is approximately one-half the cost that induces a death in the highest income quintile. Further, they showed that most of this difference is between the highest and second-highest income quintiles: differences among the bottom four quintiles are relatively small. Differences between the median and lowest quintile range from 12 to 16 percent.

Clearly, two sets of factors influence the impact of income on an individual's health: consumption of health-enhancing goods and services, and the productivity of that consumption. The former depends on income, but may be conditioned by other factors, like education. The latter depends on demographic characteristics, like age. Productivity of health-enhancing goods also depends on existing health stock: the benefits of consuming health-enhancing goods depend on whether a person is healthy or ill. A person whose health is significantly compromised may have more difficulty surviving health insults than a person in robust good health.

To completely characterize the adverse consequences of regulation-induced income losses, analysts will have to account for both consumption choices and the productivity of these choices. The most transparent way to calculate health costs of income loss is to break the relation between health and income in two parts: (1) a behavioral function, relating the demand for health-enhancing goods to prices, income, and socio-demographic factors, and (2) the health production function, relating health status to consumption of health-enhancing goods. Ultimately, the usefulness of the two functions will depend on how detailed they are with respect to social, demographic, and economic variables.

But how detailed will the two functions have to be before they are useful? If all individuals had identical incomes and identical risk preferences, health-health analysis would be a minor variation of cost-effectiveness analysis. But, as noted in the sections on the willingness-to-pay approach and cost-effectiveness analysis, we do not have to look very far to see that profound and systematic differences in risk attitudes exist. That risk attitudes vary throughout the population implies differences in willingness to prevent exposure to hazards. We can therefore expect that the likely number of induced adverse outcomes will depend on whose income is compromised and the magnitude of the loss. Keeney (1990) argues that program-induced mortality varies systematically, largely influenced by income and by gender. Lutter and Morrall (1994) suggest the importance of age and ethnicity. In any case, the demographics of income losses largely determines the count of adverse outcomes. The estimate of induced deaths depends on who bears the costs.

Keeney (1997) analyzed data from the National Longitudinal Mortality Study to estimate the relationship between income and the annual probability of death. He estimated the relation as a negative exponential function for white males, black males, white females, and black females. In effect, these distinctions recognize that income and individual physiological characteristics determine mortality probabilities.

Kuchler et al. (forthcoming) examined a proposed seasonal harvesting ban on Gulf of Mexico oysters intended to prevent exposure to the bacteria *Vibrio vulnificus*. Oyster-related deaths have been traced to consumption of infected raw oysters harvested from the Gulf of Mexico during warm weather months. Epidemiologists identified the at-risk population as adult raw-oyster consumers suffering cirrhosis or immune-compromising diseases. Kuchler et al. estimated dollar costs imposed on the oyster industry, its harvesting and processing component, and the Gulf economy. As most oyster harvesters are white males and oysters shuckers are typically black females, Keeney's estimated functions were used to distribute costs among white males and black females, reducing income levels in each demographic category. Kuchler et al. calculated that the seasonal harvesting ban would, in an expected value sense, annually induce three deaths from each category and two to six more across the Gulf region (where no particular demographic cost incidence information is available). These estimates can be compared with an estimate of 17 deaths prevented.

As illustrated above, it is important to establish the influence of economic and demographic characteristics on health outcomes. As a result, empirical applications of health-health analysis must also carefully identify the distribution of the costs and benefits of health policy. In practice, when a solution to a public health problem is proposed, analysts can often characterize the demographics of those who suffer the regulatory costs. Further, analysts are likely to know some details of incidence of the public health problem. Epidemiological evidence usually reveals the demographic characteristics of the group that might benefit from public action. For example, *Salmonella*-caused human diseases are often more serious for children than for adults (CAST, 1994).

Health-Health Analysis—
A Second Best Approach?

Health-health analysis shares some characteristics with conventional cost-benefit analysis. Like cost-benefit analysis, health-health analysis uses a single unit of account to measure costs and benefits. Therefore, like cost-benefit analysis, health-health analysis provides a measure of net benefits. For example, suppose the goal of a regulatory agency is to maximize the number of deaths prevented. Such an agency would view a policy that prevented 17 deaths but caused 12 deaths as offering positive net benefits. The policy would be inferior (in the sense of net deaths prevented) to one that prevented 15 deaths but (because of smaller taxes or compliance costs) induced 2 deaths. Either policy would be superior to one that prevented 20 deaths but induced 18 deaths.

Income and circumstance play a powerful role in both health-health analysis and conventional cost-benefit analysis. In conventional cost-benefit analysis, these variables influence the theory and practice of benefits estimation, thereby influencing policy guidance. In health-health analysis, income effects are integral components, although incorporated through costs rather than benefits. While conventional cost-benefit analysis might show relatively larger benefits when benefits accrue to wealthy individuals, health-health analysis might show relatively larger costs when costs accrue to poorer individuals. That is, health-health analysis is more likely to guide policies away from programs that impose costs on the poor.

Though health-health analysis shares many characteristics with conventional cost-benefit analysis, it is not a perfect substitute. Lutter and Morrall note that health-health analysis is a second-best test "relative to BCA [cost-benefit analysis] because it excludes from consideration those costs unrelated to health and safety risk. If used alone, rather than as the first step in a benefit-cost assessment, the health-health test is more lenient than BCA."

Of course, passing a weak test may not be informative. Analysts would not be able to say whether the passing grade occurred because benefits really exceed costs or whether there simply is not enough information available about costs. However, it is not necessarily the case that the more stringent test is always

preferred. Failing a lenient test is powerful evidence that costs really do exceed benefits.

Health-health analysis is an appropriate technique for comparing costs and benefits under limited circumstances. When analysts want to highlight both policy efficiency (net benefits) and the distribution of health (the extent to which one subpopulation might benefit at the expense of another), health-health analysis is appropriate. However, until relations between income and morbidity are understood, health-health analysis can address questions only where benefits are denominated in the number of lives saved. Further, because analysts who use health-health analysis must translate dollars (income) into health, it is surprising that they do not simply use standard cost-benefit analysis. When analysts can assign prices and can discuss dollar-denominated costs, conventional cost-benefit analysis provides a straightforward market test for government programs. In choosing to use health-health analysis, there must be some reason why analysts cannot or choose not to assign values to life. As discussed in "An Introduction to the Methodologies," one reason may be that costs and benefits that are denominated in lives convey a different type of information than those denominated in dollars. A decisionmaker confronted with a benefit-cost ratio of 5 dollars to 4 would have an easier decision than one confronted with a benefit-cost ratio of 5 lives for 4. Dollar-denominated transfers are unlikely to raise the questions that health transfers do.

Conclusions

In this paper, we examined five approaches developed by economists and health policy analysts to evaluate policy affecting health and safety: COI, WTP, cost-effectiveness analysis, risk-risk analysis, and health-health analysis. We examined what analysts measure when using each approach, determined the appropriate use for each approach, and examined the influence that assumptions embedded in each have on policy guidance. We also addressed measurement issues raised by available empirical methods.

Our analysis left us with four principal conclusions. First, the usefulness of each approach depends on the unit of account. The philosophical decision to eschew the monetization of health costs or benefits constrains the ability of the approach to rank policy options and to gauge the social desirability of policy. Second, all of the approaches except risk-risk analysis and one variation of cost-effectiveness analysis incorporate the effects of income and circumstance. As a result, policy guidance could be influenced by the distribution of income. Third, the approaches are not interchangeable: they measure different things. Even estimates using the same approach are often not comparable because, in practice, there is little consistency in the application of any approach. The fact that each approach measures something different suggests a need for some guidelines for its proper use. Fourth, the theory and practice of WTP estimation are in opposition. While it is now common practice for regulatory agencies to adopt the WTP approach to estimate health and safety benefits, they do so by ignoring the importance of individual preferences.

Unit of Account Affects Usefulness of Results

One of the first decisions that health-policy analysts must make when measuring the costs and benefits of health and safety intervention is the unit of measurement to use. In conventional cost-benefit analysis, such as WTP or COI, both the costs and benefits of policy are measured in dollars, requiring that health outcomes be translated into dollar amounts. Cost-effectiveness analysis uses dollars to measure costs but leaves benefits in physical terms, namely a count of the adverse health outcomes averted. In risk-risk analysis or health-health analysis, both costs and benefits are expressed in terms of health outcomes.

The choice of a unit of measurement reveals the philosophical underpinnings of the approach. Approaches that monetize benefits and costs are built on the philosophical stance that, like other commodities, health and life can be valued in economic terms for comparison with other goods that people value. Approaches that do not use money as the unit of measurement reflect the stance that health and life are invaluable and cannot be measured with a finite amount of dollars.

Unfortunately, analysts who, for philosophical reasons, do not choose dollars as the unit of measurement, restrict the usefulness of their analyses for ranking policy options and for determining the social desirability of policy. Only COI and WTP, the two monetized approaches, provide a full ranking of policy options and a context for determining social desirability. Because COI and WTP translate health outcomes into a common unit of account, analysts using either of these approaches can rank dissimilar programs with different health outcomes (the costs and benefits of a kidney machine can be compared with those of a nutrition program). Because COI and WTP use money as the unit of measurement, analysts using either approach can comment on the net benefit of policy options. If the net benefits of a program were negative, the program would not be worthwhile, regardless of whether it was ranked higher than every other program. In addition, because money is already in common use in ranking choices and in conveying value, analyses based on a money scale allow us to compare values and make trade-offs among all goods, whether produced in the public or private sector. With a monetized account, we can compare the relative value of various public health programs and compare public health programs with alternative ways individuals might spend their money, like consumer goods. We can compare the value of programs with the value of goods and labor services that have to be used to carry out the program. And these comparisons can be easily accomplished. If dollar benefits exceed dollar costs, the program is worth the price.

The cost-effectiveness approach cannot be used to compare programs with different health outcomes, because it measures costs and benefits in different units of account. The costs and benefits of a kidney machine cannot be compared with those of a nutrition program. In addition, cost-effectiveness estimates do not, by themselves, indicate whether either program offers positive net benefits. Cost-effectiveness analysis reveals that a program that saves 5 lives for $100 million is preferable to one that saves 2 lives for $100 million, but it does not reveal whether either of the programs is socially desirable.

Like COI and WTP, health-health analysis has the advantage that costs and benefits are measured in a common unit. And, as with conventional cost-benefit analysis, comparisons can be drawn across diverse programs and net benefits can be shown to be either positive or negative. A kidney program that saves 10 lives is ranked above a nutrition program that saves 9, and the fact that both programs cost 11 lives means that both have negative net benefits and neither is socially desirable. A primary disadvantage of health-health analysis is, unlike conventional cost-benefit analysis, particularly WTP, which assigns values to morbidity and pain and suffering, health-health analysis is restricted to mortality risks.

It is interesting to note that when analyses of costs and benefits are denominated in lives, the calculated costs and benefits usually differ from conventional cost-benefit analysis in more than accounting definitions. For example, a health program with an estimated cost of $1 million and benefits of $5 million has a benefit-cost ratio of 5, and, all else equal, the project appears to be a good return on Federal expenditures. A similar risk-risk ratio is likely to generate less enthusiasm. A 5:1 ratio of deaths averted to deaths induced could be unacceptable—as in the case of front-right passenger airbags, where one life is lost (usually a child's) for every five lives saved. That a 5:1 ratio of benefits to costs derived from conventional benefit-cost analysis is viewed differently from a 5:1 ratio of benefits to costs derived from a risk-risk analysis shows that the two techniques reveal different information. The units of account are not the only difference. One could argue that dollar costs imposed on one group can be offset one-for-one by dollar benefits another group receives. However, it is difficult to argue that a life lost in one group can be offset one-for-one by a life saved in another group. The

issue of distribution of costs and benefits takes on more importance in the evaluation of health and life than in the evaluation of other goods and services.

The Influence of Income and Circumstance Is Impossible To Avoid

WTP, COI, and cost-effectiveness analysis share a surprising feature. When analysts attempt to make their calculations relevant to public health decisions, either accounting for individual preferences or accounting for social costs, policy guidance will be influenced by income and circumstance. In this regard, policy guidance offered by an analyst using cost-effectiveness is no different from guidance derived from conventional cost-benefit analysis where all benefits are monetized. All else equal, programs that offer benefits for the wealthy will show greater net benefits or greater cost-effectiveness than programs offering identical health benefits to the poor.

In health-health analysis, income effects are incorporated through costs rather than benefits. While conventional cost-benefit analysis might show relatively larger benefits when benefits accrue to the wealthy, health-health analysis might show relatively larger costs when costs accrue to the poor. That is, health-health analysis is more likely to guide policies away from programs that impose costs on the poor.

The Approaches Are Not Interchangeable: They Measure Different Things

One of the principal reasons that analyses are not comparable is that each approach embodies a different view of what a cost is. COI, cost-effectiveness analysis, and risk-risk analysis all measure costs in terms of *ex post* damages while WTP measures costs in terms of *ex ante* risk perception. WTP reflects expectations rather than realized damages.

There are also practical problems with drawing comparisons among results. There is no template for any of the approaches. Analysts must decide what counts as a cost or benefit and must choose among different tools and techniques to measure costs and benefits. For example, we examined four methods for measuring WTP. The four approaches are substantively dif-

ferent from one another and some measure prefer-ences of different populations. In COI, analysts sometimes include defensive expenditures, and some-times do not. Some include only those costs incurred by the individuals who benefit from programs, ignor-ing the spillover. Some use observed prices, and oth-ers attempt to modify prices to eliminate effects of cross-subsidization common in health care.

The fact that the methods measure different costs and benefits suggests that there are circumstances where one would be more appropriate than another.

● The COI approach is not a valid tool for welfare analysis because it does not provide adequate esti-mates of individual or social welfare. COI estimates are not reliable measures of disease severity. Only under very unusual conditions could COI estimates serve as a lower bound to WTP. However, despite these shortcomings, the COI approach is still a useful economic tool. The COI approach provides an *accounting* of the dollars spent on medical expenses and the wage dollars forgone as a result of illness, accident, or premature death. Such an accounting provides useful information to economists and policy-makers in that it indicates the direction and magni-tude of the economic flows resulting from health shocks to the economy.

● WTP measures provide the best estimate of *indi-vidual* welfare available to economists. It is a logical and consistent application of the primary tenets of standard applied welfare economics. While there is little reason to challenge WTP from a theoretical per-spective, estimation raises practical problems because it depends on individual and idiosyncratic utility functions. With additional studies analysts may be able to estimate the demand for risk reduction throughout the population for a variety of different risks.

● Of the three variants of cost-effectiveness analy-sis in common use, the simplest, the ratio of program costs to a count of health benefits, may be the most useful. This variant of cost effectiveness may serve as a coarse filter, helping to screen out programs that more complex analyses would also show are not worthwhile. However, this use of cost-effectiveness has no theoretical appeal. It is not an individual wel-fare measure and does not fully account for costs avoided by programs. Cost-effectiveness analysis

may help minimize costs when an irrevocable deci-sion has been made to take an action, but no decision has been made about technique or method.

● Risk-risk analysis is most useful in cases of all-or-nothing decisions. That is, only one program is offered and the decisionmaker must decide either to go forward with the program or accept the status quo. When there are more options, risk-risk analysis shifts most of the burden of analysis to the decisionmaker.

● Health-health analysis is an appropriate tech-nique for comparing costs and benefits when analysts want to highlight both policy efficiency (net benefits) and the distribution of health (the extent to which one subpopulation might benefit at the expense of anoth-er). However, until the relationships between income and morbidity are better understood, health-health analysis is suitable only where benefits are denomi-nated in the number of lives saved. Further, because analysts who use health-health analysis must translate dollars (income) into health, it may be easier to sim-ply use standard cost-benefit analysis.

Theory and Practice Are in Opposition for WTP

In practice, regulatory agencies using WTP to esti-mate the value of lives saved have generally adopted a single value derived from compensating wage stud-ies. Agencies apply this value to every health risk, regardless of the population likely to receive program benefits, the type of risk that might be mitigated, or the level of risk mitigated. This practice is in opposi-tion to the reason for choosing WTP as a welfare measure and flies in the face of empirical evidence. There is no universal value that can be used in every situation. So far, no one has provided a compelling reason that labor market risk values are relevant for food safety risk assessment, where risks are especial-ly large for the very young, the very old, and the infirm. Only with additional studies targeted specifi-cally toward food safety risks will analysts be able to estimate relevant demands for risk reduction through-out the population. At that time, analysts will be faced with exactly the same problem facing those using COI. There will be a range of values that vary demographically. Cost-benefit analysts using WTP estimates will then be back in the awkward position of assigning different values to different individuals.

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Appendix
Is COI a Lower Bound to WTP?

It is generally recognized that the WTP approach is theoretically superior to the COI approach for measuring individual well-being. However, it is also often asserted that COI is less difficult to estimate than WTP. As a result, many health economists have attempted to establish a method for approximating WTP with COI measures. Many argue that COI is a lower bound to WTP and that, therefore, studies that use COI are conservative in their benefit estimates. This conclusion is usually incorrect.

Berger et al. (1994) developed a model of individual health investment that yields a general expression for the value of changes in risk to human health. This model includes health in three roles: as a variable in the utility function; as a determinant in the probability and quality of survival in the current period; and as part of the income constraint. Berger et al. use their health production model to solve for an individual's *ex ante* WTP for an improvement in health status and to derive the relationship between WTP measures, preventive expenditures, and COI measures.

In this appendix we present Berger et al.'s model along with an application to a food safety problem. Berger et al. detail the assumptions required to make WTP equal COI and to make COI a lower bound to WTP. An example of a food safety problem emphasizes the unreasonableness of these assumptions. The model shows that COI and WTP bear no relation to one another when health outcomes include death. Our example shows that practical estimation problems make the relation between COI and WTP uncertain even for analysis of morbidity.

The example we develop examines the measurement of benefits from reducing exposure to the bacteria *Vibrio vulnificus*. The bacteria naturally occurs in estuarine waters and is a normal flora in molluscan shellfish—mainly oysters and clams. Since 1979, *Vibrio vulnificus* has been known to cause food-related illnesses resulting in acute gastroenteritis and fulminating septicemia and death (ISSC, 1995). During 1988-1997, an annual average of 22 *V. vulnificus* septicemia cases and 11 associated deaths were reported to the Centers for Disease Control and Prevention.

Almost all of these cases have been attributed to half-shell consumption of live oysters harvested from the Gulf of Mexico and tributary waters between April 1 and October 31.

The median incubation period from *V. vulnificus* is relatively short—18 hours after eating the contaminated food, and the median time from hospitalization to death is 2 days (Klontz et al., 1988). Epidemiologists have identified the at-risk population largely as raw-oyster consumers with existing medical risks including liver disease and immuno-compromising illnesses.

Federal regulators have examined a variety of programs to reduce the risk of infection. Proposed programs include information campaigns to make consumers aware of the potential health risk. Other programs include time-temperature controls limiting the time between harvest and refrigeration. Other possible programs include seasonal harvesting bans across the Gulf of Mexico (Kuchler, et al, forthcoming).

The Human Health Risk Reduction Benefit Model from Berger et al. (1994)

Variables:

C = consumption = goods, services, and time
q = vector of health characteristics
X = preventive expenditures
E = policy variable such as environmental quality or food safety
Z = cost of illness = medical expenditures and forgone earnings
M = money income

Definitions:

• Utility is a function of consumption and health characteristics:

$$U = U(C, q) \qquad (10)$$

- Probability of surviving depends on health:

$$p = p(q) \qquad (11)$$

- Probability density function for health characteristics (q) defined over preventive expenditures (X) and the policy variable (E), e.g., environmental quality or food safety.

$$h(q; X, E) \qquad (12)$$

In our example, time-temperature controls (E) may affect the number and severity of *V. vulnificus* infections. The same result might occur from preventive expenditures (X) if consumers substituted oysters harvested outside the Gulf of Mexico for the Gulf oysters they currently consume.

- Cost of illness depends on health characteristics:

$$Z = f(q) \qquad (13)$$

- Income constraint requires that the sum of consumption, preventive expenditures, and cost of illness equals money income:

$$M = C + X + Z \qquad (14)$$

The Problem

Individual chooses preventive expenditures X in order to maximize expected value of utility subject to income constraint:

$$\max E(U) = \int_{-\infty}^{\infty} U(C, q) p(q) h(q; X, E) dq \qquad (15)$$

$$M = C + X + Z \qquad (16)$$

where the first term in the expression, $U(C, q)$, is utility given the health state, and the second term, $p(q) h(q; X, E)$ is the probability of a given health state, including death.

Express income constraint in terms of C and substitute into maximization problem:

$$\max E(U) =$$

$$\int_{-\infty}^{\infty} U[M - X - f(q), q] p(q) h(q; X, E) dq \qquad (17)$$

Suppose the health condition is dichotomous, measurable as a zero-one variable. Then, health is a matter only of the absence or presence of a deleterious condition and the function $h(q; X, E)$ is discrete. Let $H(X, E)$ be the probability of the absence of the condition.

$$h(q; X, E) = H(X, E) \qquad \text{if } q = 1 \quad (18)$$
$$h(q; X, E) = 1 - H(X, E) \qquad \text{if } q = 0$$

In our example, (18) implies that a person is either infected with *V. vulnificus* and is sick or is not infected and is not sick. The consumer's maximization problem reduces to:

$$\max E(U) = U_0 P_0 (1 - H) + U_1 P_1 H \qquad (19)$$

where $U_0 = U(M - X, 0)$ is utility if free of the disease; $U_1 = U(M - X - Z, 1)$ is utility with the disease; $P_0 = p(0)$ is the probability of survival if free of the disease; $P_1 = p(1)$ is the probability of survival with the disease; and $H = H(X, E)$ is the probability of contracting the disease.

Totally differentiating $E(U)$, holding $dE(U) = 0$ yields an expression for willingness to pay for an exogenous change (such as environmental improvement or improved food safety) that reduces risk.

$$-\frac{dM}{dE} = -[(U_0 P_0 - U_1 P_1) / m] H_E -$$

$$\left\{ 1 + [(U_0 P_0 - U_1 P_1) / m] H_X \right\} \frac{dX}{dE} \qquad (20)$$

$$\text{where } m = U_0' P_0 (1 - H) + U_1' P_1 H$$

Berger et al. simplify this expression to the following.

$$-\frac{dM}{dE} = -[(U_0 P_0 - U_1 P_1) / m] \left(\frac{dH}{dE} \right) - \left(\frac{dX}{dE} \right) \qquad (21)$$

Willingness to pay *(-dM/dE)* for an "environmental" improvement, like time-temperature controls, equals the sum of the utility value of the reduction in risk

and the savings in preventive expenditures. The utility value of risk reduction is the dollar value of additional enjoyment a consumer receives because of a reduced threat of a *V. vulnificus* infection from raw oyster consumption. Reductions in defensive expenditures might include time saved by not having to search for oysters harvested outside the Gulf of Mexico or by not having to cook oysters. The *dM/dE* term is negative because to maintain expected utility at a constant level, improvement in the environment is balanced by a fall in income. So, *-dM/dE* indicates a positive WTP.

Is COI a Special Case of WTP?

There are no reasonable conditions under which COI = WTP when there is any possibility that an illness can lead to a fatality. Here, we show that the conditions that have to be imposed to make

$$WTP \equiv -\frac{dM}{dE} = -Z\frac{dH}{dE} \equiv COI$$

are unreasonable. Four assumptions are sufficient to force the equality.

1. Assume no defensive expenditures are possible, *dX/dE = 0.*

2. Assume health does not enter the utility function directly, namely utility is not enhanced by health. Instead, only consumption enters the utility function. Define *U = U(C)*. Then, marginal utilities do not depend on the health state. Assumptions 1 and 2 imply that *-dM/dE* includes only the difference in utility between being sick and being well, and the difference in expected utilities only reflects reduced consumption when ill due to cost of illness incurred, *Z*.

$$-\frac{dM}{dE} = \qquad (22)$$

$$\frac{-[U(M-X)P_0 - U(M-X-Z)P_1]}{U'[P_0(1-H)+P_1 H]}\frac{dH}{dE}$$

3. Assume away any possibility that the illness is fatal, $P_0 = P_1 = 1$.

$$-\frac{dM}{dE} = \qquad (23)$$

$$\frac{-[U(M-X)-U(M-X-Z)]}{U'}\frac{dH}{dE}$$

4. Assume the value of consumption is equal to the utility of the value of consumption.

$$Z = \frac{U(Z)}{U'} \qquad (24)$$

Then, the equality of WTP and COI follow.

$$-\frac{dM}{dE} = -Z\frac{dH}{dE} \qquad (25)$$

These assumptions are unreasonable and are especially unreasonable for foodborne illness.

Assumption 1, the assumption that there are no possible defensive expenditures, is usually wrong. Regardless of which, if any, regulatory program is instituted, consumers have a variety of preventive or defensive expenditures to employ. They can seek out non-Gulf of Mexico oysters. They can substitute cooked oysters for raw. They can substitute other foods for oysters. As the at-risk population is clearly identified, those individuals can request medical testing for liver function. Such tests may not prove that eating raw oysters is safe for an individual. But a finding of severely compromised function would certainly make a consumer aware of risks of eating raw oysters.

Assumption 2, that utility is a function of consumption alone, is a peculiar view of human behavior. It says that health is not desired because people like being healthy, rather the only reason for desiring a state of robust health is that it allows greater consumption than does a state of compromised health. If consumers value good health apart from the expanded consumption opportunities that come with it, and if consumers dislike the pain and fear associated with illness, the assumption is untenable. The assumption is especially peculiar for the *V. vulnificus* case. Although the lethality rate for a *V. vulnificus* infection is 50 percent, the illness is not long-lived, and thus for those who survive, it does not compromise much

lifetime consumption. To define *U(C)* over health states including a possibility of *V. vulnificus* infection, forces attention on trivial changes in consumption and assumes the severe pain associated with the disease is of little consequence to utility.

Assumption 3, assuming away any possibility of fatalities, obviously restricts the usefulness of COI for analyses of foodborne illnesses. Clearly, *V. vulnificus* infections are fatal more frequently than almost any other foodborne illness. However, it would be unusual to find a public health problem that did not lead to at least one death. Consider for example a chemical residue that raised the lifetime probability of cancer for everyone by 1×10^{-8}. Such a risk is two orders of magnitude below conventional definitions of *de minimis* risk levels. But, when 260 million people are imagined to be exposed to the chemical, risk assessors might forecast 2.6 additional deaths.

Assumption 4, that the utility of value of consumption is equal to the value of consumption, contradicts basic economic theory. Berger et al. examine the relation between consumption expenditures and the value of the utility of consumption. They note that "conceptually it cannot be shown, strictly, what the empirical relationship should be" (p. 38). Their review of consumption theory, however, strongly suggests that the former should exceed the latter.

Clearly these four assumptions are untenable, particularly in the case of foodborne illness. WTP does not equal COI.

Can COI be a Lower Bound to WTP?

There are plausible conditions under which the theoretical COI is a lower bound to WTP. Assumption 3 leads to the conclusion that WTP exceeds COI. That is, WTP > COI if the health problem in question involves only morbidity ($P_0 = P_1 = 1$). In this case,

$$-\frac{dM}{dE}\Bigg|_{P_0=P_1=1} = \tag{26}$$

$$\frac{-[U(M-X,0)-U(M-X-Z,1)]}{m^{**}}\left(\frac{dH}{dE}\right)-\left(\frac{dX}{dE}\right)$$

where $m^{**} = U_0 (1 - H) + U_1 H$

If the marginal utilities in the two health states are similar, equation 26 reduces to

$$-(U_0 - U_1)\left(\frac{dH}{dE}\right)-\left(\frac{dX}{dE}\right) \tag{27}$$

Here, utility does vary with health states. Two conditions imposed on (27) establish the inequality WTP > COI. Let *dH/dE < 0* and *dX/dE < 0*. Health risks fall as the environment improves, and defensive expenditures and environmental improvements are substitutes in reducing health risks. The inequality is established because COI ignores savings in preventive expenditures; COI ignores that utility is enhanced by improved health, and the value of the utility of earnings should be greater than earnings.

However, practical problems in estimating COI intrude, making the inequality suspect. The inequality is based on COI estimates that are restricted to the costs that individuals privately incur. The value of COI used by Berger et al. in their derivations is entirely private costs. Recall *Z = f(q)*, or that the modeled COI depend only on the individual's health characteristics. If COI includes more than out-of-pocket costs incurred by individuals with health insurance, or if some medical procedures incorporated in direct costs include hospital subsidies, then calculated COI need have little relation to -*Zdh/dE*. Any costs above and beyond those incurred by individuals are ignored in the model. A COI estimate that includes social costs will include more costs than the theoretical individualized COI. Thus, an estimated COI value may exceed WTP.