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Valuing the Health Benefits of Food Safety: A Proceedings

Compiled by Fred Kuchler

Abstract

Because Federal agencies use different valuation methods to estimate the costs of illness, it is difficult to compare programs across agencies. If there were a consensus approach to assigning values to risk reductions and each agency used it, risk managers could more readily compare the different agencies' programs. Those comparisons would provide risk managers with information to help them choose food safety programs that reduce both foodborne illness and public costs. As a first step toward generating a consensus on the current state of knowledge and deciding on a common approach, several agencies planned this conference, held September 14-15, 2000, at the University of Maryland, College Park, Maryland, USA. The outcome of the conference will serve as guidance for a consensus approach.

Keywords: Foodborne illness, risk, value of statistical life, valuing pain and suffering, valuation methods, pathogenic risks, willingness to pay

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Valuing the Health Benefits of Food Safety

A conference held September 14-15, 2000,
at the University of Maryland, College Park

Many Federal agencies conduct cost-benefit analyses of regulations that are intended to increase the safety of foods. The agencies that implement programs and regulations to reduce the risks associated with food consumption include:

- The Food Safety and Inspection Service (FSIS), Department of Agriculture
- Economic Research Service (ERS), Department of Agriculture
- The Food and Drug Administration's Center for Food Safety and Applied Nutrition (CFSAN), Department of Health and Human Services
- Centers for Disease Control and Prevention (CDC), Department of Health and Human Services
- The Environmental Protection Agency (EPA).

The different agencies use many different methods to estimate the reductions in risk associated with their policies; they also use different methods to assign dollar values to the human health benefits from the reduced risk. Because each agency uses a different method, it is difficult to compare programs across agencies. If there were a consensus approach to assigning values to risk reductions and each agency used it, risk managers could compare the effects of different agencies' programs. Those comparisons would provide risk managers with information to help them choose food safety programs that reduce both food-borne illness and public costs.

The differences across agencies—and in some instances within agencies—in approaches to measuring health benefits make it difficult to compare the estimated benefits of different health and safety regulations. If there were a consensus approach to assigning values to risk reductions and each agency used it, risk managers could compare the health benefits of different regulations and programs. Those comparisons would provide risk managers with information to help them choose food safety (and other) programs that reduce both illness and public costs. One purpose of bringing together different agencies is to investigate methods that can be used by all agencies concerned with public health. What should economists be trying to measure when they assign values to reducing morbidity and postponing deaths? What methods should economists use to assign those values?

As a first step toward generating a common approach, several agencies sponsored a conference on valuing the health benefits of food safety. The conference was a first step toward forging a consensus across agencies on how to value improvements in food safety. Most of the issues discussed applied to general health and safety issues in addition to food safety. The topics covered included:

(1) valuing statistical lives;
(2) valuing risk reductions for different hazards;
(3) valuing risk reductions using different methods; and
(4) valuing pain and suffering and lost productivity.

Conference sessions included formal presentations, comments, and both general and small-group discussions on current best practices for valuing the prevention of food-borne illnesses and death.

Although the general sessions and the breakout sessions identified many areas of disagreement on valuing health benefits, the sessions also gave economists from different agencies an opportunity to see how other agencies estimated health benefits. Participants from the Federal agencies, academia, and private organizations agreed that getting FSIS, CDC, ERS, EPA, and CFSAN together was a major step toward reaching consensus and improving the methods used by the various agencies. Conference participants also agreed that economists from the different agencies should continue to meet and work toward consensus on methods of valuing food safety.

This report includes the major papers presented at the conference, comments of discussants who provided written remarks, and summaries of discussion sessions.

Conference Agenda

Opening Remarks
- David R. Lineback, Director, Joint Institute for Food Safety & Applied Nutrition
- Richard Williams, Food and Drug Administration, Center for Food Safety and Applied Nutrition
- Al McGartland, U.S. Environmental Protection Agency, National Center for Environmental Economics
- Steve Crutchfield, U.S. Department of Agriculture, Economic Research Service

Valuing Statistical Lives--Moderated by Nicole Owens and Nathalie Simon, U.S. Environmental Protection Agency, National Center for Environmental Economics
- "Using Estimates of the Value of Statistical Life in Evaluating Regulatory Effects" by Donald Kenkel, Cornell University
- Comments by Maureen Cropper, World Bank and University of Maryland
- Comments by Chris Dockins, U.S. Environmental Protection Agency, National Center for Environmental Economics

Valuing Pain and Suffering and Lost Productivity--Moderated by Clark Nardinelli, Food and Drug Administration, Center for Food Safety and Applied Nutrition
- "Measuring the Pain, Suffering, and Functional Disability Associated with Foodborne Illness" by Josephine Mauskopf, Research Triangle Institute
- Comments by James Hammitt, Harvard School of Public Health
- Comments by Amber Jessup, Food and Drug Administration, Center for Food Safety and Applied Nutrition

Valuing Risk Reductions Using Different Valuation Methods--Moderated by Elise Golan, U.S. Department of Agriculture, Economic Research Service
- "Valuing Pathogenic Risk: Methods, Skill & Rationality" by Jason Shogren, University of Wyoming

- Comments by V. Kerry Smith, North Carolina State University
- Comments by Fred Kuchler, U.S. Department of Agriculture, Economic Research Service

Valuing Risk Reductions for Different Hazards--Moderated by Tammy Riggs, U.S. Department of Health and Human Services, Centers for Disease Control and Prevention

- "Benefits Transfer and the Value of Food safety" by Alan J. Krupnick, Resources for the Future
- Comments by Ian Savage, Northwestern University
- Comments by Carol Scotton, U.S. Department of Health and Human Services, Centers for Disease Control and Prevention

Reports from breakout sessions

- Report from breakout session on valuing statistical lives--David Widawsky, U.S. Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances
- Report from breakout session on valuing pain and suffering and lost productivity--Clark Nardinelli, Food and Drug Administration, Center for Food Safety and Applied Nutrition
- Report from breakout session on valuing risk reductions using different valuation methods--Jean Buzby, U.S. Department of Agriculture, Economic Research Service
- Report from breakout session on valuing risk reductions for different hazards--Tammy Riggs, U.S. Department of Health and Human Services, Centers for Disease Control and Prevention

Conference Summary

Clark Nardinelli, Food and Drug Administration, Center for Food Safety and Applied Nutrition

SESSION I

VALUING STATISTICAL LIVES

Moderators' Notes

Moderators: Nathalie Simon and Nicole Owens (Environmental Protection Agency)

Currently, in order to value mortality risks associated with foodborne illness, analysts in various Federal agencies rely on the existing economic literature in this area, comprised primarily of hedonic labor market studies. The resulting values from these compensating wage studies have a number of shortcomings in the context of valuing food safety risks. First, the risks addressed by the labor market studies generally befall prime-aged males, whereas the populations most susceptible to foodborne mortality risks are children and the elderly. Second, the mortality events in the labor market studies are accidental and are therefore preceded by short, if not non-existent, morbidity periods. Foodborne mortality events in contrast can sometimes follow extended and very painful morbidity periods that vary in length from one illness to another. The discussion in the breakout session focused on the shortcomings of existing statistical measures and the need for more appropriate measures (either pulled from a re-examination of the existing literature or new VSL studies). Before embarking on a quest for new estimates on the value of a statistical life, however, several issues need to be addressed:

1. How should the agencies define "high-quality" VSL studies? Is there a set of characteristics that should be present for a study to be characterized as such? If so, what features are included in this set?
2. Which foodborne illnesses pose the greatest mortality risk to the population and what are the characteristics (symptoms, population at risk, length of morbidity period, etc.) of these illnesses?
3. Should VSL estimates be developed for deaths resulting from specific illnesses? If so, for which illnesses should specific values be estimated?
4. Should the mortality event be treated separately from the morbidity period that often precedes a death due to foodborne illness? Are there circumstances in which it is appropriate to value the illness as a whole (morbidity + mortality)? If so, what are these circumstances?
5. Should new VSL studies focus on risk reductions for specific illnesses or is it more appropriate to focus on risk reductions resulting from a particular program? That is, should we be valuing health endpoints or programs?
6. How can analysts more adequately transfer VSL estimates derived from studies in which the magnitude of the risk reduction is stated explicitly to situations in which the magnitude of the risk is very uncertain.

Using Estimates of the Value of a Statistical Life in Evaluating Regulatory Effects

by Donald Kenkel

Basic Concepts and Current Practice

The problem of allocating scarce societal resources to life-saving activities arises when evaluating a wide variety of regulations and government programs. Most economists and policy analysts agree on the general principle that the life-saving benefits of public sector activities should somehow be compared to the costs of the activities. The agreement fades, however, when this general principle is put into practice to evaluate specific regulations. Several different conceptual approaches that have been proposed over the years continue to influence the current practice of economic evaluation of the life-saving benefits of regulations. This section briefly reviews selected evaluations conducted by the U.S. Environmental Protection Agency (EPA), the Economic Research Service of the U.S. Department of Agriculture (USDA), and the U.S. Food and Drug Administration (FDA). The review of current practice also allows some basic concepts to be defined and illustrated.[1] The following sections of the paper propose a common-sense rule for improving current practice: The same life-saving benefit should always be given the same value, but different life-saving benefits should be given different values.

The standard approach to placing a dollar value on the life-saving benefits of regulations is based on societal willingness to pay (WTP) for mortality risk reductions. Unlike an emergency rescue operation, the specific people whose lives are saved by regulations cannot be identified. Instead, regulations reduce mortality risks in the population affected by the regulation. As a hypothetical example, suppose a new food safety regulation reduces the annual risk of dying of a foodborne illness by 0.00001. In a population of 100,000, the regulation is expected, in a statistical sense, to result in 1 fewer death from foodborne illness each year. Using this reasoning, regulations are sometimes said to save "statistical lives" as opposed to identified lives. If each person in that population of 100,000 is willing to pay $20 a year for the reduction

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The author is with the Department of Policy Analysis & Management, Cornell University, Ithaca, NY 14853 (607-255-2594; dsk10@cornell.edu). Comments welcome. The author thanks Maureen Cropper, Chris Dockins, and other participants at the conference for useful comments. All views expressed are those of the author and do not necessarily reflect the views of the U.S. Environmental Protection Agency, the Economic Research Service of the U.S. Department of Agriculture, the U.S. Food and Drug Administration, or any other Federal agency.

[1]The phrase "current practice" is used loosely and refers to the selected published evaluations conducted by the EPA, USDA, and FDA. These past evaluations may no longer be representative of "current practice." In addition, it is simplistic to describe the methods used by an agency as a single, current practice; in reality, each agency may use a variety of methods depending upon the circumstances of the regulatory evaluation.

in mortality risks, the total WTP is $2 million for an annual risk reduction that can be expected in the statistical sense to save one life. In this case, $2 million is said to be the value of a statistical life (VSL). The VSL should be thought of as a convenient way to summarize the value of small reductions in mortality risks. It is not meant to be applied to the value of saving the life of an identified person (i.e., the value of changing the risk of mortality from one to zero).

Based on an extensive review of the research literature, the U.S. EPA (1997) suggests that a reasonable estimate of the VSL has a mean of $4.8 million with a confidence interval of plus or minus $3.2 million (in 1990 dollars). The suggested range for the VSL suggested by the EPA is consistent with other reviews including Fisher, Chestnut and Violette (1989), Viscusi (1992, 1993), and the meta-analysis by Desvousges et al. (1998). The EPA's review identified 26 studies that were judged to reflect "sound and defensible" methods. Five of these studies used the contingent valuation method, where survey respondents are directly asked about their WTP for mortality risk reductions. The remaining 21 studies estimated the value of risk reductions based on workers' willingness to accept riskier jobs in return for higher wages. The conceptual foundation of both empirical approaches to estimating the VSL is that societal WTP for risk reductions should reflect individuals' risk valuations, whether elicited directly through surveys or revealed in their labor market decisions.

The WTP approach to valuing the lifesaving benefits of regulatory effects is consistent with Haveman and Weisbrod's (1983, p. 82) more general argument that "cost-benefit analysis can be viewed as an attempt to develop a public-sector analogue for private market decision-making." In their private-market decisionmaking, consumers do not demonstrate an infinite WTP for safety. Instead, they often demonstrate their willingness to trade off safety for other desirables, such as time and money. Evaluating regulatory effects based on estimates of consumers' WTP allows public-sector safety decisions to reflect that same willingness to make tradeoffs involving safety. However, the relevance of private-market decisionmaking will be limited when there are questions about the competence of individual decisionmaking under uncertainty. For example, evidence shows that people tend to underestimate risks of common causes of death, while they tend to overestimate the risks of rare causes of death (Slovic, Fischhoff, and Lichenstein, 1985). Ideally, public-sector safety decisions should reflect people's preferences but not reflect their mistakes.

Several recent evaluations of EPA regulations use the $4.8 million VSL estimate, with the only adjustment being for inflation to express benefits in current dollars. As part of its estimates of the benefits of drinking water regulations related to disinfectants and disinfection byproducts, the EPA (1998) uses a value per statistical life saved for fatal bladder cancers represented by a distribution with a mean of $5.6 million (1998 dollars). In a Regulatory Impact Analysis of a proposed rule on surface water treatment, improvements in drinking water filtration are estimated to reduce mortality from Cryptosporidium illnesses (EPA, 2000a). The benefits of these mortality reductions are based on a mean value of $5.7 million (January 1999 dollars) per statistical life saved. In a Regulatory Impact Analysis for a proposed ground water rule, the EPA (2000b) estimates the monetized benefit from viral deaths avoided using a VSL of $6.3 million (1999 dollars).

In several of its evaluations conducted several years ago, the Economic Research Service of the USDA supplemented WTP-based estimates of the VSL with estimates based on the human capital/WTP hybrid approach (Landefeld and Seskin, 1982). Estimated this way, the VSL ranges from roughly $15,000 to $2,037,000 (1996 dollars), depending on the age group benefiting from the mortality risk reduction (Buzby and Roberts, 1997). The conceptual foundation of this empirical approach to estimating the VSL reflects two schools of thought. In the human capital or cost of illness approach, life-saving benefits are estimated by the impact of mortality reductions on the measured productivity of the economy. In the standard human capital approach, the VSL is therefore equal to the discounted present value of lifetime earnings lost due to the premature mortality. This approach has been criticized on a number of grounds, with the most fundamental objection being that an individual's WTP to reduce mortality risks has no necessary relationship to his or her discounted lifetime earnings.[2] Landefeld and Seskin (1982) develop an adjusted process to calculate forgone earnings, allowing for the individual's perspective in that earnings are computed net of tax, nonlabor income is included, an individual discount rate is used (as opposed to the social discount rate), and a risk-aversion factor is applied. The USDA's analyses also include the value of housekeeping services as a component of lifetime earnings. Compared to the methodology of the original human capital approach, this hybrid approach yields VSL estimates that are closer theoretically and empirically to individual WTP-based estimates of the VSL, such as those reviewed by the EPA (1997).

The USDA used estimates from the hybrid human capital/ WTP approach in two conceptually distinct types of analyses. The first type are cost-of-illness studies that quantify or account for the impact of specific conditions on the economy (Kuchler and Golan, 1999, p. 53). Cost-of-illness studies include medical expenditures as the direct costs of treating illness and productivity losses, including the present value of future earnings forgone due to premature mortality, as the indirect costs of illness. Cost-of-illness studies use a standardized accounting framework and methodology, enhancing the comparability of studies of different illnesses and conditions (Hodgson and Meiners, 1982). The National Institutes of Health [NIH] (1998) presents over 50 disease-specific estimates of the direct and/or indirect costs of illness. USDA analyses include a study of the economic costs of congenital toxoplasmosis, which can result from handling raw meat or eating undercooked pork and other meats (Roberts and Frenkel, 1990). The present value of an infant's lifetime earnings, estimated at $983,000 (1989 dollars), is one component of the indirect costs of toxopolasmosis. Similarly, Roberts and Pinner (1990) use an estimate that the present value of forgone lifetime earnings is $1.1 million per infant to estimate the economic costs of disease caused by *Listeria monocytogenes*. Buzby, Roberts, Lin, and MacDonald (1996) include forgone lifetime earnings in their estimate that foodborne bacteria impose between $2.9 and $6.7 billion of economic costs. In an update, Buzby and Roberts (1997) include estimates of the costs of Guillain-Barré, syndrome related to *Campylobacter jejuni* infection.

[2]In one response to the criticisms of this approach, Robinson (1986) argues that it is based on assumptions that are similar to the propositions of the material welfare school of thought, dominant in English economics between 1880 and 1940. Robinson agrees with the critics that the approach is not consistent with the approach of modern welfare economics that provides the conceptual foundation for cost-benefit analysis.

The USDA also used estimates from the hybrid human capital/WTP approach as an alternative approach to estimating the value of the life-saving benefits of specific interventions. Compared with the WTP-based estimates such as those reviewed by the EPA (1997), the hybrid human capital/WTP approach generally yields lower estimates of the VSL, so this approach is sometimes seen as a more conservative approach to estimating the value of life-saving benefits. For example, Roberts, Buzby, and Ollinger (1996) and Crutchfield et al. (1997) use the hybrid approach to estimate the value of the life-saving benefits of a food safety regulation the Hazard Analysis and Critical Control Point regulation for meat and poultry plants. The VSL estimates ranged from $12,000 to $1,585,000 (1993 dollars), or $15,000 to $1,979,000 (1995 dollars), depending upon age. Crutchfield et al. (1997) explicitly acknowledge that their VSL estimates are low compared with WTP-based estimates around $5 million used in other agencies' evaluations of regulatory effects. In these studies, as well as in the review by Kuchler and Golan (1999), WTP is described as the conceptually correct approach, with the VSL estimates based on the hybrid human capital/ WTP approach presented as more conservative.

Several evaluations conducted by the FDA measure the life-saving benefits based on the value of a life year (FDA 1999a, 1999b). For example, the FDA (1999b) values each life year saved by a nutrition labeling regulation at $100,000. Similar values for a life year are suggested by Zarkin et al. (1993), Tolley, Kenkel, and Fabian (1994), and Cutler and Richardson (1997). Placing a dollar value on a life year begins to build a bridge between two different conceptual approaches to economic evaluation: cost-benefit analysis and cost-effectiveness analysis. Cost-effectiveness analysis avoids placing a monetary value on health. Instead, the analysis compares the incremental cost of the intervention to the incremental health effect achieved. The quality-adjusted life year, or QALY, has emerged as a standard measure of effectiveness, and the cost per QALY saved has been estimated for a wide range of health interventions (Gold et al., 1996). The QALY approach not only incorporates the quantity of life or years of life extension from an intervention, but also the quality of life, based on individuals' preferences over different health states. For example, a year of life with a serious illness might be weighted as being as valuable as 0.7 of a year of life with perfect health. Placing a monetary value on a QALY allows the health effects to be monetized, converting any cost-effectiveness analysis into a cost-benefit analysis.

The use of the life year approach is illustrated in the FDA's (1999b) analysis of a proposed rule about food labeling related to trans fatty acids, nutrient content claims, and health claims. By encouraging more healthful dietary choices, changes in food labeling regulations have the potential to reduce mortality from coronary heart disease. In the FDA's analysis, the cost of a fatal event is the discounted years of life lost multiplied by the dollar value of a quality-adjusted life year. FDA estimates that the average victim of coronary heart disease loses 13 years of life, which discounted at 7 percent becomes 8.4 discounted years. Valuing each life year at $100,000, the average value per fatal case, i.e., the analogue to the VSL, is about $840,000.

The Same Life-Saving Benefits Should Be Given the Same Value

Although there is general agreement on the principle of valuing the life-saving benefits of regulations, the review of recent practice suggests that the EPA, the USDA, and the FDA rely on somewhat different VSL estimates. A hypothetical example provides an extreme case of the

extent of disagreement. Suppose that each agency were considering the life-saving benefits of a regulation that reduced mortality risks for a group of 50-year-olds. The EPA's (1997) review of WTP estimates suggests the benefits should be based on a VSL of $4.8 million. The hybrid human capital/ WTP approach used by the USDA suggests a VSL of $721,418. The value of a life year approach used by the FDA implies that a VSL of $1.2 million should be used.[3] This range shows substantial disagreement; for example, both the USDA and FDA estimates fall outside the confidence interval around the EPA's estimate of the mean VSL.

If different regulatory agencies' efforts are guided by an inconsistent set of VSL's, the result will be an inefficient set of regulations. Consider a stylized regulatory decisionmaking process, where each agency uses cost-benefit analysis to decide whether to enact possible life-saving regulations. Given their different areas of regulatory responsibility and authority, assume each agency faces a schedule showing that it can save additional lives through more regulations, but only at an increasing marginal cost imposed on the economy. Each agency chooses to regulate until the marginal benefits of life saving, as measured by its preferred estimate of the VSL, just equal the marginal costs. When decisionmakers in the different agencies use inconsistent estimates of the VSL, the result is inefficient, in the sense that it is possible to re-allocate regulatory efforts to reach an outcome that all decisionmakers would agree is an unambiguous improvement.[4] Using the different VSL's from the hypothetical example, suppose the EPA marginally reduced its regulatory efforts and saved two fewer lives, while at the same time the USDA and the FDA marginally increased their regulatory efforts to save one more life each. The net result would be the same number of lives saved, but the regulatory costs would fall by $7.7 million.

Tengs and Graham (1996) provide a detailed analysis of the inefficiency that results from inconsistent, or in their perhaps more appropriate term, "haphazard," public investments in life-saving activities. They consider 185 life-saving interventions, which included but were not limited to regulatory efforts like those of the EPA, USDA, and FDA. In total, the interventions currently implemented are estimated to cost the economy approximately $21.4 billion and save approximately 56,700 lives. By choosing interventions to minimize costs, Tengs and Graham estimate that it is possible instead to save the same number of lives and save about $31.1 billion of costs. This surprising result is because Tengs and Graham identify many untapped interventions that save both lives and money. Implementing these interventions makes it possible not only to save the $21.4 billion currently being spent, but to save another $10 billion as well. Alternatively, holding the cost constant at the current level of $21.4 billion but choosing interventions to maximize lives saved, Tengs and Graham estimate that it would be possible to save about twice as many lives 117,000 annually than results from the current set of regulations.

The analysis of Tengs and Graham raises an important question: Are decisions about life-saving regulations based on inconsistent estimates of the VSL, or simply made haphazardly with little

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[3]Following the FDA (1999b), the value of a year of life is assumed to be $100,000, and a discount rate of 7 percent is applied. Assuming an individual at age 50 has a life expectancy of 29 years, discounting at 7 percent yields 12.3 years.

[4]This explanation draws on Sugden and Williams (1986, pp. 187-190) general discussion of the importance of consistency in decisionmakers' valuations of costs and benefits.

described above, where cost-benefit analysis drives every regulatory decision, is not a literal description of how decisions are made. Several reviews provide a mixed picture of the role of consideration of the benefits and costs? Clearly, the stylized regulatory decisionmaking process cost-benefit analysis in regulatory efforts. Based on a review of the record of the 1980's, Viscusi (1996) suggests that different agencies' reliance on cost-benefit analysis makes a systematic difference in their regulatory efforts. Using a VSL of $5 million as the cutoff for efficient regulations, Viscusi lists 13 regulations that pass a cost-benefit test per life saved, and 20 regulations that fail a cost-benefit test. Similarly, Hahn's (1996) review of 92 final and proposed rules for 1990 to mid-1995 finds that, using the agencies' estimates of benefits and costs, only 17 would pass a cost-benefit test. However, Viscusi (1996) notes an interesting pattern in the earlier record. He argues that the fact that all of the listed regulations that were issued by the U.S. Department of Transportation (DOT) pass a cost-benefit test is no accident: The DOT relies heavily on cost-benefit analysis, using $3 million for the VSL in its evaluations.

Aside from regulatory decisions of the DOT, it is hard to escape the conclusion that few decisions about life-saving regulations are being made primarily based on benefits and costs. These so-called "haphazard" decisions may reflect other systematic influences, such as political pressure. Whether these influences are a legitimate part of the regulatory decisionmaking process is a much broader question. For the narrower question considered here, using a consistent VSL estimate in evaluations of life-saving regulations by different agencies is clearly an important step toward the more limited goal of improving the economic efficiency of regulatory efforts.

Different Life Saving Benefits Should Be Given Different Values

The last section emphasized the desirability of different regulatory agencies using the same VSL when they are evaluating the same life-saving benefits. However, different regulations often result in fundamentally different types of life-saving benefits. The selected evaluations reviewed in section 1 address the life-saving benefits of reducing mortality from bladder cancer, cryptosporidium illnesses, viral illnesses, congenital toxoplasmosis, Guillain-Barré, syndrome, and coronary heart disease. This section discusses when it is desirable to use different estimates of the VSL for these different risk reductions. Two sources of heterogeneity in the VSL are discussed. First, there is heterogeneity in the willingness to pay across different health risks for the same individual. Second, there is heterogeneity across individuals in their willingness to pay for risk reductions.

Individual WTP for a given reduction in mortality risks probably differs depending upon the cause of death. The VSL typically estimated applies most directly to WTP to reduce the risks of unforeseen instant death, such as a workplace or traffic accident. However, people may be willing to pay substantially more to reduce risks where there is a lengthy period of morbidity preceding death, both because of the value of morbidity avoided and the psychic costs of imminent death. Empirical evidence on WTP for different types of mortality risks appears to be fairly limited. Jones-Lee, Hammerton, and Philips (1985) report that, given a choice between preventing 100 deaths from cancer, heart disease, or motor vehicle accidents, most respondents preferred to prevent deaths from cancer. The means of responses indicate that preventing 100 deaths from heart disease is worth almost twice as much preventing 100 deaths from motor

vehicle accidents, while preventing 100 cancer deaths is valued at about three times the value of preventing accidental deaths. Based on this and other evidence, Tolley, Kenkel, and Fabian (1994) argue that the appropriate VSL for lung cancer mortality may be twice the size of the VSL appropriate for mortality due to unforeseen, instant death. Similarly, it may be appropriate to use a higher VSL to evaluate the benefits of reducing mortality from bladder cancer due to water pollution and a lower VSL to evaluate the benefits of reducing mortality from acute infection from foodborne illness.

While the same individual may have a different WTP to reduce the risks of different causes of death, different individuals may also have different WTP's to reduce the same risk. Just as for other commodities, people may value health and safety differently due to idiosyncratic differences in tastes and preferences, income levels, and so on. Just as for schooling human capital, people may value their health and safety capital differently at different points in the life cycle (Cropper, 1977). In addition to variation over the life cycle in WTP to reduce risks to adults, altruism in societal WTP means that there may be a special premium on reducing mortality risks for children.

The various sources of heterogeneity in WTP lead to the somewhat controversial conclusion that different VSL's should be used to evaluate the life-saving benefits of regulations that affect different groups of people. The EPA (1997, p. 77) notes that the population most affected by reductions in air pollution-related mortality risks is likely to be older than average, disproportionately drawn from those aged 65 and over. Improvements in drinking water filtration to prevent infection by cryptosporidium will reduce risks especially for sensitive populations, including children, especially the very young, the elderly, pregnant women, and the immunocompromised (EPA, 2000a). Regulations to prevent exposure to *Toxoplasma gondii* in food will reduce risks for infants (Roberts and Frenkel, 1990). Ideally, the benchmark VSL of $4.8 million suggested by the EPA (1997) should be adjusted to account for these differences. For example, because of the methods used the standard estimate of the VSL mainly reflects the preferences of workers with an average age around 40. The correct VSL to evaluate an air pollution regulation might be somewhat lower, while a higher VSL should be used when evaluating food-handling regulations that affect the risks to infants. The conceptual justification for the use of different VSL's is that, in private decisions, individuals display different WTP to reduce risks depending upon their age and other characteristics, so public decisions should reflect the same preferences.

Limited evidence suggests that WTP to reduce mortality risks varies systematically over the life cycle of working age adults. In a theoretical analysis, Shepard and Zeckhauser (1982) predict that the relationship between the VSL and age will show an inverted U-shape, with a peak around the age of 40 years, dropping to about 50 to 70 percent of the peak by the age of 60. This pattern is roughly consistent with the empirical results of Jones-Less et al. (1985), but the magnitude of the changes in VSL over the life cycle are estimated to be smaller than predicted by theory. For example, the VSL at age 65 is estimated to be still about 90 percent of the peak VSL from age 40. These patterns are also similar to the life cycle patterns in the VSL estimated by the hybrid human capital/WTP approach.

Moore and Viscusi (1988) extend the standard wage-risk study to explore if workers of different ages reveal different WTP for job risks. Using data from the 1977 Quality of Employment Survey, their results imply that the value of a life year averaged more than $170,000 (1986 dollars), and that the VSL is about $6 million. The results imply that different types of life-saving activities will have much different values depending upon the age of the affected individuals and the timing of the risk reduction. For example, to a worker who expects to live for 35 more years, a 1-year life extension is estimated to be worth only $11,000 now. But a one-year life extension is estimated to be worth about $400,000 for an older worker with a life expectancy of 5 years.

The wage-risk approach does not provide information on the value of life-saving activities that affect children, the elderly, and other groups who are not in the labor force. Studies that examine revealed preferences for risks in other market contexts are beginning to provide preliminary estimates of the appropriate VSL for these groups. Blomquist et al. (1996) analyze decisions about seat belt use for children, and estimate that WTP to reduce risks to children is equal to or larger than WTP to reduce risks to adults. Mount et al. (2000) use data on automobile purchases to estimate how much single-car families and families of different composition spend on safety. This approach allows them to estimate the VSL for children, adults, and the elderly. For example, one set of estimates suggests the VSL for adults is $6.34 million, while the VSL for children is $4.28 million and the VSL for the elderly is $4.59 million. This suggests the same inverted U-shape predicted by the theoretical analysis of Shepard and Zeckhauser (1982). However, the estimated VSL for children is sensitive to certain assumptions made in the analysis. Under some sets of assumptions, the VSL for children exceeds that of adults and the estimated VSL steadily declines over the life cycle.

Another approach to estimating WTP for life-saving activities that affect different age groups is to conduct surveys that directly ask about preferences for hypothetical life-saving programs. Cropper, Aydede, and Portney (1994) report the results of surveys of over 3,000 respondents given choices between various pairs of life-saving activities. For the median respondent, saving one 20-year-old is equivalent to saving seven 60-year-olds, while saving the lives of 20-year-olds and 40-year-olds are viewed similarly. This suggests a somewhat different pattern for the VSL over the life cycle, with the VSL being roughly constant until the age of 40 but sharply dropping at older ages. However, in these surveys respondents were put in the role of social decisionmaker. Asking people about how they think societal decisions should be made is different that asking them about their willingness to pay to reduce their own risks. Because of this difference, it could be argued that these survey responses are not that relevant to the empirical pattern of VSL over the life cycle.

In addition to the role of age, other individual characteristics may affect WTP for risk reductions. The role of income is another controversial example. If regulatory efforts are judged solely on the basis of economic efficiency, the principles of cost-benefit analysis imply that the VSL should also depend on the average income of the population experiencing the risk reduction. Many analysts object to this implication on the grounds of equity or social justice, and in fact it is often cited as a reason to prefer cost-effectiveness analysis over cost-benefit analysis when evaluating health interventions. As Pauly (1995) notes, this objection is often a red herring because many health and safety interventions do not have a wealth bias. Kenkel (1997) argues

further that concern about the unequal distribution of benefits and costs is not new or unique to the analysis of health interventions. He points out that there are several methods, including the distributional weights approach and the basic needs approach, to bring distributional concerns into cost-benefit analysis in a systematic way. Taking this approach suggests the use of income-adjusted VSL's for strictly efficiency-based cost-benefit analysis of life-saving regulations, to be supplemented with additional analysis that account for the distribution of costs and life-saving benefits.

Conclusions

Another way to summarize the arguments made in the preceding sections is that the evaluations of the life-saving benefits of regulations should use consistent and specific estimates of the VSL. When different agencies reduce similar health risks for similar populations, they should use consistent estimates of the VSL; but each agency should use VSL estimates that are specific to the health risk and population affected by its regulations. This presents a challenge for both the research community that generates VSL estimates and the policymaking community that uses them.

One way to develop a catalogue of consistent and specific VSL estimates is the "monetized QALY approach" such as that used by the FDA (1999a, 1999b). Achieving consistency would be straightforward: different agencies could use consistent dollar value per QALY when evaluating all regulatory efforts. The monetized QALY approach would also yield specific VSL's that depend on age, pre-existing health state, and cause of death. Whether the monetized QALY approach yields specific VSL's that are good estimates of societal WTP is more problematic. For example, the monetized QALY approach might understate societal WTP for regulations that save the lives of children, because there is some evidence that people are willing to pay a special premium for such risk reductions. Empirical evidence also suggests that the VSL declines more slowly with age than that implied by the monetized QALY approach.

The conceptual foundation for monetizing QALY's needs to be examined closely and linked to the VSL literature. QALY weights are based on individual preferences over health states, as revealed in surveys or experiments. These methods deserve at least the same level of scrutiny as the contingent valuation method. A noted limitation is that many methods used to develop QALY weights rely on asking respondents about health states that they have not experienced. As a validity check, market behavior should be analyzed to see if it is consistent with QALY approach and weights. This might also provide a revealed-preference approach to monetizing QALY's. Until a number of important issues along these lines are resolved, it is premature to view the monetized QALY approach as meeting the need for a set of consistent and specific VSL estimates.

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Comments by Chris Dockins on

"Using Estimates of the Value of a Statistical Life in Evaluating Regulatory Effects"
(by Donald Kenkel)

My goal here is not to recapitulate the state of the literature or to outline a detailed conceptual framework for discussing the subject of health risk valuation in the context of food safety. Rather, I'd like to give you the perspective of someone inside a Federal agency facing these challenges in applied work. Dr. Kenkel provided an appropriate starting point for our discussions over the next few days, and the two fundamental propositions he submitted are sensible: the value of similar risks should be similar; the value of different risks should differ. I hesitate to use his exact words "the same risk should be given the same value" because in my capacity I have found it valuable to always be conscious of the language we use to discuss economics with non-economists. It is certainly a convenient shorthand to say that we "give values" to risk. It is shorthand that we use frequently to mean, "we expect to observe individuals to value similar risks similarly." However, when we say that we should "give" values to risk some might infer that these values are ours to give. In fact, they are ours only to observe and to estimate, if we can.

In any case, the most pressing question for an economist inside a regulatory agency is not whether we should follow through on these propositions, but whether we can, in practice, do so. I submit to you that this is not as simple as it may appear.

The subject of consistency in valuation of health risk reductions has come to the fore in EPA as we have undertaken efforts to revise our Guidelines for economic analyses. As part of this process we established an Economic Consistency Workgroup to assess how we can approach these questions more consistently than we may have done in the past. The conversations of the workgroup made it clear that different offices within EPA had approached these questions in different manners, in no small part because of the variety of statutes and requirements under which they operate. For example, the 1996 amendments to the Safe Drinking Water Act allow, for the first time, the consideration of benefits and costs in setting maximum contaminant limits. The amendment even specifies that benefits are to be measured in terms of willingness to pay. The Clean Air Act, on the other hand, does not allow for considerations of benefits and costs in setting ambient air quality standards. These are familiar examples to many of you.

These varying requirements affect the decision processes in the program offices, including the types of information seen and considered in decisionmaking. I don't know the details of the statutes under which FDA and other Federal agencies operate, but if such diversity exists within

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Chris Dockins is with the National Center for Environmental Economics, U.S. Environmental Protection Agency. Any opinions, findings, and conclusions or recommendations expressed here are those of the author and do not necessarily reflect the views of the Environmental Protection Agency.

a single agency, a more thorough review of statutory requirements across the Federal Government would surely reveal even greater variation.

This diversity is reflected in the decisions made by Federal agencies. A relatively recent review of the cost-effectiveness of these regulations labels these investments as "haphazard." This struck me as curious so I turned to my *Webster's II New Riverside University Dictionary*, the one given to me when I came to work for EPA and with "Property U.S. Government" stamped in gold across the cover, and looked up the word. There is only one definition, "dependent upon or marked by chance." I don't fault the authors for their choice of title because it obviously served its purpose, getting me among others to read the article and think about it afterward. But the decisions analyzed are by no means haphazard. Instead the implications of regulatory actions are carefully considered before a final decision is made. I would like to see an estimate of the mean number of hours that go into analysis and consideration of EPA regulations. My guess is that it would be in the thousands. No, the investments are not haphazard. One may argue, however, and this is what the authors do, that the individual investments are not efficient, and that, taken together, they are not the most cost-effective use of resources. That is, they are not economic.

I note this only because it serves to underscore the importance of considering the context in which such regulatory decisions are made. Those of us who would like to see economics play a larger role in these decisions do ourselves no favors by downplaying these contexts. In fact, a better understanding allows us to make our case more convincingly and credibly.

Nor does the lack of economic considerations in some regulatory decisions let us "off the hook" in our economic analyses. Actually, I believe that it does just the opposite, placing an even greater burden on us to demonstrate that applied economic work, especially the analysis of health benefits, can lead to better decisions. But to do this we must demonstrate that we can do economics well – or, at least, that our analyses are consistent with one another and with theoretical expectations. We must demonstrate that we can produce reliable, sensible estimates for health benefits.

Can we do this for a variety of types of health risks? Can we produce analyses that value different risks differently?

Recently, EPA raised this issue to its Science Advisory Board for their consideration. Specifically the issue was how we may value reduced cancer fatalities given that we don't know much directly about how people value these kinds of risks.

The EPA produced a white paper that intentionally extrapolated beyond the existing literature on the subject. The white paper drew on speculative conclusions drawn from Revesz (1999) and other studies that have pushed this particular envelope in the field of valuing health risks. In comparing cancer risks (which we know little about) and accidental fatality risks (which we know much more about) the white paper enumerated many differences in risk characteristics (e.g., dread, voluntariness and controllability, the timing between exposure and death, morbidity periods prior to death) and population characteristics (e.g., age, income, health status).

The question put to the Committee was what could we do empirically in a benefit cost analysis to account for these factors? In the opinion of the SAB the only thing we can do empirically to date is to adjust for a latency period through discounting. Some of the other factors were identified as potentially or theoretically important, but lacking the empirical research necessary to be included into the valuation of reduced cancer risks.

I don't necessarily disagree with the conclusions of the Science Advisory Board. In most cases there is precious little empirical research to rely upon in accounting for these factors, despite the fact that psychometric factors that affect the perception—and perhaps the value—of risk have been studied for over 20 years in the cognitive psychology literature. The conclusion of the Science Advisory Board highlights the fact that we have a great deal of work to do before we are able to systematically and appropriately value different risks differently.

We should not give up hope on this, but should instead accept this conclusion as a call for additional research. I know that several empirical studies that may provide some insight are underway even now and I hope that many of the questions will be much clearer when the results are considered. But perhaps this also tells us that, on a practical level within Federal agencies, we should focus on the first proposition of valuing similar risks similarly. My experience suggests that even this seemingly simple task is not without its challenges. However, we have the ability to do this now—or at least to make a credible start. We must move down this path if we wish to make a sincere case that benefits analysis play a serious and substantive role in policy decisions.

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Rappporteurs' Notes for Valuing Statistical Lives

Rapporteurs: Linda Chappell, Nicole Owens, David Widawsky, and Nathalie Simon,
all with the U.S. Environmental Protection Agency

The Value of a Statistical Life discussion centered around four primary themes: limitations of the current VSL approaches used by the various agencies, ideal measures of VSL, applications in a regulatory setting and future research needs.

The breakout session was attended by 18 participants, some of whom were not necessarily familiar with foodborne illnesses and the nature of these illnesses. The session therefore began with a brief discussion of the types of foodborne risks, the nature of the ensuing illnesses, and the populations with greatest mortality risk. This was followed by a recap of the approaches taken by the various agencies in valuing fatal risks. Generally, EPA separates the morbidity period from the mortality endpoint and values each separately. Premature mortality is valued at $5.8 million (1997 dollars) regardless of age, health status, etc., while the morbidity period is generally valued using cost-of-illness numbers in the absence of willingness-to-pay values. The VSL figure used by EPA is based on a summary of 26 studies that estimate VSL (primarily labor market studies). FDA uses a value of $5.0 million, based on similar studies.

The use of a single value for mortality risk valuation was recognized as one of the most significant limitations of the VSL numbers currently in use by the agencies. These values are not illness specific and, since they are based primarily on labor market studies as noted above, are based on values for reductions in risks of accidental (relatively immediate) deaths. Deaths associated with foodborne illness on the other hand are sometimes preceded by extended and often painful periods of morbidity. While some participants argued that, in many cases, analysts could value the morbidity period separately from the mortality endpoint, there was general concensus that cancers should be treated as a separate class of illness. It was recognized that cancers generally have an lengthy morbidity period, are often fatal, and have a large "dread" factor associated with them that in all likelihood would affect willingness to pay to reduce cancer risk.

Another serious limitation of the current values used by the agencies is that they are derived from studies of prime-aged males with an average age of 40 years. In the case of foodborne illness, however, the exposed population most susceptible to mortality risks are children and the elderly. It is not clear that the VSL values currently in use are appropriate to value risk reductions to these subpopulations with such disparate ages.

Yet another concern identified by the group involved benefit transfer. When VSL values are derived from survey results or even hedonic wage studies, the risks are treated as certain and of a given magnitude. The resulting VSL numbers are transferred to scenarios where the magnitude

of the risk is often very uncertain given the nature of the risk assessment. This uncertainty could have serious implications for VSL.

Given the limitations of the current values, the group agreed that ideally specific values should be developed; however, there was some discussion as to whether it was most appropriate to value health endpoints or specific reductions in exposure, involving specific populations and ranges of risk levels. It was also recognized that specific values, regardless of whether they were for specific illnesses or reductions in specific contaminants, would be very costly to obtain. A concensus was eventually reached that specific values for reductions in cancer risk should be developed.

The remainder of the discussion centered around identifying priorities for future research in the short, medium, and long term. In order to avoid duplicated efforts, it was noted that agencies sponsoring or engaging in mortality risk valuation research should at the very least make abstracts of funded research projects available to the public. The agencies involved should also consider jointly funding some of projects as well as working with the EPA/NSF grant program. A number of projects were identified that could make better use of existing information as well as expanding the information available for economic analyses of food safety regulations. Research goals are categorized below by the time necessary to realize results.

Short term (1 to 2 years):

1. *Determine which foodborne illnesses pose the greatest mortality risk*
   In order to focus future mortality risk valuation studies, it will be important to identify which foodborne illnesses create the greatest mortality risk to the population. It will also be important to identify the characteristics of the illnesses in question, such as length of morbidity period, symptoms, age distribution of those affected, etc.

2. *Revisit mortality risk valuation literature*
   EPA and other agencies rely on various combinations of 26 VSL studies, including examples of hedonic wage and contingent valuation approaches, identified by Viscusi (1992) as Ahigh quality.@ Since the publication of Viscusi=s review article however, other studies may have been completed that could be relevant to mortality risk valuation from a food safety context, while others may since have been deemed inappropriate for various reasons. The mortality risk valuation literature should be revisited with the aim of identifying the most relevant high-quality studies for food safety risk valuation. Prior to completing this task, a general understanding should be reached regarding the definition and desirable characteristics of Ahigh-quality@ studies.

3. *Rework existing data*
   Economists should follow the lead of epidemiologists and allow other researchers to attempt to replicate results using available data. Some of the heavily cited VSL studies were completed 5 to 10 years ago. While many of the mortality risk valuation studies were completed using publicly available data, the datasets from which these data were compiled are large and cumbersome to use. Researchers should attempt to obtain access to previously utilized data to reanalyze them and to determine whether VSL figures vary according to sample characteristics, sub-sample of focus, etc.

4. *Explore more refined ways to aggregate studies*
   In addition to reworking the existing data, researchers should explore more refined ways of aggregating results from existing studies through meta-analysis and other techniques. In order to accomplish more meaningful aggregations, it will be necessary to obtain more detailed information on the age distribution of individuals included in each study as well as other socio-demographic characteristics, details regarding estimation approaches and data-cleaning techniques.

5. *Pilot Experimental Studies for Calibration of VSL*
   Using a relatively small sample of respondents, calibration factors for VSL figures can be developed by observing risk-averting behaviors in some detail. Using the observed behaviors, researchers can calculate an implicit VSL and accompanying calibration factors for extrapolation to a larger population.

Medium Term (2 to 3 years):

1. *Expanded Experimental Studies*
   Conditional on the relative success of the pilot studies, expanded experimental studies should be considered for calibration of VSL values. These expanded studies may combine market research data (brands purchased, quantity purchased, etc.) with experimental approaches.

2. *Revisit Benefit-Cost Analysis of Selected Regulations*
   Using the improved VSL figures derived in studies described above, the economic analysis for several regulations should be revisited in order to determine the effect of the updated estimates on the outcomes of the analyses.

Long term (more than 3 years):

More VSL studies need to be conducted with the aim of answering a number of specific questions:

1. *Does the contingent valuation method yield similar results to those from a revealed preference study?*
   A paired CVM and revealed preference study should be conducted in which the same good is the focus of each. The results should from the two approaches should then be compared.

2. *How does VSL vary by cause of death?*
   It is generally thought that VSL may be affected by various factors associated with the illness considered. For instance, the higher the amount of dread associated with the illness, the higher the willingness to pay to avoid the illness. Cancer, for instance, is one category of fatal illness thought to carry a high dread level. Other illnesses may be similarly positioned and other factors may have similar effects on willingness to pay. Researchers should conduct studies that focus on mortality by specific causes to gauge the effect of illness specific mortality on VSL.

3. *How does VSL vary across socio-demographic characteristics?*

In cases where a specific sub-sample of the population is more susceptible to the risk in question than the rest of the population, it is important to gauge how VSL varies by specific characteristics of the population. Age is a potentially important characteristic in this regard as is income. In the context of foodborne illnesses, children and the elderly are more susceptible to mortality risks than middle-aged and young adults. While some analysts advocate adjusting VSLs according to the number of life-years remaining for specific sub-groups of the population, there is no empirical evidence to date indicating that the value of a statistical life year is constant across the life span of an individual. Furthermore, almost no information exists on the value of a statistical child=s life.

4. *How does VSL vary across different risk sources?*
   As mentioned above, most of the VSL studies used by agencies to value health risks are labor market studies. Researchers should determine whether the source of the risk (such as foodborne risks versus labor market risks) affects willingness to pay.

5. *How does the nature of the risk affect valuation?*
   Even if the vehicle of exposure is the same, other aspects of the risk may affect willingness to pay such as whether the risk is manmade or whether it occurs naturally in the environment.

6. *How does altruism affect VSL?*

SESSION II

VALUING PAIN AND SUFFERING AND LOST PRODUCTIVITY

Measuring the Pain, Suffering, and Functional Disability Associated with Foodborne Illness

Josephine Mauskopf, Ph.D.
Roberta A. Morales, D.V.M., Ph.D.

Abstract

The annual impacts of foodborne illness on the U.S. population can be estimated by multiplying the number of cases of illness at different levels of severity each year by the impact on pain, suffering, and functional disability associated with each case. In this paper, we categorize the methods that have been used to estimate the number of cases of illness into 'top-down' and 'bottom-up' approaches, depending on whether or not they start with observed cases or use dose response relationships to estimate cases. We describe these methods and identify the strengths and weaknesses of each. We then describe a methodology to estimate the impact on pain, suffering, and functional disability of a case of foodborne illness. This method first estimates the number of deaths, number of hospital days, number of restricted-activity days (bed-days or house-days), and types of symptoms associated with each foodborne illness at each level of severity. These health outcomes are then combined into a single measure of disease burden, the quality-adjusted life years (QALY's) lost by associating the disease outcomes with utility weights and duration. The paper concludes by demonstrating how these estimates of the QALY's lost can be used to estimate the impact of food safety regulations on the pain, suffering, and functional disability of the U.S. population.

For more information contact Josephine Mauskopf, Ph.D., Center for Economics Research, Research Triangle Institute, 3040 Cornwallis Road, Research Triangle Park, NC 27709.
Phone 919-541-6996; Fax 919-541-6683; E-mail JOM@RTI.ORG

Introduction

Foods produced or imported for human consumption in the United States are regulated for safety and quality under as many as 35 different laws implemented by 12 different Federal agencies (GAO, 1990). Some of these agencies have major roles in implementing the food safety laws:

- the Food and Drug Administration (FDA), which is part of the U.S. Department of Health and Human Services;
- the U.S. Department of Agriculture (USDA) Agricultural Marketing Service (AMS), Federal Grain Inspection Service (FGIS), and Food Safety and Inspection Service (FSIS);
- The Environmental Protection Agency (EPA); and
- the National Marine Fisheries Service (NMFS), which is part of the U.S Department of Commerce (GAO 1990).

One of the chief goals of U.S. food safety laws is to reduce the presence of contaminants and adulterants in domestic and imported foods. Consuming foods that contain illegal contaminants or adulterants (e.g., pesticide residues, illegal food dyes, microorganisms) increases an individual's risk of foodborne illness**.**

The probability that a violation of the food safety laws will adversely affect a consumer's health depends on the type of violation, the level of contamination, the food processing pathway before consumption, and the typical portion size for the contaminated product. For example, a food product contaminated with salmonella is more likely to adversely affect a consumer if the level of contamination is high, the product is eaten without further cooking, and the portion size is large. In addition, excess risk of cancer from exposure to pesticides is likely to be related to both duration and intensity of exposure. Biologists and toxicologists have studied these relationships for many years, but it is still difficult to predict accurately the association between ingesting a particular product that violates the U.S. food safety laws and the probability and severity of a particular adverse health effect.

The impact of a particular adverse health effect on the patient depends on the expected symptoms, duration, and effect on functional status. Clearly, the impacts are greater for adverse health effects that have serious symptoms, require extensive treatment, last for a long period of time, and/or cause premature death.

In this paper, we describe methods that are currently used to measure the impacts of foodborne illness on the U.S. population. The focus is on non-monetary measures of these impacts; measures of pain, suffering, and functional disability. These measures include the number of deaths, number of hospital days, number of restricted-activity days (bed-days or house-days), types of symptoms, and the number of disability-adjusted or quality-adjusted life years lost. The annual impacts of foodborne illness on the U.S. population are estimated by multiplying the number of cases of illness at different levels of severity each year by the impact on pain, suffering, and functional disability associated with each case. We also describe how estimates of the population impacts of foodborne illness can be combined with information on the impacts of Federal regulation on violation rates and level of contamination to estimate the benefits of these regulations.

Measuring the Annual Number of Cases of Foodborne Illness

The non-monetary impacts of foodborne illness depend critically on the number of cases of each illness at each level of severity that occur each year. There are two main methods that have been proposed for estimating the number of cases occurring each year in the United States—a "top-down" method and a "bottom-up" method. The "top-down" method is based on the number of cases reported each year to the Centers for Disease Control (CDC) or the number of cases observed in other national surveys. The "bottom-up" method combines estimates of number of exposures to the violative food and of the level of contamination with dose-response relationships.

Buzby et al. (1999) identify several sources of data that can be used for estimating the number of new cases of different illnesses attributable to the food supply each year in the United States. These include data from large national surveys such as the National Ambulatory Care Survey or the Hospital Discharge Survey or the Healthcare Cost and Utilitization Project that give estimates of annual US physician visits or hospital stays by diagnosis. A second data source is the CDC, including annual reporting data and epidemiologic data, such as outbreak investigation and surveillance data. A third data source is case studies of individual cases or groups of cases from the same causative organism that are published in the medical literature. Other data sources include risk models that combine information on the prevalence of pathogens in food and on the size of the infectious dose (i.e., exposure assessments) and dose response relationships to obtain estimates of the distribution of disease severity (i.e., hazard characterization). The first three data sources are generally used to derive "top-down" estimates and risk models are used to derive "bottom-up" estimates.

CDC has recently proposed a methodology that should be used for estimating the number of cases of foodborne illness by severity using a "top-down" approach. Their approach uses an inverted pyramid (see figure 1). In developing this model, CDC augmented the data on reported cases from the Foodborne Diseases Active Surveillance Network (FoodNet) with laboratory, physician, and population surveys from the eight sentinel sites. This top-down approach enabled CDC to sequentially develop several estimates:

- culture-confirmed cases, culture/testing of submitted specimens from the laboratory surveys;
- specimens collected as part of treatment regime from the physician surveys; and
- individuals becoming ill and proportion seeking medical care from the population surveys.

They used these estimates to arrive at an overall estimate of the number of cases of foodborne illness (CDC, 1999). Mead et al. (1999) expands this approach to develop estimates of foodborne illnesses and deaths in the United States.

The CDC approach has been used by Buzby et al. (1999) to estimate the number of cases of several bacterial foodborne diseases. For example, for salmonellosis cases, they use an extrapolation method based on CDC's surveillance system and outbreak data. CDC's surveillance system for salmonellosis includes reporting from the State health departments based

on physician reports as well as reports from State health department laboratories. Since both surveillance data and outbreak data are underestimates of the total number of cases, these data are adjusted upwards.

The upward adjustments in the Buzby study were calculated using multipliers derived by Chalker and Blaser (1988) to account for the underreporting inherent in passive surveillance systems. Three methods were employed by Chalker and Blaser to derive these multipliers. In the first approach, information on carriage rate and median duration of excretion were obtained from the literature and used to calculate an annual incidence of infection for a particular pathogen. The second method uses the passive surveillance system as a starting point then, through a literature review of the sequential steps required for a case to be reported, identifies or develops corresponding estimates of those sequential artifacts resulting in underreporting. The sequential steps that are required for a foodborne illness to be reported to the CDC as defined by Chalker and Blaser (1988) are:

1) The patient must be infected with the organism;
2) The patient must be ill;
3) The patient must consult a doctor;
4) The doctor must obtain a culture;
5) The culture must be positive;
6) The laboratory must report the isolation to the county or State health department;
7) The State health department must report the isolation to the CDC.

The resulting underreporting estimate is multiplied by the number of reported cases to obtain an annual incidence rate. The third approach involves a review of outbreak investigation data (case definition is the presence of acute gastroenteritis) and the ratio of cases initially reported to those cases identified upon completion of the outbreak investigation provides an overall estimate of underreporting. This adjustment is applied to the number of cases reported to the CDC to give the total number of salmonellosis cases in a year. The estimates of annual incidence obtained for *Salmonella* using each of these approaches were 3.7 million, 1.6 million, and 800,000, respectively and this range of estimates was used in the Buzby study.

An alternative data source was used for estimating the number of people and days with symptoms of acute foodborne illness by Golan et al. (2000) in their study of the distributional consequences of improvements in food safety. They used estimates of total days with symptoms of foodborne illness that caused at least half a day of restricted activity or required a physician visit as reported in the National Health Interview Survey. This is a good measure of the total impact of acute foodborne illness on the U.S. population, but the impact of specific diseases cannot be measured and so it would be hard to estimate the impact of food safety regulations targeted at specific diseases on these restricted-activity days. In addition, the estimates from the NHIS may not include the mildest cases of illness, may not include foodborne illnesses with primarily neurological symptoms, and may include illness from non-foodborne causes with similar symptoms. Finally, the NHIS does not include the institutionalized population.

To estimate the losses associated with these cases of salmonellosis (either in terms of cost of illness or in measures of pain, suffering, and functional disability), it is necessary to subdivide them by degree of severity. In the Buzby study, salmonellosis cases are subdivided into four

categories, those who do not seek medical attention, those who visit a physician, those who are hospitalized, and those who die prematurely.

Death rates for salmonellosis in the Buzby study were estimated based on a 1984-85 survey by the CDC that estimated the death rate for reported cases. This was applied to the estimated number of salmonellosis cases. The proportion of people who were hospitalized or who visited a physician were estimated using survey data from the largest recent U.S. outbreak of salmonellosis (Chicago, 1985). This survey provided estimates of the percent hospitalized among those who had symptoms and the percent who visited a physician among those who had symptoms. These percentages were applied to the total number of cases. The number of people who had symptoms but received no medical attention and did not die was then calculated as the difference between the total number of cases and those who received medical attention and/or died.

The main strength of the "top-down" approach is that it is based on observed data. Its main weakness is that no explicit relationship is derived between the number of exposures to the pathogen and the level of contamination and the resulting disease incidence by severity. Thus, using this approach, it is not immediately obvious how to estimate the impact on the number of cases of foodborne illness of regulations that have as their goal a reduction in the number or intensity of exposures to different contaminants. Another weakness of this approach is that it can be used to estimate only the number of cases of acute or chronic illness that can readily be associated with a foodborne cause and thus form part of the CDC surveillance system. Cancer cases from ingested pesticides would not be included, nor would chronic conditions unless they were reported as sequelae to diagnosed acute illness.

An alternative method that has been proposed and is now being used for the estimation of cases of foodborne illness is the "bottom-up" approach. In this approach, the number of cases of foodborne illness of different degrees of severity are estimated based on the:

- probability of foods having a specific violation of the food safety laws and the level of contamination;
- number of people eating these violative foods and their estimated level of exposure to the violation; and
- probability distribution of different levels of severity of illness that result from this exposure.

These three estimation steps will be described below and illustrated using estimates of the number of cases of foodborne illness associated with imported foods and estimates of the number of cases of foodborne illness associated with shell eggs.

The probability of foods' having a specific violation of the food safety laws and the level of contamination will depend on multiple factors including the:

- likely association of the violation with different types of food; and
- conditions of growth and/or preparation, handling, and distribution of the food before it reaches the consumer.

For example, imported foods may have different probabilities of being in violation of the food safety laws both because of different natural growth conditions as well as different local

regulations about pesticide use and food processing. Foods from different parts of the United States may also vary in their likelihood of being violative because of different growing conditions. In a study of imported foods, Martin et al. (1993) assumed that the probability of a given imported foodlot's having a specific violation of the FD&C Act was dependent on the history of violations in similar foodlots and import alerts for that foodlot issued by FDA's Office of Compliance. The results from government testing laboratories were used in the Martin study to estimate the levels of contamination likely to be observed.

A USDA/FDA risk assessment for *Salmonella* Enteritidis (SE) in shell eggs and egg products (USDA, 1998) simulated the probability of contamination of eggs with *Salmonella* Enteritidis based on the total number of egg-producing flocks, the prevalence of SE in these flocks, flock size, and frequency of molting. This resulted in an estimated total number of contaminated eggs produced annually by the U.S. egg industry. For example, using U.S. Agriculture Census data from 1992, a simulation estimated a total of 5,028 flocks, stratified according to flock size (< 20,000, 20,000-49,999, 50,000-99,999, and 100,000 or more), had either high or low SE prevalence. An estimated 22 percent of flocks producing eggs on any given day were assumed to have molted previously, and an increased frequency of SE-positive eggs for 70 days post-molt was assumed. This simulation resulted in estimates that on average, 37 percent of egg-laying flocks were SE-positive, 11 percent of which were high-prevalence flocks, and a mean frequency of 1 in 20,000 SE-positive eggs were produced per year.

The level of exposure to the violation for people eating violative foods depends on the level of contamination, whether or not the contamination is detected before the food is eaten, serving size, handling, and preparation before eating. Whether or not the contamination is detected before the food is eaten will depend on government inspections as well as the consumer's inspection. Martin et al. (1993) estimated the probability that the violative food reached the consumer based on whether or not the food is inspected and/or tested and the accuracy of the instrument used to test the sample. Another relevant factor is the likelihood that a violative substance would not be in the actual sample taken for analysis, even though the food lot did include the violation. Some violations are detected by the consumer before use. An example of this type of violation is filth. Standard serving sizes are used to estimate the amount of the violative food ingested per person. Final exposures to the contaminant are then estimated based on common food preparation practices and the persistence characteristics for the contaminant**.** The exposure assessment of the USDA/FDA SE risk assessment models identifies two key factors that affect the growth of the organism in eggs—cumulative ambient storage temperatures and length of storage as the eggs move from production to processing, transportation, and distribution (see figure 2). For example the relationship between the number of SE at time of use of a shell egg and the number of SE at laying, can be illustrated with the following simplified equation:

Number SE at use (e.g., 10,000) = Number of SE at laying (e.g., 100) x (Weeks to use (e.g., 13) – Weeks to yolk membrane breakdown (e.g., 1)) x Average growth rate per week (e.g., 8.33)

The values for the independent variables in this equation depend on processing time and temperature.

Other factors influencing final human exposure, such as pooling of eggs, institutional versus home use, and the effect of "bacterial kill steps" including common preparation and cooking methods, on levels of contamination are also incorporated in modeling the associated probability and level of contamination in consumed eggs (see figure 3). For example, for an undercooked egg eaten by a single consumer, the relationship between the number of SE in the consumed egg and the number of SE at time of use can be illustrated with the following simplified equation:

Number of SE consumed (e.g., 100) = Number of SE at use (e.g., 10,000) x Proportion of SE remaining in undercooked egg (e.g., 0.01) x Proportion of egg eaten (e.g., 1)

The proportion of SE remaining in the undercooked egg depends on the cooking type and time.

The probability distribution of different levels of severity of illness that result from specific exposures to a violative food product is the final piece of information that is needed in the "bottom-up" approach for estimation of the number of people experiencing foodborne illness. There is likely to be a dose-response relationship between the level of the contaminant and the likelihood that the person exposed will experience different levels of severity of illness. In addition, this dose-response relationship will likely be different for different population subgroups. For example, susceptible populations such as those with conditions that adversely affect the immune system such as HIV/AIDS, diabetes, chemotherapy for cancer, solid organ and other transplants, pregnant women, and children or the elderly, are likely to experience more serious disease at lower exposure levels.

Martin et al. (1993) assumed that the population was a mix of susceptible and non-susceptible people and obtained estimates for the total population only. Potency factors estimated by the EPA for pesticide residues were used to estimate dose-response relationships for exposures to carcinogens. Dose response relationships for the microbial violations were developed through an expert elicitation procedure similar to procedures that have been used in the past by EPA for estimating the health impacts of lead exposure and ozone exposure (Whitfield and Wallsten, 1989; Whitfield et al., 1991). These elicitation procedures were based on a fact sheet for each microbial agent. These fact sheets included all the available data on the dose-response relationship derived from both animal and human studies. The elicitation procedure resulted in estimates of the likelihood of observing both acute and chronic sequelae from the microbial violations at different levels of severity (mild, moderate, severe) for different exposure ranges of the contaminants.

The hazard characterization of the USDA/FDA risk assessment linked exposure to contaminated eggs with a dose-response relationship to model public health outcomes of varying severity. The morbidity and mortality outcomes of concern that were modeled included acute gastroenteritis followed by uneventful recovery without medical care, recovery following a physician visit, recovery following hospitalization, death, and chronic reactive arthritis. These outcomes were estimated for both susceptible and normal populations, and resulting simulations demonstrated more severe outcomes in susceptible populations including a disproportionate contribution to deaths. To demonstrate the differing outcomes in susceptible and normal populations, a simulation was conducted for two hypothetical populations of 100,000 persons, each exposed to 1,000 cfu of the bacteria, one population with normal susceptibility and one with high

susceptibility. The results of the simulation are presented in table 1. Of particular relevance are the differences in case fatality rates between these two populations with mean estimates of 20 and 98 deaths in the normal and highly susceptible populations, respectively.

One of the main strengths of the "bottom-up" approach is that it can be used to estimate the number of chronic sequelae from acute illness and the number of cancer cases attributable to pesticide residues as well as the number of cases of acute illness. This approach also explicitly relates contaminant exposure levels to the number of cases of illness at different levels of severity. Because of this, the health impacts of regulations designed to reduce contaminant exposures, for example through more targeted inspections or through required changes in food processing techniques, can readily be estimated. The main weakness of this approach is that it is not based directly on observed cases of foodborne illness. However, the dose-response relationships are generally derived from observed outbreak data. In addition, estimates of the number of cases derived using the "bottom-up" approach can be validated using surveillance or outbreak data.

Measuring the Pain, Suffering, and Functional Disability from a Case of Foodborne Illness

Most foodborne illness can be subdivided into three categories:

- Acute illness, which occurs with a very short latency period after exposure, has a well-defined duration, and ends in death, complete cure, or transitions into a chronic illness.

- Chronic illness, which has a short or long latency period after either a short or prolonged exposure, may be a sequel to an acute illness, has a prolonged duration, and ends in either premature or natural death.

- Cancer (a subcategory of chronic disease), which has a long latency period after either a short or prolonged exposure, has a short or prolonged duration, and ends in premature death, natural death, or complete cure.

The amount of pain, suffering, and functional disability is very different for these different types of illness. However, it is possible to use a uniform set of measures to describe the patient impacts.

In general, foodborne illness can occur at various levels of severity. Each level of severity affects a person to a different extent. To simplify the analysis, we can consider three levels of severity for all acute and chronic illnesses, mild, moderate, and severe. The severity levels vary in severity and types of symptoms, functional disability, and mortality risk. Cancers can be categorized in terms of extent of spread at first diagnosis in terms of local, regional, and distant. For each severity level of the illness, we can describe the effect of the illness in terms of typical symptoms, mortality rate, duration of treatment and recovery, frequently used medical treatments including time spent in the hospital, and functional status of the patients during treatment and recovery. This information can be derived from the medical literature (e.g., Bryan, 1982; the

Merck Manual). This information can be used to compare the impact of different diseases and levels of severity on proxy measures for pain and suffering (e.g., deaths, symptom days, hospital days) and functional status (e.g., restricted-activity days). For example, based on Bryan (1982) and Cohen (1978) and Mauskopf et al. (1988), we estimated the following patient impacts for salmonella:

- Mild disease—1 bed day and 1 house day with nausea/vomiting, diarrhea, abdominal pain, anorexia, and weakness and a zero risk of mortality;
- Moderate disease—4 house bed days and 3 house days with the same symptoms as for mild plus fever, headache, and prostration and a zero risk of mortality; and
- Severe disease—5-14 hospital days, 3 house bed days, 3 house days, with the same symptoms as for moderate disease plus enteric bacteremia or septicemia and a mortality rate of 13 percent.

To determine the relative burden on patients of different illnesses, it is useful to have a single measure that combines the mortality and various morbidity effects. One measure that is currently used by the World Health Organization (WHO) for estimating the combined impact of mortality and morbidity associated with a specific disease is the disability-adjusted life-year (DALY) (Murray, 1994). The DALY is the product of four factors:

- A disability weight (ranging between 0 and 1 depending on productivity levels with the illness);
- Age at onset and duration of the illness;
- An age weighting function to reflect social value for each year lost (ranging from 0 at birth peaking to 1.5 at age 25 and then declining slowly with age); and
- A discounting function.

The DALY thus measures the impact of an illness in terms of the loss in productivity. It does not include any weighting for pain and suffering.

Another unit frequently used in economic evaluations of health care interventions for measuring the total impact of a disease on the patient in a single unit of measure is the quality-adjusted life-year (QALY). A QALY has been defined by Zeckhauser (1985) as 1 year in perfect health or its equivalent. QALY's lost because of illness are computed as follows: assume the illness lasts for 2 years, during which time the patient is in a health state that is less than perfect and has, for example a utility weight of 0.35. Thus, during the 2 years, the patient experiences only 0.70 QALY. In this case, the QALY loss relative to perfect health is 1.3 QALY's. Gold et al. (1996) suggest for a "reference case" cost- effectiveness analysis that the utility weights used to compute the QALY's lost be derived from community-based surveys and reflect both the financial (e.g., productivity losses) and health status impact (e.g., pain, suffering, and functional disability) of morbidity. The surveys should be designed so that the utility weights reflect people's overall well-being in different health states.

In the most general sense, a health status index converts the concepts of healthy and unhealthy into quantifiable measures of an individual's perception of the impact of their health status on their general sense of well-being. For example, Bush, Chen et al. (1972) classified all possible health states based on the degree of restriction of mobility, social interaction, and physical activity, and the pain or other symptoms a person may experience. The utility weights for these health states were derived using a survey of 867 subjects in California. The subjects were asked

to indicate the relative disutility of different health states, assuming that each health state lasted for only 1 day, that zero was as bad as dying, and that 1 was perfect health. Another set of health states was constructed by Rosser and Kind (1978) using a two-dimensional description of health, based on disability and distress level. There are eight disability levels based on ability to work, social interactions, and mobility. There are four levels of distress. The weights were derived from 70 subjects, and they were told to assume that the health states were permanent and that zero represented death and 1 perfect health. The resulting indexes are very different for the two studies, possibly because of the different time horizons assumed for the surveys. One possible strategy is to use the Bush, Chen et al. (1972) utility weights for estimating the loss in patient well-being for acute illness and cancer and the Rosser and Kind (1978) utility weights for estimating the utility losses for chronic illness.

Based on the disease symptoms and estimates of their duration, any specific adverse health effect can be translated into the time spent in different health states. These health states can have utility weights assigned to them such as those estimated by Bush, Chen et al. (1972) or Rosser and Kind (1978). The health utilities index (HUI) (ref) is a more recent set of health states for which utility weights have been estimated. In order to take the duration estimates for each health state into estimate of the QALY's lost with each illness, assumptions also need to be made about some or all of the following:

- Age at onset (e.g., 30 years);
- Remaining life expectancy (e.g., 46 years);
- Quality of life in the absence of the foodborne illness (e.g., 1);
- Discount rate (e.g., 3 percent);
- Number of different functional states (e.g., hospital days, bed days, and house days);
- Morbidity for those dying from acute conditions (e.g., none);
- Pattern of utility loss for chronic conditions and cancer (e.g., constant utility loss); and
- Life expectancy loss for chronic conditions (e.g., no life expectancy loss).

The adverse health effects for each illness can then be assigned utility weights and durations. For example, a moderately severe case of salmonellosis is estimated to result in an adverse health effect consisting of gastrointestinal symptoms as well as fever and headache that results in about 7 days lost from work. Using the Bush, Chen et al. (1972) measures, we assumed:

- 4 days in bed, in the house, needing help with self care and with symptoms of vomiting, diarrhea, fever, headache, and spells of feeling hot, nervous, or shaky (utility weight = 0.4407); and
- 3 days in the house, no problem walking and performing self care with symptoms of diarrhea and spells of feeling hot, shaky, or nervous (utility weight = 0.6533).

Based on these utility weights and duration, the QALY's lost associated with a moderate case of salmonellosis can be estimated (0.00932**).**

In a recent regulatory impact analysis of food labeling for trans fatty *acids (Federal Register*, 1999), FDA used an estimate of the utility weight for a survivor of coronary heart disease (CHD) of 0.71 (Cutler and Richardson). Their estimate of remaining life expectancy after onset of CHD was 13 years or 8.4 discounted life years (7 percent discount rate). Thus, the loss attributable to a nonfatal case of CHD was estimated to be 0.29 x 8.4 or 2.436 QALY's (*Federal Register*, 1999). The loss attributable to a fatal case of CHD was 8.4 QALY's.

Hypothetical Estimate of the Impact of Federal Regulations

The benefits of different government inspection programs, measured as the reduction in pain, suffering, and functional losses, depends critically on:

- The ability of the inspection program to prevent products that violate food safety laws from reaching the consumer;
- The probability that violations would cause foodborne illness; and
- The impact of the foodborne illness on the patient.

A hypothetical example will illustrate this. For example, assume that there is a choice between inspecting product A for *C. botulinum* toxin or product B for pesticide residue. Second, assume that the proportion of products like A that are contaminated with *C. botulinum* toxin is 0.001 and the probability of product B being contaminated with the pesticide residue is 0.001. Further, we assume that if product A contains *C. botulinum* toxin, there is a 0.25 probability that the person eating it will get a severe case of botulism (QALY loss = 5.96), a 0.25 probability they will get a moderate case (QALY loss = 0.03), and a 0.25 probability they will get a mild case (QALY loss = 0.005), and a 0.25 probability that they will not get ill (QALY loss = 0). For a person eating product B contaminated with the pesticide residue, we assume that there is only a 0.000001 excess probability of getting liver cancer (QALY loss = 10.16) if they eat one serving of the contaminated product. The expected benefits for preventing product A from being consumed are given by:

EBA = (0.001 x .25 x 5.96) + (0.001 x .25 x 0.03) + (0.001 x .25 x 0.005)
= 0.0015 QALY's

The expected benefits for preventing product B from being consumed are given by:

EBB = (0.001 x 0.000001 x 10.16)
= 0.00000001 QALY's

Thus the expected benefits of preventing product B from being consumed are much lower than those of preventing product A from being consumed, even though the value of the utility losses associated with a case of liver cancer is higher than that associated with a case of botulism. However, in this calculation we did not consider that, if the product with *C. botulinum* toxin is consumed, the contamination will be detected and other similar products prevented from reaching the consumer. By contrast, if the product with the pesticide residue is consumed, that contamination will not be detected and more exposures may take place so that value of inspecting for pesticide residues is, in fact, higher than our calculations indicate.

Picking up on the egg example again, the USDA/FDA *Salmonella enteritidis* (SE) risk assessment model was constructed to allow simulation of the effects of different mitigations on total human illnesses due to SE from egg consumption. Sensitivity analysis was conducted as a first step in identifying the possible strategies for reducing the foodborne illnesses associated with SE in eggs. Then selected mitigation strategies chosen and modeled either singly or in

combination to demonstrate their comparative effect on public health outcomes of interest. For example, simulating the reduction of either storage time or ambient temperature by 25 percent at the home, institutional, or retail setting resulted in an estimated reduction in mean number of SE cases by 13 percent and 11.6 percent respectively; while a reduction in both time and temperature resulted in a 21-percent reduction. Reducing prevalence rates of SE in large flocks (> 100,000) by 25 percent resulted in an estimated 15.2-percent reduction in mean illnesses. A combination of mitigations which included 25% reduction in storage time in homes, institutions, and retail coupled with an equivalent reduction in prevalence rates in large flocks resulted in an estimated 32% reduction in illnesses. In the simulated examples, combining several mitigation strategies aimed across the continuum resulted in a greater reduction in mean numbers of cases than any single mitigation strategy alone, implying that broad-based policies may be more effective in achieving a desired improvement in public health.

When estimates of the number of cases of foodborne illness avoided due to a regulation are derived using the "top-down" approach, the reduction in number of cases of illness is generally assumed to be equal to the reduction in pathogen levels attributable to the regulation. For example, Roberts et al. (1996) estimated that a HACCP program for inspection of meat and poultry would reduce levels of pathogens between 10 and 100 percent and would reduce the incidence of the relevant foodborne illnesses by the same percentage amounts.

Conclusions

In estimating the pain, suffering, and productivity impacts of foodborne illness, it is critical to be able to measure both the annual number of cases subdivided by disease severity as well as the impact of each case. There are two methodological approaches for estimating the number of annual cases, the top-down and bottom-up approaches. The advantage of the top-down approach is that it is based on observed cases. The advantage of the bottom-up approach is that one can estimate the number of chronic conditions and cancers attributable to food causes and one can more readily estimate the impact of new regulations on the number of cases. Both methods are currently used by the U.S. Government for evaluations of food safety regulations.

The impact on a patient of each case of foodborne illness in terms of pain, suffering, and productivity loss can be measured by proxies for pain and suffering such as deaths, hospital days, and restricted-activity days and by direct measures of productivity loss such as work loss days. Alternatively, a single measure can be derived that combines these factors into a single measure, either the DALY or the QALY. The QALY is frequently used in the United States in the economic evaluation of programs designed to improve health outcomes. Utility weights representing general well being in different health states are combined with estimates of the duration of those health states to compute the QALY's lost attributable to specific foodborne illnesses.

There are many uncertainties in the measurement of the number of cases of illness and in the measurement of the impact of that illness whatever methods are used. Thus the results of such measurement should be viewed with caution and subject to sensitivity or threshold analyses. Threshold analyses can be especially useful when decisions have to be made despite uncertain

data. Threshold values can be chosen that would result in different decisions, and then scenarios identified that give the threshold values.

If the impact of foodborne illness on pain, suffering, and productivity is measured in QALY's, then the benefits of new regulations can be measured in QALY's gained. These QALY's gained can be compared with the net costs of the regulation (the cost of implementing the regulation minus any direct medical care cost savings because of the reduction in foodborne illness). This comparison can occur by computing a ratio of the incremental cost per QALY gained (Gold et al. 1996). Alternatively, Stinnett and Mullahy (1998) have proposed a method for estimating net benefits from new health care programs by assigned a value to a QALY equal to the benchmark value for cost effectiveness in a society—say $50,000 per QALY. Each QALY gained can be converted into dollars by multiplying it by $50,000. The net costs are then subtracted from these dollar benefits to give an estimate of the net benefits. If the net benefits are positive, then the intervention is acceptable based on the $50,000 per QALY threshold.

Another method for applying a dollar value to a QALY (Mauskopf and French, 1991) is to take an estimate of the value of life and convert it into an implied value for a QALY depending on the average remaining life expectancy for the person in the value-of life study. For example, if the value of a statistical life is $5,000,000 and the discounted life expectancy for the population from which the estimate was derived is 22.5 years, then the value of a QALY is $222,222 ($5 million/22.5). This value can then be used to convert the QALY's into dollar estimates that can be compared to the net costs of the regulation. This method was used by the FDA in its evaluation of nutrition labeling for trans fatty acids.

The measures that we have described in this paper are designed to measure the impact on the patient of foodborne illness in terms of pain, suffering, and lost productivity. Although the impact of foodborne illness on productivity is frequently estimated directly as part of the cost-of-illness approach, pain and suffering have not generally been measured. In this paper, pain and suffering are measured either by proxy with death rates, hospital days, and restricted activity days or directly through the utility weight for different health states. It is critical that these benefits of regulations to reduce foodborne illness be captured in regulatory impact analyses.

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Table 1. "Bottom-Up" Approach Example, Part IV: Severity of Illness Caused by *Salmonella* Enteritidis in Eggs in 100,000 Normal and 100,000 Susceptible Persons Each Exposed to 1,000 SE Organisms Using Dose-Response Functions

Outcomes	Normal population	Susceptible population
Total number ill	65,000	82,000
Recover, no treatment	61,607	76,121
Physician visit, recover	3,146	5,150
Physician visit, hospital, recover	227	631
Die	20	98
Reactive arthritis	1,949	2,458
Percent of U.S. population	78%	22%

Figure 1: CDC Pyramid for "Top-Down" Estimates of the Annual Number of Cases of Foodborne Illness

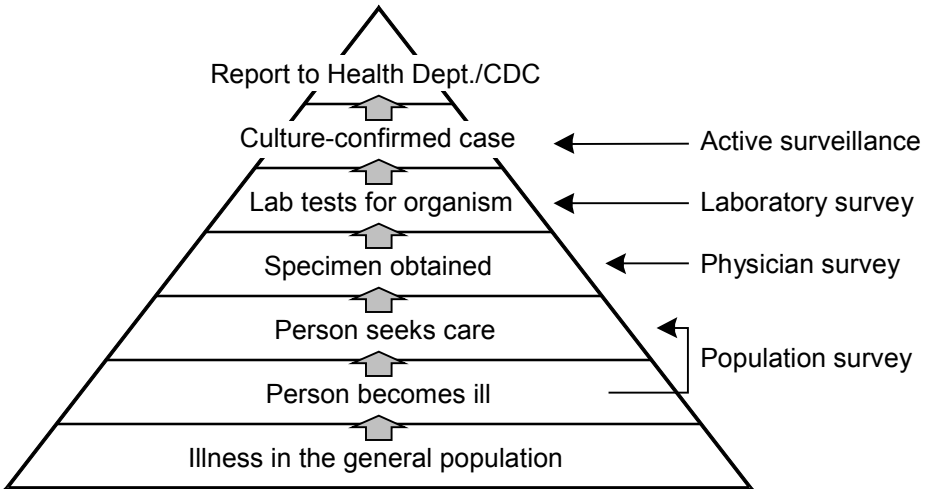


Figure 2: Number of *Salmonella* Enteritidis in Each Egg at Time of Use Using "Bottom-Up" Estimation Model

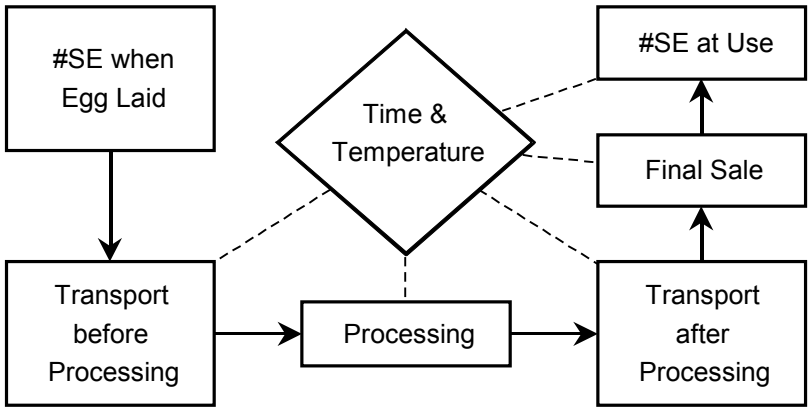
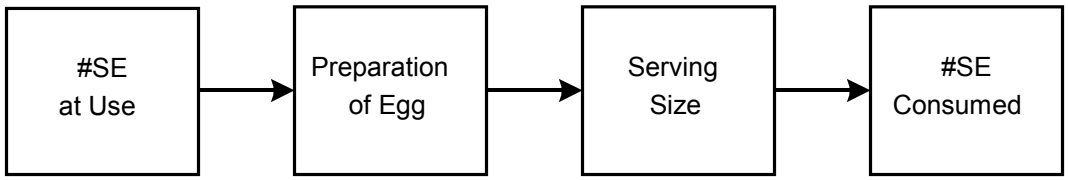


Figure 3: Number of *Salmonella* Consumed in Undercooked Egg Using "Bottom-Up" Estimation Model



Comments by Amber Jessup on

"Measuring the Pain, Suffering, and Functional Disability Associated with Foodborne Illness"
(by Josephine Mauskopf and Roberta Morales)

1. I enjoyed the paper.

2. This paper dealt with a number of difficult problems. First, how to "count" the number of foodborne illnesses. Second, how to assess the impact of regulatory actions on the number of foodborne illnesses. Third, how to quantify pain, suffering, and disability associated with foodborne illness. Fourth, how to use quality-adjusted life years (QALY's) to value pain, suffering, and disability.

3. The paper identifies two primary methods for counting the number of foodborne illnesses, a "top-down" and a "bottom-up" approach. The top-down approach takes the number of reported cases and multiplies it by a surveillance multiplier that accounts for non-reported cases; the bottoms-up approach takes exposure to the hazard and multiplies it by the probability of illness, given exposure. The top-down approach is limited by uncertainty surrounding the correct value of the surveillance multiplier. The multiplier should vary with how the case is observed, whether outbreak, passive, or active surveillance and the severity of the observed cases. The bottom-up approach is limited by its specificity. For example, a *Salmonella Enteritidis* risk assessment for eggs is only applicable for eggs and *Salmonella Enteritidis.* Each bottom-up analysis is a very difficult undertaking, which is limited by uncertainty about the prevalence of the bacteria, how the bacteria grows before consumption, the dose-response relationship, the susceptibility of different populations, food preparation practices, and the quantity of tainted food consumed.

4. For analysis of the economic impact of regulatory actions, the bottom-up approach can potentially be more useful. It allows the analyst to directly link illness to a food source and, ideally, each regulatory requirement can be linked to a reduction in illness. The top-down approach is helpful for assessing baseline levels of foodborne illness, but does not link illness to a particular food source. However, although often associated with the top-down approach, outbreak data can helpful for tying illness to specific food sources.

5. There are a number of methods commonly used to assess QALY's.
   - *Rating Scale*—The rating scale asks consumers to rate the level of utility associated with condition A along a line between 1 and 100. The QALY associated with condition A is calculated by a linear transformation.
   - *Time Trade-Off*—Time trade-off asks an individual what number of years at full health is equivalent to some other number of years with condition A. The QALY associated with condition A is the number of years in full health divided by the number of years with condition A.

- *Standard Gamble*—Standard gamble offers two alternatives to an individual, a number of years in full health with some probability of death, or the same number of years with condition A. They are then asked what probability of death would make them indifferent between full health with a chance of death and the same number of years with condition A. The QALY is the acceptable probability of death.
- *Expert Opinion*—Health care professionals offer their opinion on the QALY loss associated with condition A.
- *Multivariate Analysis*—Multivariate analyses of large data sets can be used to estimate the marginal effect of a given condition on a health status. The results of these analyses can then be adjusted to represent a QALY value. A fully specified model requires data on self-perceived health status, activity limitations, other illnesses, and basic demographics. This method corrects a number of shortcomings of the other methods. For example, responses may be colored by individual characteristics, be based on indirect knowledge of the condition, be strategic responses, and reflect embedding in the other methods. Using large surveys, such as NHIS, it is possible to control for individual characteristics and other conditions. However, this method shares some of the limitations of other approaches. The primary limitation is that the interpretation of self-perceived health status varies by individual. For example, blind persons may perceive themselves as in full health.

Rapporteurs' Notes for

Valuing Pain and Suffering and Lost Productivity

Rapporteurs: Clark Nardinelli and Cristina McLaughlin

We talked about many issues associated with measuring the benefits of preventing food-borne illness and the session's specific topic, which was pain and suffering and lost productivity. The conversation dealt with these three general questions:

1. What should be included in the measure of lost welfare associated with foodborne (or other) illness? We discussed what we should be trying to measure when we estimate the benefits of increasing food safety.
2. How should we measure the value of preventing foodborne (or other) illness? We mostly talked about the relative merits of quality-adjusted life years (QALY's) and contingent valuation (CV) measures of willingness to pay.
3. What should we do next? We agreed that the goal remains consensus, but we need to find a way to get there.

1. What should be included in the measure of lost welfare associated with foodborne (or other) illness?

The session began with a general discussion of whether pain and suffering should be counted as a cost of illness. Many regulatory agencies do not include the value of pain and suffering in cost-benefit analyses of health and safety regulations. Some agencies only count lives saved, rather than pain and suffering avoided, because lives saved dominates the measure. One discussant pointed out, however, that for chronic conditions and for end-of-life issues, pain and suffering can give you big numbers. An example is post-bacterial reactive arthritis.

Most of us agreed that in principle pain and suffering belonged in a measure of the losses associated with illness. We then discussed some of the problems involved in measuring it. If you use individual valuations, you can weigh the suffering of some people more than the suffering of others. Third-party valuations of pain and suffering also have drawbacks; physicians apparently do not do a good job valuing pain and suffering.

Timing is another issue. If we use individual valuations, should we use the valuations of people who have not had the illness (and must imagine how it would feel) or of those who have had it (and can draw on experience)? For some conditions, the difference is large.

The talk about individual valuations of various health conditions led us to the question of dread. Some risks inspire more dread than others. We discussed the reasons for and against including dread as a cost of illness. Dread tends to vary with education, income, information, risk aversion, and other variables not directly associated with the hazard. Dread can be based on inaccurate

information or unknown risks. People also tend to overvalue small, unknown risks. Perhaps a focus group approach, in which people were given information and a chance to discuss their fears, might isolate the "pure" dread factor. We discussed whether public health policy should be made on the basis of dread; Superfund, for example, may be a response to dread.

The government economists and policy analysts all agreed that a major reason to include all of the benefits of preventing illness in our measures is that the Office of Management and Budget (OMB) asks that all benefits be included. OMB wants full estimates both as a way to value the overall effects of health and safety regulations and as a way to compare regulations.

2. How should we measure the value of preventing foodborne (or other) illness?

By far the greater part of the breakout session was devoted to the relative merits of contingent valuation (CV) and quality-adjusted life years (QALY's) as measures of the value of preventing illness. The group failed to reach consensus on the larger issue of which approach is better, but many smaller issues were resolved.

Several participants described the advantages of quality-adjusted life years as follows:

- QALY's are bounded, running between zero for death and 1 for perfect health.
- QALY's are relatively easy to compute.
- QALY's can be used in cost-effectiveness analyses.
- There is a large medical literature on QALY's.

Many discussants questioned these advantages of QALY's. If some health states are worse than death, then QALY's are not necessarily bounded. The ease of computing QALY's may hide their inaccuracy. The use of QALY's for cost-effective or medical intervention purposes may not be easily transformed into use for cost-benefit analysis of public health policies. Medical interventions convey a very large benefit on a very small number of people, whereas public health policies convey very small benefits on a very large number of people.

We discussed methods of measuring QALY's: expert opinion, surveys, and questionnaires. We agreed that functional disability is much easier to measure than pain, suffering, dread, and other subjective losses.

QALY's alone are not sufficient to value reductions in illness. Most of us agreed that the biggest problem in using QALY's for cost-benefit analysis was transforming them into dollars. One way to do so would be to ask what people are willing to pay to avoid the loss of QALY's (or some other characterization of the hazard). Another discussant suggested that we get monetary values by asking people how they would allocate public funds across different risk reduction programs.

One discussant said that in many instances the values placed on QALY's are arbitrary. In response, a discussant summarized how the speaker from the first day of the conference found a non-arbitrary value for QALY's. The method starts with the value of a statistical life and works down to the value of a life-year, which can then be multiplied by QALY's to get the value of preventing the loss of QALY's. The dollars per life-year measure derived from the value of a statistical life, however, falls linearly with life expectancy, a result that contradicts the direct

empirical evidence on the value of statistical life for people of different ages. We discussed other factors that influence value of a statistical life year (in addition to age), including attitudes toward risk, time preference, other activities, and capital market imperfections. Some people questioned whether we could get good enough measures of the value of statistical life-years to make valuing QALY's worthwhile.

According to some discussants, QALY measures of the loss from illnesses tend to be biased upward. One reason may be that we measure the lost QALY's associated with an illness or condition as the difference between the QALY in the reduced Health State and the QALY for perfect health (1.0). If the average QALY is when health is less than one, then our measure overstates the QALY loss from illness.

We talked about surveys is general, and about the following approaches to getting responses on health states:

- Place a mark on a visual scale (works well)
- Standard gamble—live the rest of your life in state x, or risky operation
- Trade-off: 40 years in impaired health state vs. x years in perfect health

The session participants who disliked the use of QALY's generally supported using direct willingness to pay, based on contingent valuation (CV) studies. The main advantage of CV is that it directly measures what we are interested in—the person's willingness to pay to avoid illness. An advantage of straight CV questions—as opposed to standard gamble or time trade-off questions—is that they usually represent a real choice people could make.

One objection raised to direct surveys is that it is difficult to keep psychological factors out of people's responses. Another potential problem is strategic behavior from respondents. We discussed whether strategic behavior might be more of a problem for health conditions than for environmental issues.

We discussed the problems of misperceptions and attitudes toward risk. For example, should we take a paternalistic attitude toward 20-year-olds? Economists generally say no; if young people have a low willingness to pay for risk reduction, so be it. It seems inconsistent for regulators to say that people have good enough information to value risk, but that their information is so imperfect that we have to regulate risk. Better information might remove the need to regulate, if 20-year-olds simply miscalculate risk. Is the problem attitude or information? We may be regulating attitudes.

Another problem with direct measures of willingness to pay is the private versus social question. Surveys asking for private willingness to pay might give us different answers than surveys asking for social willingness to pay.

The main objection to CV voiced during the session was that the surveys have great practical problems. We discussed how sensitive CV studies are to how the question is posed, for example. Another question was how stated willingness-to-pay deals with sick leave and health insurance. Some participants pointed out that QALY studies are also based on questionnaires and are thus

sensitive to how questions are posed, as well as being sensitive to many of the same issues that affect CV studies.

One participant described how to do a contingent valuation approach to health states associated with various illnesses. We could start with stated willingness-to-pay to not have the illness, and then place implicit values on the various symptoms associated with the illness. For example, diary studies give the data needed to estimate willingness-to-pay as a function of symptoms, severity, frequency, length illness lasted, and other confounding factors. In a manner similar to hedonic housing studies, a well-designed CV study would allow us to compute the marginal willingness to pay for avoiding the different symptoms (of a given severity and length) associated with an episode.

The session's participants appeared to agree on the theory but disagree on what works best. Most participants agreed that a direct measure (such as CV) of willingness to pay was theoretically preferable. We failed to reach consensus on whether the practical difficulties were greater for actual CV studies or for QALY plus value of statistical life-year studies. We did agree that the ideal QALY study and ideal CV study should include the same list of independent variables.

3. What Should We Do Next?

The goal is for the responsible agencies to meet and establish common guidelines for regulating food safety. The guidelines should start with OMB guidelines. How can the different agencies work together to standardize the values placed on symptoms and illnesses?

We discussed the lack of standardization within agencies, much less across agencies. It is probably better to standardize across agencies first, and within-agency differences will take care of themselves. We then discussed the desirability of adopting standards to allow flexibility, given limits imposed by data, time, and political constraints. Standardization must be designed to allow evolution and improvement. Standardization should not be numbers, but should be methods, criteria, ways of thinking, and level of acceptable evidence. We also need some benchmarks to make comparisons.

We discussed the benefits of jointly sponsored studies that would compare CV and QALY approaches. The two studies we identified as desirable were: (1) an empirical study comparing the two approaches, and (2) a conceptual comparison of the two approaches. Both studies should be strongly oriented toward policy applications.

SESSION III

VALUING RISK REDUCTIONS USING DIFFERENT VALUATION METHODS

Valuing Pathogenic Risk: Methods, Skill, & Rationality

**Jason F. Shogren, Tommy Stamland,
Todd L. Cherry, Thomas D. Crocker**

Introduction

Constrained budgets and increased fiscal accountability prevent a policymaker from reducing all foodborne risk to all individuals. Deciding which risks to reduce and by how much requires evaluation of each new or revised regulation. Comparability of value across all sectors of the economy requires that policymakers rank regulatory alternatives in terms of a common unit. Arguably, the most common denominator is money, or monetary equivalence. Risk valuation systematically evaluates each regulation by estimating the monetary value—both benefits and costs—of a reduction in risk from unsafe food.

Here, we explore some issues in how rational people might value a reduction in risk from foodborne pathogens. Valuing the costs and benefits of reduced risk is formidable and controversial. While measuring the cost to control risk is more straightforward, the benefits are a challenge to quantify. Problems arise because goods associated with reduced risk—death and injury—are often not bought and sold on the auction block. These goods rarely if ever enter a private market, and remain unpriced by collective agency action. Stores and restaurants often do not like to market "safer food" because to do so would suggest that their food might otherwise be "unsafe."

Valuing risk reductions requires that we value death and illness. These efforts give rise to the loaded term: "the value of life." The idea of a monetary value of life, or more correctly the value of reduced mortality risk, raises more than a few eyebrows (see Schelling, 1968; Viscusi, 1992). Ethical and moral beliefs often force a person to balk at the idea. But our everyday choices put a value on life, whether we explicitly quantify it or not. Whenever a policy change is enacted or whenever the status quo remains, life and limb are implicitly valued. For example, a North Carolina hospital once refused to spend $150 per health care worker for an inoculation against

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The authors are with the Department of Economics and Finance, University of Wyoming, Laramie, WY 82071-3985. The authors gratefully acknowledge the support of the Economic Research Service, U.S. Department of Agriculture.

hepatitis B. Given the workers odds of catching the disease, the hospital had implicitly placed a relatively low value on life. Nothing is lost by explicitly examining the value of reduced statistical risk.

How do we value a reduction in risk? One straightforward answer:

$$\text{The value of risk reduction} = \frac{\text{Willingness to pay for risk reduction}}{\text{Change in risk}}$$

Rational risk policy says that a person's value for a risk reduction equals his or her maximum willingness to pay to increase the chances to stay healthy, conditional of his previous private actions to reduce risk. For example, suppose a person was willing to pay $6 to reduce the risk of death to 1 life in 1,000,000 from 4 lives in 1,000,000—a 3 in 1m risk reduction. The value of life is then $2,000,000 (= $6 /[3/1,000,000]). If the person was willing to pay $0.60, the implied value of life would be $200,000. This willingness to pay is called the *option price*. The option price is the maximum a person is willing to pay that keeps him indifferent between the gamble and the next best alternative.

What methods exist to actually measure the value of risk reduction? The literature on rational risk valuation has developed two general approaches to measuring the economic benefits of reduced risk: the human capital and willingness-to-pay approaches. *The human capital approach* values risk reductions by examining a person's lifetime earnings and activities. The value of a risk reduction is the gain in future earning and consumption. The value of saving a life is often calculated as what the individual contributes to society through the net present value of future earnings and consumption. The human capital approach has an advantage in that it is actuarial, i.e., it uses full age-specific accounting to evaluate risk reductions. A major drawback of the approach is that it assigns lower values to the lives of women and minorities, and zero value to retired individuals. The approach also lacks justification based on traditional economic welfare theory. For this reason, economists have downplayed the human capital method in favor of the willingness-to-pay approach (see, for example, Buzby et al., 1999).

Economists have advocated the *willingness-to-pay approach* since it is based on the theory of welfare economics. Welfare economics lays the foundation for estimating the value of risk reduction. People value risk reduction if it leads to a greater level of utility or welfare. The welfare change is measured by the maximum that the average person would be willing to pay to reduce risk or the minimum compensation he would be willing to accept for an increase in risk. Economists then use this willingness to pay or accept to estimate the implied value of life and limb. And although far from perfect, economists argue that the willingness-to-pay approach is preferable to the alternative—many believe it is better to have a rough estimate of a well-grounded theory than a precise estimate of a questionable one (see, for instance, Kuchler and Golan, 1999). One can reveal this value indirectly by teasing out the implied willingness-to-pay values from real choices within market settings or one can directly estimate values by asking people what they would be willing to pay for a change in risk. See Freeman (1993) for a good general overview on non-market valuation, and see Caswell (1995) for specific case studies using standard valuation methods for food safety work.

In what follows, we quickly review the key methods used to value risk. We concentrate mainly on two key behavioral underpinnings on the value of food safety—the hidden skill and debatable rationality of the people who confront pathogenic risks. We explore how skill affects the value of reduced risk in indirect methods, and we consider how presumptions of rationality in direct methods compare to and can be modified by exposure to active exchange institutions.

Indirect Methods: Risk and Skill

Valuing risk indirectly is often done in two ways—exploring the wage-risk tradeoffs people make, and exploring the expenditures made on averting behavior, or self-protection. Wage-risk tradeoffs are based on the theory of hedonic prices. Hedonic price theory captures the idea that a person's wage rate depends on skill, education, occupation, location, environment of work, and job safety or risk. A worker will accept a higher wage for more risk, holding all other job attributes constant. More risk, higher wages. And a worker selects his job to equate the incremental willingness-to-pay for each attribute to the incremental contribution of each attribute to the wage rate. The value of risk reduction is the incremental willingness-to-pay for the attribute "job safety." Workers then compare their risk-wage tradeoffs to the rate that the market is willing to trade risk for wages. The market equilibrium between workers and employers then determines the risk premium—the extra compensation for risky jobs. The wage-risk tradeoff is thus determined, other job attributes held constant. A review of the early (1974-1983) empirical results of the hedonic wage-risk model indicates that value of statistical life estimates fall in two ranges—$450,000-$720,000 and $4-$10 million (in 1990 dollars). Wage-risk studies set the value of a statistical life between $900,000 and $6,800,000 (see Viscusi, 1993). But note that these values can be challenged. Critics question the presumptions that workers know all the risks in the job, and can change jobs costlessly. Also they point out the weak correlation between job safety and environmental hazards. They also stress that hedonic models consider only a segment of the population—people with a job; children and seniors are under-represented.

The averting behavior method estimates willingness to pay for risk based on what people actually pay to protect their families and themselves. People reveal their preferences for lower risk through the market for self-protection such as smoke detectors, seat belts, medicine, bottled water, and water filters. The current estimates of the value of life range from $0.46 million to $0.61 million (in 1986 dollars) (see Fisher et al., 1987; Viscusi, 1993).

The idea that people can use private markets to reduce risk themselves raises an important issue in the value of life and limb. The value of life or limb is usually defined as the cost of an unidentified single death or injury weighted by a probability of death or injury that is uniform across people. The willingness-to-pay approach captures this cost by revealing the previously unobserved preferences for risk reduction. But here is the rub. These estimates actually contain more than just unobserved preferences—they capture preferences for risk reduction conditional on each person's unobserved ability to reduce risk privately.

Consider an example. Suppose people have identical preferences for risk reduction from contaminated food supplies but they differ in their ability to access private risk reduction markets. And now say each person is asked to reveal his or her value for a collective program to reduce risk. Each person's value for this collective risk reduction is conditional on his or her private actions (see Ehrlich and Becker, 1972). Following the standard procedures to value life, one might assume that people with a low value for collective risk reduction are willing to tolerate greater risk. But in fact it just might be that they have access to effective private risk reduction and have reduced the risk themselves.

But why does this matter? This matters because the key to estimating the benefit side of rational risk policy is the value of a statistical life (VSL). Of concern is whether the use of the value of statistical life estimate overestimates the actual value of reduced mortality risk. We know that health, safety, and environmental concerns drive most new regulations promoted in Washington, DC. By far, the most critical category of benefits that economists can quantify and monetize is the VSL. The greater the value for reduced mortality risk, the greater the odds the benefits of any given regulation will justify the extra costs. Recent reviews suggest that the VSL is somewhere between $2 million and $8 million, from the overall range of $100,000 to $10 million (Viscusi, 1993). From this range of estimates, the VSL currently used in the Federal Government, first by the Environmental Protection Agency (EPA) and now by other agencies, is $5.9 million (1997 dollars).

But is this value of reduced mortality risk potentially misleading for foodborne pathogens? In discussing how wage-risk tradeoffs are estimated by the wage differential between jobs with different risks, researchers have suggested that worker heterogeneity can affect the value of reduced mortality risk. The marginal worker sets the wage differential and hence the inferred value of risk reduction. And if this marginal worker's unobserved risk preference differs from that of other workers, this local tradeoff can be a misleading index of the required wage premium. The same can be said about protection from foodborne pathogens—different people have different skill to avoid risks from food.

Consider now why worker heterogeneity might matter more to the value of statistical life than many people think (Shogren and Crocker, 1991, 1999). Let workers be heterogeneous in two respects: they have unique risk preferences (i.e., they put different values on life and health) and they have unique skill to protect themselves so that they encounter different risks even if their occupations and job activities are identical. Workers select occupations of different inherent risks based on both their skill to protect themselves and their risk preference. This means that the occupation selection is unlikely to reveal perfectly both personal characteristics (Stamland, 1999). When a choice is made based upon two pieces of private information, the choice is unlikely to perfectly reveal either piece although it conveys some information about both. Hence, one would expect workers in a more risky occupation to be more skilled or more tolerant to risk or both. They need not be equally skilled or equally tolerant to risk due to self-protection, self-insurance, job stickiness, switching costs, irreversibility, imperfect mobility across occupations, life cycle in skills, experience, education, and safety.

One can show that the VSL is likely to be systematically biased upward once one accounts for worker heterogeneity in both *skill* and *risk preference* (Shogren and Stamland, 2000a). A worker's unobserved skill to privately reduce his own risk affects the value of risk reduction. The reason for this is now the marginal worker is not randomly selected. Rather he is the person among those in the occupation who demands the highest compensation for *his* risk in the job. Relative to other workers, the marginal person has either higher risk or lower tolerance to risk or both. This implies that when the *marginal worker's* wage differential is divided by the statistical risk in the occupation, which measures the average risk of all the workers in the occupation, the resulting VSL estimate is biased. The VSL estimate is most likely upwardly biased because the *highest* required wage differential among the workers is divided by their *average* risk. The result holds even if one allows workers to self-select between risky and safe occupations.

These results support those who have argued that currently used VSL estimates could overestimate the benefits of new major regulatory decisions. An EPA Science Advisory Board's Advisory Council in its evaluation of the health and ecosystem effects of the Clean Air Act Amendments (CAAA) between 1970 to 1990 worried that the values were biased upward. Additional observers have pointed out that EPA's *best* CAAA benefit estimate of $22 trillion is nearly the value of total U.S. households and nonprofit organization assets in 1990 ($22.8 trillion), and actually exceeds the gain in the stock market from 1970 to 1990 ($1.2 trillion). The idea that skill matters does not contradict the general concern that the operative value of reduced mortality risk used in public policy is suspiciously high.

Consider workers who differ in two respects: they are unequally skilled and they disagree on the value of reduced mortality risk. Different skill levels imply that workers do not face the same probability of a fatal accident in the same job; different risk preferences means that they have different tradeoffs between job wages and the on-the-job risk of a fatal accident. For simplicity, assume there are two types of jobs, safe and dangerous jobs, and two types of workers, highly skilled (H) and low skilled (L).

In the safe job, both types of workers face a probability $p \geq 0$ of a fatal accident. In the dangerous job, the likelihood of an accident decreases as the worker's skill increases. Assume the low-skilled worker faces a probability $q > p$ of a fatal accident in this job, whereas the high-skilled worker accident probability remains at p. The safe job pays a compensation w_s, and the dangerous job pays w_d. The difference in the wages, $w_d - w_s$, is endogenously given so that the dangerous job is able to attract low-skilled workers, i.e., we are considering an equilibrium in the labor market so that the dangerous job employs workers of different skills. This equilibrium means that the difference in wages, $w_d - w_s$, is just sufficient to make the low-skilled, high-risk worker indifferent between the dangerous and the safe jobs. In general, with two types of jobs, it must be the case in equilibrium that the wage difference is just sufficient to compensate the worker in the dangerous job who requires the highest compensation.

Let $\pi(t)$ denote the fraction of type t workers in the dangerous job. We denote the workers' utility functions by $u(t,P,W)$ where $t \in \{L,H\}$ is the worker's type, $P \in \{p, q\}$ is the worker's fatality

risk in his job, and $W \in \{w_s, w_d\}$ is the worker's wage. For now, assume the worker's utility function takes this simple form:

$$u(t,P,W) = W - P \cdot VOL_t \quad (1)$$

where VOL_t is the monetary equivalent of type t's opportunity cost associated with premature death in the current period; i.e., VOL_t is type t's value of life, or more precisely, the value of reduced mortality risk. Allowing VOL_t to depend upon the type allows different types of workers to have different life expectancies and different non-wage utility of life. For instance, the low-skilled workers may be young, inexperienced workers who have longer life expectancies (outside work) than the high-skilled workers.

The wage difference is set so that

$$u(L,q,w_d) = u(L,p,w_s) \quad (2)$$

which, given equation 1, yields the following solution for the wage of the safe job, w_s, in terms of the wage of the dangerous job, w_d:

$$w_d = w_s + (q-p)\, VOL_L \quad (3)$$

If we do not observe VOL_t directly, we can infer from the wages and the risks that:

$$VOL_L = \frac{w_d - w_s}{q - p}, \quad (4)$$

if a type's risk is observable. We shortly consider the case in which it is unobservable. The overall probability that a randomly selected worker will have a fatal accident in the safe job is $P_s \equiv p$ because all types of workers have the same risk, p, in this job. The corresponding probability in the dangerous job is $P_d \equiv p\pi(H) + q\pi(L)$ and, rearranging, we have that

$$P_d = p + (q-p)\pi(L) \quad (5)$$

The true probabilities of an accident, p or q, are likely to be unobservable. If the wages and the statistical probabilities of an accident are used to infer the value of a statistical life, *VSL*, as follows:

$$VSL = \frac{w_d - w_s}{P_d - P_s} \quad (6)$$

then we have

$$VSL = \frac{w_d - w_s}{P_d - P_s} = \frac{w_d - w_s}{(q - p)\,\pi(L)}$$

and comparing with equation 4, we have

(7) $$\mathrm{VSL} = \frac{1}{\pi(\mathrm{L})}\,\mathrm{VOL_L}$$

For example, if we plug VOL_L = \$1,000,000 into equation 7, this yields a VSL of \$4.8 million when $\pi(L)$=0.2083. Currently, many Federal agencies including the EPA use a VSL of \$4.8 million (1990 dollars).

We now present two useful results about the VSL that follow directly from expression 7. To facilitate our discussion, define $VOL_L < VOL_H$ as the case in which a low-skilled worker *undervalues* reduced mortality risk relative to the high-skilled worker. First, unless the low-skilled worker undervalues reduced mortality risk, the VSL overestimates the average value of mortality risk reduction. Second, unless the low-skilled worker undervalues reduced mortality risk, the less the proportion of low-skilled workers in the dangerous job, the more VSL overestimates the value of mortality risk reduction.

The third result follows from the observation that high-skill/low-risk workers earn a rent which equals the difference between their wage and their reservation wage, $(q-p)\mathrm{VOL_L}$. The high-skill/low-risk worker earns a skill rent, $(q-p)\mathrm{VOL_L}$, that is higher,

1) the larger the difference in skill as measured by the risk difference q - p.
2) the higher the low-skilled worker's value of reduced mortality risk, $\mathrm{VOL_L}$.

For the VSL to be an unbiased estimator of the average value of reduced mortality risk, we must have:

$$(1-\pi(\mathrm{L}))\,\mathrm{VOL_H} + \pi(\mathrm{L})\,\mathrm{VOL_L} = \mathrm{VSL}$$

which is equivalent to:

(8) $$\mathrm{VOL_H} = \frac{1-\pi(\mathrm{L})^2}{\pi(\mathrm{L})-\pi(\mathrm{L})^2}\,\mathrm{VOL_L} \quad (> \mathrm{VOL_L})$$

These three results hold as long as $\mathrm{VOL_H}$ is lower than the critical value identified in expression 8. And on examination one sees that it would be a coincidence if expression 8 holds; it would have to satisfy rather stringent constraints. Noting also that $\mathrm{VOL_H}$ may be higher than the critical value given by expression 8, we obtain the fourth result: *VSL is an unbiased estimator of the value of mortality risk reduction in certain cases, but this occurs on a null set. VSL may underestimate the value of reduced mortality risk if the high-skilled workers value mortality risk reduction much more highly than the low-skilled workers.*

These four results suggest that value of lives saved is likely to be systematically biased upward once we account for worker heterogeneity in both *skill* and *risk preference*. The reason for this systematic bias is that the marginal worker is the person who demands the highest compensation for *his* risk in the job. That means that this marginal person faces relatively higher risk because of less skill or has lower tolerance to risk or both relative to other workers. And if his wage differential is divided by the statistical risk in the occupation, which measures the average risk of all the workers, the estimate of the workers' value of reduced mortality risk is biased upward

because the highest required wage differential among the workers is divided by their average risk. Our results are robust as one allows for more than two types and more general utility functions (see Shogren and Stamland, 2000a).

We now take this perspective on skill and valuation and apply it directly to the question of food safety and the VOL (Shogren and Stamland, 2000b). Consider a consumer who chooses a consumption vector of N available goods and services, some of which reduce health risk and some of which are foods. Consumers may derive different levels of enjoyment and different levels of health and fatality risk from the same food. Risks differ for physiological reasons such as allergies and pre-existing health issues whereas enjoyment levels differ due to taste. Let x_t denote individual t's consumption vector. This vector may include - in addition to the consumption all possible foods, all possible ways of dining, etc. - also all other consumption goods and services. But for our purposes, we focus on the consumption of food and other goods or services that impact health risks caused by food.

Let β_t be a N-vector and A_t a positive definite (and, without loss of generality, symmetric) NxN matrix so that $\beta_t'x - x'A_tx$ denotes the enjoyment that individual t derives from the consumption vector x. The first term denotes the utility gain from small levels of consumption and the second term captures satiation effects in the consumption of single foods and the interaction effect between the consumption of different foods. Both β_t and A_t depend upon the consumer, t, due to differences in taste, nutritional needs, etc. We have not included any threshold consumption necessary for survival because we assume that at any optimal choice the individual might make, this 'survival constraint' is non-binding. But the food consumption may involve other health issues such as the possibility for food poisoning and the potential consumption of types of food or quantities of food that engender health risk. The level of risk induced by the food consumption depends upon the individual due to individual risk characteristics such as age, health, etc. We represent this risk induced by the consumption vector by the scalar product $\rho_t'x$ where ρ_t is the vector of the individual's risks per unit of consumption. Finally, we assume there is an (opportunity) cost induced by increased health risk, VOL_t, that also depends upon the individual so that the consumer's utility function can be represented as

$$(9) \quad u(t,x) = \beta_t' x - x' A_t x - \rho_t' x VOL_t$$

We denote the consumer's wealth by W_t and the vector of food prices by P so that the consumer seeks to maximize $u(t,x)$ subject to $P'x = W_t$. We assume that the budget constraint is binding, meaning that the individual would change the consumption choice if he or she became wealthier.

The first-order conditions for the maximization of $u(t,x)$ with respect to x subject to the budget constraint form a set of linear equations. The first N first-order conditions (equating to zero the partials, with respect to x, of individual t's Lagrangian, $L(t,x,\lambda_t) \equiv u(t,x) - \lambda_t (P'x - W_t)$) yield the following solution for x, in terms of the budget constraint's shadow price, λ_t:

$$(10) \quad x^* = A_t^{-1} \alpha_t$$

where

$$(11) \qquad \alpha_t = \frac{1}{2}\left(\beta_t - VOL_t \rho_t - \lambda_t P\right)$$

The second-order conditions hold because A_t is positive definite so the Hessian is negative definite. When this is plugged into the budget constraint, we obtain the following solution for λ_t:

$$(12) \qquad \lambda_t = \frac{P' A_t^{-1} \gamma_t - 2W_t}{P' A_t^{-1} P}$$

where

$$(13) \qquad \gamma_t = \beta_t - VOL_t \rho_t .$$

From the first-order conditions for food i and j, we obtain the following result: *assuming there are no interaction effects in food consumption, the individual's opportunity cost of health risk satisfies the following relationship:*

$$(14) \qquad VOL_t = \frac{P_j(\beta_{ti} - 2a_{tii}x_i) - P_i(\beta_{tj} - 2a_{tjj}x_j)}{P_j \rho_{ti} - P_i \rho_{tj}}$$

To prove this note that when there are no interaction effects A_t is a diagonal matrix so that the first-order condition obtained by taking the *i*th partial of the Lagrangian is as follows:

$$(15) \qquad \beta_{ti} - 2a_{tii}x_i - VOL_t \rho_{ti} - \lambda_t P_i = 0$$

where β_{ti} is the *i*th element of β_t, a_{tii} is the *i*th element along the diagonal of A_t, and so forth. By solving this equation for λ_t, plugging the result into the *j*th first-order condition, and rearranging, we obtain equation 14.

Researchers have identified some pitfalls in estimating the opportunity cost of health or fatality risk by using variables that are determined by the equilibrium behavior of a group of heterogeneous individuals. The problem is that an estimator based upon this group behavior may be biased by a sorting effect. This sorting determines the equilibrium's marginal individual who winds up determining the equilibrium numbers that enter into the estimator. Since this marginal individual was not randomly selected, but rather according to a particular sorting of the individuals, this individual is almost never representative of the whole group. Thus arises the bias.

Here we take a completely different approach. Rather than looking at the equilibrium behavior of a group of people, we look at the utility-maximizing choices made by each individual. The estimator we obtain in equation 14 is therefore the estimator of one particular person's opportunity cost of health and fatality risks. This therefore explicitly accounts for the heterogeneity among the individuals. Furthermore, equation 14 defines not one but rather N(N-1)/2 estimators of VOL_t per person where N is the number of health risk relevant consumption choices that are sampled. With the expansion of the model in the next subsection, we obtain an additional N estimates for a total of N(N+1)/2 estimates per person. If there were no noise in the estimation process, all these estimates would of course be the same. But in the presence of noise, such collections of many estimates of VOL_t for each of many persons in a sample may provide

the possibility of bringing the estimation of the opportunity cost of health risks to a new level of accuracy.

If we want to use equation 14 to estimate VOL_t correctly, we need to know the relevant six terms from β_t, A_t, and ρ_t, as well as the chosen quantities, x_i and x_i, and the prevailing prices, P_i and P_j. Most likely, these parameters need themselves to be estimated so that the resulting VOL_t estimates are noisy. In the next subsection we look at an expanded and more complex model that, far from yielding a more complicated estimator for VOL_t, actually yields estimators that require fewer consumer specific variables to be estimated. The present model therefore provides a menu of estimators between which one may select.

Now let's expand the model. Define the indirect utility function $u^*(t,\rho_t)$ as the maximum of $u(t,x)$ over x subject to the budget constraint. This indirect utility is, as denoted, a function of the risk levels, ρ_t, that the individual faces from the food consumption vector, x. Given the above, we have that:

$$(16) \qquad u^*(t,\rho_t)=(\alpha_t+\lambda_t P)'A_t^{-1}\alpha_t$$

We assume that as well as having wealth that can be spent in markets to buy goods and services, some of which reduce health risks, the individual may exert effort in order to reduce the health risk engendered by consumption, ρ_t. One example of such an effort would be physical exercise. The benefits obtained from exercise are not necessarily (or only) obtained through the purchase of a service in a market, but is perhaps primarily a service one does oneself at a personal opportunity cost. Other similar "personal" services include choice of leisure activities, lifestyle, etc. To capture this, we assume that the individual chooses his or her optimal risk reduction efforts by maximizing the indirect utility function less opportunity costs that, in net, takes the following form:

$$(17) \qquad U(t,\rho_t)=u^*(t,\rho_t)+\sum_{i=1}^{N} c_{ti}\,ln(\rho_{ti}-\underline{\rho_{ti}})$$

where $\underline{\rho_{ti}}$ might be thought of as a physiologically defined minimum risk, which very well could be zero (or even negative if the good or service in question is a risk reduction activity), from a given consumption good.

We have then the following implicit solution to the first-order condition for maximizing $U(t,\rho_t)$ with respect to ρ_{ti}:[1]

$$(18) \qquad \rho_{ti}=\underline{\rho_{ti}}+\frac{c_i}{-u_{t\rho i}^*}$$

where

$$(19) \qquad u_{t\rho i}^* \equiv \frac{\partial u^*(t,\rho_{ti})}{\partial \rho_{ti}}=-VOL_t\, 1_i' A_t^{-1}\alpha_t$$

and 1_i is a N-vector with 1 in its ith element and zeroes elsewhere.

[1] The second-order conditions for this maximization problem are checked in each instance in the numerical analysis below because we cannot determine whether they are satisfied in general.

One issue, which we return to in the connection with numerical examples below, is that we are unable to verify that the second order conditions for the implicit solution in equation 18 do hold. Numerical examples verify that the second order conditions do not hold always since we are in some cases unable to generate a solution using equation 18 iteratively. However, we encountered no difficulties in finding instances where iterations of equation 18 converge and in most of these instances the second-order conditions do hold.

Plugging equation 11 into equation 19, we obtain

$$u_{t\rho i}^{*} \equiv -VOL_t x_i^{*} \quad (20)$$

and so we can rewrite equation 18 as

$$\rho_{ti}^{*} = \underline{\rho_{ti}} + \frac{c_i}{VOL_t x_i^{*}}. \quad (21)$$

Solving equation 21 for VOL_t, we obtain the following result: *assuming the individual spends effort to reduce health risks and the second-order conditions hold, the individual's opportunity cost of health risk satisfies the following relationship:*

$$VOL_t = \frac{c_{ti}}{(\rho_{ti}^{*} - \underline{\rho_{ti}})x_i^{*}}. \quad (22)$$

Thus we obtain an additional estimator of VOL_t for each health risk relevant consumption choice. Furthermore, the estimator in equation 22 is simpler than that in equation 14 since it relies on estimating only three variables for each consumption choice, it does not require price information, and it does not require comparisons across consumption goods. It may be difficult to obtain good estimates of some of the parameters in equation 22, perhaps especially c_{ti}. Accounting for the heterogeneity between individuals necessarily makes it more complicated to infer these individuals' opportunity costs of health risk. We hope that this model, by providing a potentially large number of estimates for each individual, takes a step toward resolving these complications. Clearly, to assess the usefulness of the estimators we propose, one must employ them empirically and assess the resulting insights.

An additional benefit our model may provide is the fundament for a deeper statistical analysis of the uncertainty with which we estimate the opportunity cost of health risks. Our framework holds the possibility that one may obtain many estimates of this health risk for each single person in a sample. This may provide an opportunity to analyze the errors we make in estimating the opportunity cost of health risk. Are the different estimates for a single person's opportunity cost typically narrowly, or widely, spread around the mean estimate? The answer to this question should be of considerable interest.

Direct Methods: Risk and Rationality

Direct methods to estimate the value of reduced risk can be grouped into two categories—stated preferences and experimental auction methods. Among others, key differences between the two is whether the choice is actually binding when made, and the context of information that can be provided.

Stated preferences methods (e.g., contingent valuation) directly ask people, through a survey or interview, how much they would be willing to pay to reduce risk. The approach constructs a hypothetical market, in which a person buys or sells safety. The method attempts to reveal a person's willingness to pay for a risk reduction. The challenge is to make these hypothetical markets realistic and relevant to people. The judgmental best estimate of the value of a statistical life was approximately $0.1-$15.0 million for both studies (in 1990 dollars). The range of values is consistent with the high-range estimates of the hedonic wage-risk model, thereby dampening the complaints of its critics. Although a carefully designed survey can add information on tradeoffs between safety and income, the method has its critics. A major complaint is that people are asked to answer a hypothetical valuation question that neither puts their money on the line nor enforces a budget constraint.

Experimental auction markets are a relatively recent approach to directly value reductions in risk. Experimental auctions use the laboratory to sell real goods to real people within a stylized setting. Laboratory experiments can isolate and control how different auctions and market settings affect values in a setting of replication and repetition. Experiments with repeated market experience provide a well-defined incentive structure that allows a person to learn that honest revelation of his or her true preferences is his or her best strategy. With demand-revealing auctions (e.g., the second-price, sealed-bid auction mechanism), subjects participate in an auction market that allows for learning as participants realize the actual monetary consequences of their bidding. The non-hypothetical auctions with repeated market experience can improve the precision of risk valuation.

Hayes et al. designed a set of experimental auctions to explore the ex ante willingness to pay for safer food.this question. They constructed an experimental auction to elicit both the option price and compensation measures of value for five different foodborne pathogens. They also used additional treatments to evaluate how subjects respond to changes in the risk of illness for a given pathogen, *Salmonella*, and to explore if pathogen-specific values act as surrogate measures of general food safety preferences. All experiments used real money, real food, repeated opportunities to participate in the auction market, and full information on the probability and severity of the food-borne pathogen. The design also used a Vickrey second-price auction to provide incentive to reveal preferences for risk reduction truthfully.

Four results emerge from their experiments. First, people underestimated the objective risk of foodborne pathogens. Second, values across foodborne pathogens were not robust to changes in the relative probabilities and severity, suggesting that people place more weight on their own prior perceptions than on new information on the odds of illness. Third, marginal willingness to pay an option price decreases as risk increases, again suggesting that the people weighed their prior beliefs more than new information. Fourth, they found support that values for specific pathogens might act as surrogates for general food safety preferences.

Overall, the results suggest that the average subject in our experimental environment was willing to pay approximately $0.70 per meal for safer food. The *Salmonella* treatments under alternative risk levels indicate that the average person would pay about $0.30 per meal to reduce risk of

foodborne pathogens by a fraction of 10. If one could transfer these values to the U.S. population, the value of food safety could be at least three times the largest previously available estimates.

Use of the lab to elicit value raises several questions of method. Consider three. First, does the unique lab environment inflate values? The observed premium paid in the Hayes et al. experiment exceeded some expectations of what people would pay in a real retail market. One explanation might be the novelty of the experimental experience. These auctions are usually a one-time experience, and the concern is that people might experiment with their bids, bidding high because the costs of doing so are low. Theory suggests an alternative explanation for the high price premia—the novelty of the good. Many bidders have never experienced the goods up for auction, e.g., irradiated meat. In this case, theory says that a bid will reflect two elements of value—the consumption value of the good and the information value of learning how the good fits into his or her preference set. *Preference learning* would exist if people bid large amounts for a good because they wanted to learn about an unfamiliar good they had not previously consumed, because it was unique, or because it was unavailable in local stores. Shogren et al. (2000a) tested these competing explanations by auctioning off three goods that varied in familiarity—candy bars, mangos, and irradiated pork, in four consecutive experimental auctions over two weeks. Their results suggest that preference learning seems to explain the high price premia. No statistical change in bids was measured for candy bars and mangos, whereas the price premia for irradiated pork dropped by 50 percent over the four sessions. These findings suggest that people benefit from the information they gain about how an unfamiliar good fits into their preference ordering.

Second, how do posted prices affect bidding behavior? Lab valuation exercises use multiple trials with posted market prices to provide experience to bidders who walk into these auctions cold. The information sent by a posted market price helps bidders learn about the market mechanism and the upper support of the valuation distribution. Concern exists that market experience will contaminate bids as posted prices turn independent private values into *affiliated* private values, especially if people are unfamiliar with the good up for sale (Harrison et al., 1995).[2] List and Shogren (1998) explore this possibility by examining panel data from over 40 second-price auctions with repeated trials. Three results emerge. First, the market price affects bidding behavior for unfamiliar products, as implied by affiliated private values. Second, the price effect dissipates when bidders receive non-price information about the good or are familiar with the product before entering the lab. Third, evidence of strategic behavior independent of any price signal still exists; buyers start bidding low and sellers start offers high, and then bids quickly stabilize after one or two trials. These results suggest posted prices can influence bidding behavior for unfamiliar products, but the effect dissipates when people have non-price information about the good or are familiar with the good.[3]

[2] Affiliation exists when one bidder who values the good highly increases the chance that other bidders will also put a high value on the good.

[3] The results have two pragmatic implications for lab valuation research. First, the affiliation of private values can be reduced, if not removed, by providing product information prior to bidding. Second, a few trials help people learn about the market mechanism. Some people might need the experience since it appears that they did not fully comprehend the strategic implications of the second-price auctions.

Third, how does direct lab valuation for food safety within the lab and using surveys match up with an actual retail market behavior? Lab experiments introduce new price and non-price information and then observe the subsequent changes in bidding behavior. People still know that they are being monitored, however, and the range of alternative purchases is more limited than in a retail setting. Valuation surveys usually use hypothetical questions, and no guarantee exists that hypothetical answers would match those that occur under more realistic circumstances. Respondents know they are not accountable for their choices. Since these institutional differences send unique information flows to consumers, it is possible that distinct decision processes are involved that may cause a person to respond differently to the same choice. Shogren, Fox, and Hayes (1999) explore the similarity of these choices for risk reduction via irradiation, and how they match up with actual choices in a retail setting. All subjects came from the same small college town, and made choices between typical chicken breasts versus chicken breasts irradiated to reduce the risk of foodborne pathogens. Figure 1 shows that the results from both the survey and experimental market suggested significantly higher levels of acceptability of irradiated chicken than were shown in the retail trial at an equal or discounted price for irradiation. Consumer choices were more similar across market settings at a price premium for irradiation.

But all this work rests on the idea that the foundation of the economic theory of choice lies in the expression of values through repeated give and take with others in an exchange institution. The institution defines incentives and articulates knowledge and beliefs about relevant laws of nature and of humans. It relates a person's choice to the choices of others and to the consequences these aggregated choices produce. Moreover, it conserves resources and goods by redistributing them in accord with desires. The exchange institution is therefore a collective habit. When it is absent, a person must draw more intensely upon his or her personal resources.

But since exchange institutions often, even usually, do not exist for environmental assets, a person can act as if his value expressions will go uncontested; he is asocial, and need not be accountable to others. Unless one presumes he is a complete image of a nonstrategic, anonymous, competitive market that is broad in scope, the person may lack the incentives to act in accordance with the utility maximization paradigm and the economic theory of choice that follows from it. Economic and psychological evidence is abundant that, absent the disciplines and the protections of exchange institutions, people often depart from the axiomatic foundation of the economic theory of choice. When no exchange institution provides the gravity to hold his rationality together, the unsocialized person commonly engages in anomalous behaviors (naïve expectations or sucker behaviors) inconsistent with the paradigm. Unsocialized individuals fail to exploit existing gains from trade *and* often engage in behaviors that allow others to exploit these gains. Thaler (1992) presents a lengthy catalogue of these violations, including endowment effects, framing effects, and preference reversal effects.

Because exchange institutions—especially markets—are thin or nonexistent for environmental commodities, individual irrationalities plausibly exercise great influence over the allocation of these commodities and thus the values derived from their presence and use. Delivery of a means to allocate these commodities rationally might be viewed as a major purpose of benefit-cost

analysis, the kit of tools that economists use to infer the values people would attach to these commodities if market discipline were in place. The delivery may be less than the acme of perfection however, if only because applications of the kit usually require the introduction of strong auxiliary conditions linking a person to the market. The auxiliary conditions can be used to make what appears to be an ill-structured problem even to the researcher appear as a well-structured problem to that same researcher (Simon, 1973).

But risks from foodborne pathogens can conjure up images of either a secure chain of food inspections that guarantee our food arrives in sanitized, air-tight receptacles, or a risky adventure every time one goes out to eat. The two images induce vividly different perceptions of risk to public health. Yet such a range of public risk perceptions can exist simultaneously in a community, causing considerable disagreement as to whether a risk is acceptable or not. Determining whether the risk needs to be regulated depends on how people are willing to trade off risks for the benefits they can generate to society. Their willingness to surrender benefits for reduced risk represents the value they place on risk reduction. Estimating this value for risk reduction is a critical component of risk-benefit analysis, now commonly used in policymaking on environmental risk.

This value of reduced risk depends in part on the rationality we are willing to presume when people confront risk. People deathly afraid of the risks they see around every corner are likely to value risk reduction more than those who live to take risks. This statement seems straightforward enough, and the logic behind it guides most economists who address environmental risk. Those at most risk who are most afraid of risk and who have the most income should consistently value risk reduction the most.

Economists who work with risk most often use the expected utility framework, which presumes people have well-defined preferences for risk and can logically form rational perceptions of risk. The working presumption is that people have a solid foundation that drives their choices, such that when they confront a risk, new or old, they are able to evaluate the odds and consequences in a systematic and predictable way. A person's stated value for risk reduction is based on a logical foundation of choice—welfare economics, and thus economics, is able to judge the overall economic efficiency of some policy decision. Without well-grounded preferences and perceptions, there is a crack in the foundation of the rational theory of choice on which the economist's risk-benefit analysis rests.

But cracks exist. Psychologists and some economists have documented numerous exceptions to the idea of a rational theory of choice (see Machina, 1987; Camerer, 1995). These behavioral researchers have shown how people use rules of thumb, or heuristics, to simplify their reasoning about risk. Using these rules, people often react to risk in broader patterns than predicted by expected utility theory. This suggests that the standard model used to guide risk-benefit decisions is "too thin"—the model does not predict systematic aspects of behavior under risk regularly observed in many situations. In fact, the evidence suggests that risk preference and perceptions seem to be systematically influenced by the context of choice. People who make judgments about risk use heuristics, or rules of thumb, that the popular expected utility

framework fails to capture. There is a long list of behavioral anomalies and paradoxes uncovered by cognitive researchers.

In the case of food safety, one key bias in judgment is when people overestimate low-probability risks and underestimate high-probability risks. Imagine a 45º line that represents the case in which the general public's subjective risk equals objective risk as defined by expert opinion. Now imagine a slightly flatter line intersecting the 45º line from above reflects the evidence from different experiments and surveys examining how people actual rank the threats posed by different risk. People seem to inflate low risks that they have little to no control over (e.g., nuclear power) and deflate high risks that they can control to some degree (e.g., driving to work). They tend to worry more about how and where a risk arises than its magnitude, e.g., synthetic versus natural carcinogens. This poor calibration between experts' objective opinions and the lay person's perceptions can lead to rejection of potentially beneficial technologies, e.g., commercial nuclear power.

Such irrational reactions can affect the values collected with stated preference methods. The isolated individual, in response to a researcher request to do so, is presumed to be able to imagine an exchange institution, visualize the details of his and others' participation in it, and then to state his one-time value for a nonmarketed environmental commodity. Though contingent valuation employs a data gathering tool that psychologists and sociologists apply to study the cognitive processes that generate a person's choice, its economist practitioners do not often address the general reluctance of these other disciplines to use the utility maximization paradigm to explain the isolated behaviors of individuals. These non-economic disciplines prefer to downplay the quantitative features of a decision process to focus on the framing of the problem, learning about it, clarifying options, etc. These are the functions an effective exchange institution performs on a person. And though the verdict is still out, enough empirical evidence exists to fuel skeptics who wonder whether asking an isolated person to visualize active participation in a repeated give and take situation is sufficient to cause him to behave for one time in accordance with the utility maximization paradigm. A polite request to visualize a nonexistent market does not obviously cause the rationality of the real market to rub off on him.

We posit that a Coasean corollary exists for nonmarket valuation—if information processing costs are zero, the researcher will have enough understanding to provide identically perceived information such that the beliefs of respondents will be complete, and, consequently, elicited values would be identical to the market price, if it existed. But if information costs really are zero, respondents will endogenously generate their own information frames that will be identical to the exogenously provided information frames, i.e., elaborate information packages in survey research would be redundant as respondents would select the same frame endogenously. Information costs are not zero, obviously, thereby implying that the rules and exchange institutions implied by a researcher's exogenous frame impact a respondent's elicited value. Therefore, artificially restricting the range of rules and exchange institutions will result in revealed values that underestimate the true value of the resource. Allowing for the endogenous choice of exchange institution in nonmarket valuation is needed to permit incomplete beliefs to become more complete such that the respondent has the opportunity to participate in the selection of both *what* goods will

be produced and *how* they will be provided. Additionally, some form of arbitrage, albeit possibly mock, should be used to make beliefs even more complete.

Maximum extraction of potential surplus is performed at the level of the exchange institution rather than at the level of the individual (Becker, 1962; Smith, 1991; Grether, 1994; Plott, 1996). Consider the odds that you will suffer a dreaded environmental disease by a given date. You will be able to specify a lower probability value such that odds less than this value are incredibly low and another, higher value such that odds greater than this value are incredibly high. You will insist or try to placate someone who insists that you pick a single, unique value. de Finetti (1974) shows how the selected lower value, upper value, and single-value odds can be interpreted as your greatest buying price, your lowest selling price, and your no-arbitrage price. Your beliefs are complete at the no-arbitrage price (Nau and McCardle, 1991).

If a person has incomplete beliefs, they can be made more complete if he chooses to participate in one or more exchange institutions. It is exchange institutions that pressure the individual to behave in accordance with the utility maximization paradigm (see for example Chu and Chu, 1991; Gode and Sunder, 1993). However the manner in which these pressures induce the individual to submit his beliefs and preferences may differ considerably across institutions and a person may well have preferences over the manner of submission. For example, a person may prefer the anonymity of the nonstrategic, competitive market over a public good club that compels him to divulge more than he would like in interminable meetings for which he does not care. The incompleteness of his beliefs about and thus the value he attaches to a lottery for the environmental commodity will therefore differ with the exchange institutions in which he chooses to participate and with the intensity of his participation.

As we stated, experimental evidence suggests that an isolated person often acts outside the ropes of economic theory. We discussed how he commonly reverses his preferences, makes different bids and offers for the same good, and puts too much weight on his initial endowments. But people usually return to the ring when they interact with other intelligent self-interested people in an active exchange institution. These institutions arbitrage the irrational decisions of people by rewarding those acting rationally or learning to act rationally. As such, economists often question the importance of isolated anomalistic behavior to explain behavior in thick, well-functioning markets and economic systems.

But markets for several key goods and services are thin or non-existent; they lack sufficient arbitrage opportunities that can induce rational economic behavior. Most environmental assets, for instance, lack well-defined exchange institutions, and as a consequence, behavior in the allocation and valuation of environmental goods is more likely to be irrational. This observation calls into question the reliability of nonmarket valuation surveys that have emerged to understand behavior for these goods. The typical survey asks the unsocialized person to imagine an exchange institution, visualize the details of his and others' participation in it, and then to state his one-time value for a non-marketed environmental good. While these surveys generate numbers, the hypothetical institutions are perilously thin and provide the undisciplined and uncontested values that raise fears that irrational behavior is the rule not the exception.

But most people participate in both thick and thin markets simultaneously. The key question is whether the rationality induced from arbitrage in a thick market could spill over to behavior in a thin market. If so, non-market valuation surveys might be improved by a explicit connection to an active market with arbitrage. Cherry et al. (2000) provide experimental evidence of such rationality spillovers—induced rationality in an arbitraged market can spill over to a second non-arbitraged market that would otherwise consist of irrational behavior in the case of preference reversals. Only arbitrage and socialization appear to stop the phenomena (Chu and Chu, 1990). But will the rationality induced in a market with arbitrage spill over to a second market without arbitrage?

Here we extend the account of induced rationality in Crocker et al. (1998) to rationality spillovers. To reduce notational clutter, we consider one representative agent who makes his choices in one time period and takes the state of nature as fixed. A lottery is sequentially available to the agent in two settings, first an arbitrage, market-like setting, MK, and then an isolated, nonmarket setting, NM. Let θ^{NM} be the agent's effort to overcome any irrationalities that his cognitive and computational limitations cause him to have in the isolated setting. Represent the agent's irrationalities by $\Delta^k, k = MK, NM$, the inconsistency between his choice and the fair price for a lottery ticket. Any such gap, Δ^k, invites efforts to close it – like a gap in potential that, when sufficiently great, is crossed by electric energy as a spark. But this need not mean that the agent's shock is great enough to elicit enough effort to close the gap and thus maximize extracted surplus.

The gap Δ^{MK} affects the agent's rationality in the isolated setting parametrically. Assume this effect is independent of the agent's wealth. With a result, Δ^{MK}, the agent's surplus extraction problem in the isolated setting is to choose effort to maximize

$$(23) \qquad \underset{\theta^{NM}}{\text{Max}}\ W^{NM} = \left[Z^{NM} - \left(1-\theta^{NM}\right)\Delta^{NM}\left(\theta^{NM},\Delta^{MK}\right) - C^{NM}\left(\theta^{NM},\Delta^{MK}\right)\right],$$

where Z^{NM} is the maximum surplus the agent could extract if he were fully rational in the isolated state. This surplus corresponds to that which would be generated in a world of non-strategic, anonymous, competitive markets for a lottery ticket. Let θ^{NM} be continuous. It can be characterized as lying in the unit interval [0,1], in which the upper bound implies that the agent expends enough effort to override his endowed cognitive and computational limitations completely and the lower bound implies no overriding whatsoever. Getting more education or a new set of eyeglasses might be examples of effort expenditures. Expenditures like these are costly in terms of time and resources. Expression 23 makes both the agent's residual irrationality or unextracted surplus, Δ^{NM}, and his costs of extracting surplus, C^{NM}, in the isolated setting functions of his irrationality, Δ^{MK}, in the arbitrage setting and his effort expenditures, θ^{NM}, in the isolated setting. His irrationality in the isolated setting is determined by what he learned in the arbitrage setting and his willingness to apply that learning in the isolated setting.

Assume

$$\frac{\partial \Delta^{NM}}{\partial \theta^{NM}} \leq 0; \qquad \frac{\partial \Delta^{NM}}{\partial \Delta^{MK}} = 0; \qquad \frac{\partial C^{NM}}{\partial \theta^{NM}} > 0; \qquad \frac{\partial C^{NM}}{\partial \Delta^{MK}} \geq 0 \ ,$$

and

$$\frac{\partial^2 \Delta^{NM}}{\left(\partial \theta^{NM}\right)^2} < 0; \quad \frac{\partial^2 C^{NM}}{(\partial \theta^{NM})^2} > 0; \quad \frac{\partial^2 C^{NM}}{\left(\partial \Delta^{MK}\right)^2} > 0; \quad \frac{\partial^2 C^{NM}}{\partial \theta^{NM} \partial \Delta^{MK}} > 0.$$

We discuss the sign of $\frac{\partial^2 \Delta^{NM}}{\partial \theta^{NM} \partial \Delta^{MK}}$ subsequently. Assume $\frac{\partial \Delta^{NM}}{\partial \Delta^{MK}}$ equals zero because, by definition, the isolated agent can be more rational only by trying to be so, i.e., by drawing upon his internal resources to make lessons from his prior arbitrage experiences.

In the isolated setting, the agent's optimal residual irrationality is

(24) $$\Delta^{NM} \ : \frac{\partial W^{NM}}{\partial \theta^{NM}} = -\left(1 - \theta^{NM}\right)\frac{\partial \Delta^{NM}}{\partial \theta^{NM}} + \Delta^{NM} - \frac{\partial C^{NM}}{\partial \theta^{NM}} = 0$$

(25) $$\left(\Delta^{NM}\right)^2 \ : \frac{\partial^2 W^{NM}}{(\partial \theta^{NM})^2} = -\left(1 - \theta^{NM}\right)\frac{\partial^2 \Delta^{NM}}{(\partial \theta^{NM})^2} + \frac{\partial \Delta^{NM}}{\partial \theta^{NM}} - \frac{\partial^2 C^{NM}}{\left(\partial \theta^{NM}\right)^2} < 0$$

Analogous conditions exist in the arbitrage setting which produced Δ^{MK} if the extraction of surplus in that setting involves agent efforts to grasp the implications of and to implement transactions, coordination, and negotiation.

Now differentiate the first-order equilibrium conditions for the arbitrage and the isolated settings with respect to a parametric shift in the agent's residual irrationality in the arbitrage setting. Better arbitrageurs than the agent previously had to face might cause this shift. They force the agent to get smarter. This differentiation yields

(26) $$\frac{d\Delta^{NM}}{d\Delta^{MK}} = -\frac{\Delta^{NM}\Delta^{MK}}{\left(\Delta^{NM}\right)^2},$$

where Δ^{MK} is the agent's optimal residual irrationality in the arbitrage setting alone. The $\Delta^{NM}\Delta^{MK}$ term on the right-hand-side of expression 26 is

(27) $$\Delta^{\mathrm{NM}}\Delta^{\mathrm{MK}} \ : -\left(1 - \theta^{\mathrm{NM}}\right)\frac{\partial^2 \Delta^{\mathrm{NM}}}{\partial \theta^{\mathrm{NM}} \partial \Delta^{\mathrm{MK}}} + \frac{\partial \Delta^{\mathrm{NM}}}{\partial \Delta^{\mathrm{MK}}} - \frac{\partial^2 \mathrm{C}^{\mathrm{NM}}}{\partial \theta^{\mathrm{NM}} \partial \Delta^{\mathrm{MK}}}.$$

If the agent does not carry over his residual irrationality in the arbitrage setting to the isolated setting, then expression 27 will be zero, implying from expression 26 that the agent does not choose to use whatever he learned in the arbitrage setting to improve the quality of his decisions in the isolated setting. For expression 26 to be positive such that a rationality spillover occurs, isolated effort and reductions in arbitrage irrationality must be complements. Reductions in

arbitrage irrationality must increase the marginal product, $\left(\frac{\partial^2 \Delta^{NM}}{\partial \theta^{NM} \partial \Delta^{MK}}\right) < 0$, and reduce the marginal costs, $\left(\frac{\partial^2 C^{NM}}{\partial \theta^{NM} \partial \Delta^{MK}}\right) > 0$, of the agent's efforts in the isolated setting. Our null hypothesis is that the net effect of these two cross-partials causes expression 26 to be zero or negative in sign, which means respectively that arbitrage experiences do not impact the quality of the agent's unarbitraged decisions or that these experiences are dysfunctional for these decisions.[4] The alternative hypothesis is that expression 26 will be positive. To state our hypotheses in the text formally, first consider arbitrage and rationality spillovers.
For a person in the k^{th} institution, (k= MK, NM) let w^k denote his initial wealth level; A^k, B^k , and ψ^k indicate his holding of lottery A, lottery B and no lottery; and $WTP(A)^k$ and $WTP(B)^k$ is his maximum willingness to pay for lotteries A and B. Preference and indifference are indicated by ($\succ$) and ($\sim$). By definition of $WTP(A)^k$, and $WTP(B)^k$, the following holds for the k^{th} institution:

$$[w^k + WTP(A)^k, \psi^k] \sim [w^k, A^k] \text{ and } [w^k + WTP(B)^k, \psi^k] \sim [w^k, B^k].$$

Preference for lottery A over lottery B implies $[w^k, A^k] \succ [w^k, B^k]$ and by transitivity

$$[w^k + WTP(A)^k, \psi^k] \succ [w^k + WTP(B)^k, \psi^k].$$

Given wealth provides positive utility, $WTP(A)^k > WTP(B)^k$ follows from the initial preference of lottery A over lottery B. Rational behavior leaves no arbitrage opportunities, i.e., surplus on the table available for others to capture.

In reality, isolated people often contradict this theoretical result. They reverse their preferences by either indicating

$$[w^k, A^k] \succ [w^k, B^k] \text{ and } [WTP(A)^k] < [WTP(B)^k].$$

or

$$[w^k, A^k] \prec [w^k, B^k] \text{ and } [WTP(A)^k] > [WTP(B)^k].$$

These inconsistent preferences create opportunities for others to extract gains through exchange.

Surplus left on the table from inconsistent preferences may arise from errors in judging preferences or valuations or both. Errors may be reduced or eliminated when the surplus is captured through the arbitrage provided within an exchange institution. Let the preference of lottery A over lottery B be denoted as

$$[A^k + \varepsilon(A)^k] \succ [B^k + \varepsilon(B)^k],$$

[4] By treating arbitrage rationality levels tomorrow as positive functions of isolate rationality levels today, this framework could readily be adapted to a multiperiod, sequential process in which irrationality declines with each passing period. This learning-by-doing process need not presume dynamic elemental rationality in the sense that the agent weighs the value of behaving today in terms of what such behavior will do for the temporal conjunction of his irrationalities in all tomorrows. Unintentional rationality spillovers can, in principle, occur over time, events, states, institutional settings, or any other economic dimension.

where $\varepsilon(\ )^k$ is the error in judgement for lottery in institution k (= A, B and k = MK, NM). Summing judgment errors yields the total error in preference ordering for institution k, $E^k = \varepsilon(A)^k + \varepsilon(B)^k$. The valuations for lotteries A and B for the preference- reversing individual are given by

$$[WTP(B)^k + \varphi(A)^k] > [WTP(A)^k + \varphi(B)^k]$$

where $\varphi(\ )^k$ is the error in valuing lottery in institution k (= A, B and k = MK, NM). Total error in valuation for institution k is given by $\vartheta^k = \varphi(A)^k + \varphi(B)^k$. The total error in institution k is the sum of the error in preference ordering and valuation, $\Delta^k = E^k + \vartheta^k$.

Let total error within the kth institution with and without arbitrage be $\Delta^{k(1)}$ and $\Delta^{k(0)}$, in which k(1) and k(0) represent arbitrage and no arbitrage. Direct rationality effects from arbitrage imply that total error is reduced or eliminated in the presence of arbitrage such that $\Delta^{k(1)} < \Delta^{k(0)}$. Accordingly the direct rationality hypothesis refers to the rationality effects of arbitrage within a single institution,

$$H_O: \Delta^{k(1)} = \Delta^{k(0)};\ H_a: \Delta^{k(1)} < \Delta^{k(0)}. \quad k = MK, NM$$

Plentiful theoretical and experimental evidence supports direct rationality effects from arbitrage.

Now consider the indirect or rationality spillover effects of arbitrage in the jth institution, $j \neq k$. "Rationality spillover" simply assumes that the individual's total error in the kth institution is reduced after he is subjected to arbitrage in the jth institution. The rationality spillover hypothesis is thus

$$H_O: \Delta^{k(0)}_{j(1)} = \Delta^{k(0)}_{j(0)};\ H_a: \Delta^{k(0)}_{j(1)} < \Delta^{k(0)}_{j(0)} \quad j \neq k = MK, NM$$

where $\Delta^{k(0)}_{j(1)}$ is the individual's total error in the kth institution subsequent to his participation in arbitrage in the jth institution.

For a given institution, do his preference orderings or do his valuations register the effect that arbitrage has on the person's rationality? Arbitrage may induce him to correct errors in his preference ordering alone such that $dE^{k(1)} < 0$ and $d\vartheta^{k(1)} = 0$, in his valuations alone $dE^{k(1)} = 0$ and $d\vartheta^{k(1)} < 0$, or both $dE^{k(1)} < 0$ and $d\vartheta^{k(1)} < 0$. Further, rationality effects may occur in only a single lottery type as in $dE(\ )^{k(1)} < 0$ and $d\vartheta(\ )^{k(1)} < 0$ or pairs as in $dE(\ )^{k(1)} < 0$, $d\vartheta(\ )^{k(1)} < 0$, = A,B, k= MK, NM. Three hypotheses follow:

- Preference adjustment hypothesis – *total errors are reduced by correcting preference orderings alone,* $H_O: E(\ )^{k(0)}_{j(1)} = E(\ )^{k(0)}_{j(0)};\ H_A: E(\ )^{k(0)}_{j(1)} < E(\ )^{k(0)}_{j(0)}$
- Valuation adjustment hypothesis for low-risk lotteries – *total errors are reduced by adjusting valuations of lottery A,* $H_O: \vartheta(A)^{k(0)}_{j(1)} = \vartheta(A)^{k(0)}_{j(0)}; H_a: \vartheta(A)^{k(0)}_{j(1)} < \vartheta(A)^{k(0)}_{j(1)}$
- Valuation adjustment hypothesis for high-risk lotteries – *total errors are reduced by adjusting valuations of lottery B,* $H_O: \vartheta(B)^{k(0)}_{j(1)} = \vartheta(B)^{k(0)}_{j(0)}; H_a: \vartheta(B)^{k(0)}_{j(1)} < \vartheta(B)^{k(0)}_{j(1)}$

Cherry et al. (2000) designed an experiment to address this question using a computer program to simulate two choices—market and non-market. Treatment 1 was the no-arbitrage baseline—

both choices had real money lotteries and no arbitrage. In treatments 2, 3, and 4, the market choice was held constant—real money lotteries with arbitrage (after round 5). The non-market choice varied across the treatments: (a) real money lotteries without arbitrage in treatment 2; (b) hypothetical money lotteries without arbitrage in treatment 3; and (c) hypothetical environmental lotteries without arbitrage in treatment 4.

In an arbitraged treatment, all possible rents from subjects reversing their preferences were extracted in three steps. The market (1) sells the least preferred and most valued lottery to the subject; (2) trades the least preferred lottery for the most preferred lottery; and (3) buys the most preferred and least valued lottery from the subject. The subject is left with no lotteries and a monetary loss equaling the difference between the indicated values of the lotteries. Note that the arbitrage mechanism was not active until after the fifth round. Under a non-arbitraged treatment, reversals were left unchecked for all rounds.

Figures 2-4 summarize the key results. First, the results suggest that arbitrage directly impacts individual rationality. The non-arbitraged reversal rate is about 33 percent and persists over the 15 rounds. Second, rationality spillovers exist. Once arbitrage is introduced in the market, the rate of reversals in the non-market choice decreased too. Reversal rates were about 20 percent after 11 trials, and 10 percent after 15 trials. Rationality spillovers were also strong in the hypothetical treatment, and weaker in the environmental treatment. Third, and of key importance, people adjusted valuations rather than preferences, which indicates the potential for rationality spillovers to improve non-market valuation. Although isolated individuals often fail to behave in accordance with the classic economic paradigm of utility maximization, these results suggest a case in which such irrationality can be overcome if people receive information and discipline from an active exchange institution.

Concluding Remarks

Valuing food safety from collective action is complicated by the fact that people have private information on both their risk preferences and their skill to avoid risk privately. They also make many decisions on low-odds risks in non-market situations in which their rationality can be called into question. Herein we explore how hidden skill and shaky rationality can affect both the theory and methods used to define and estimate value of reduced pathogenic risk. The results suggest that both skill and rationality matter, and as such both factors are worthy of attention in future research efforts.

Pathogen risk to children is one factor we have not discussed in this paper, but it deserves more attention. Children can face disproportionately greater risk from foodborne pathogens because they are kids—smaller bodies, faster metabolisms, shorter attentions spans, less knowledge, and fewer resources. Food safety programs that reduce risks to children produce benefits to society that should be adequately represented so policymakers have more information to help them decide which policies are the most worthwhile relative to their costs. The open question is just how exactly to value these reductions in risks to children, which can either arise from a direct effect on their health or an indirect effect on their life chances due to illness in other family members or the degradation of the environment. Do standard benefits estimation adequately

capture the indirect effects on healthy children? In some cases, risks to children might be accounted for in revealed and stated values, and estimating these effects could imply double counting of benefits. But if policymakers fear that caregivers face choice without complete information or experience, the benefits of reduced risks to children might be understated. It also seems constructive to devote resources to explore the link between adults, children, and the value of safer food.

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Figure 1 — Ratio of consumers who prefer irradiated meat, given relative price

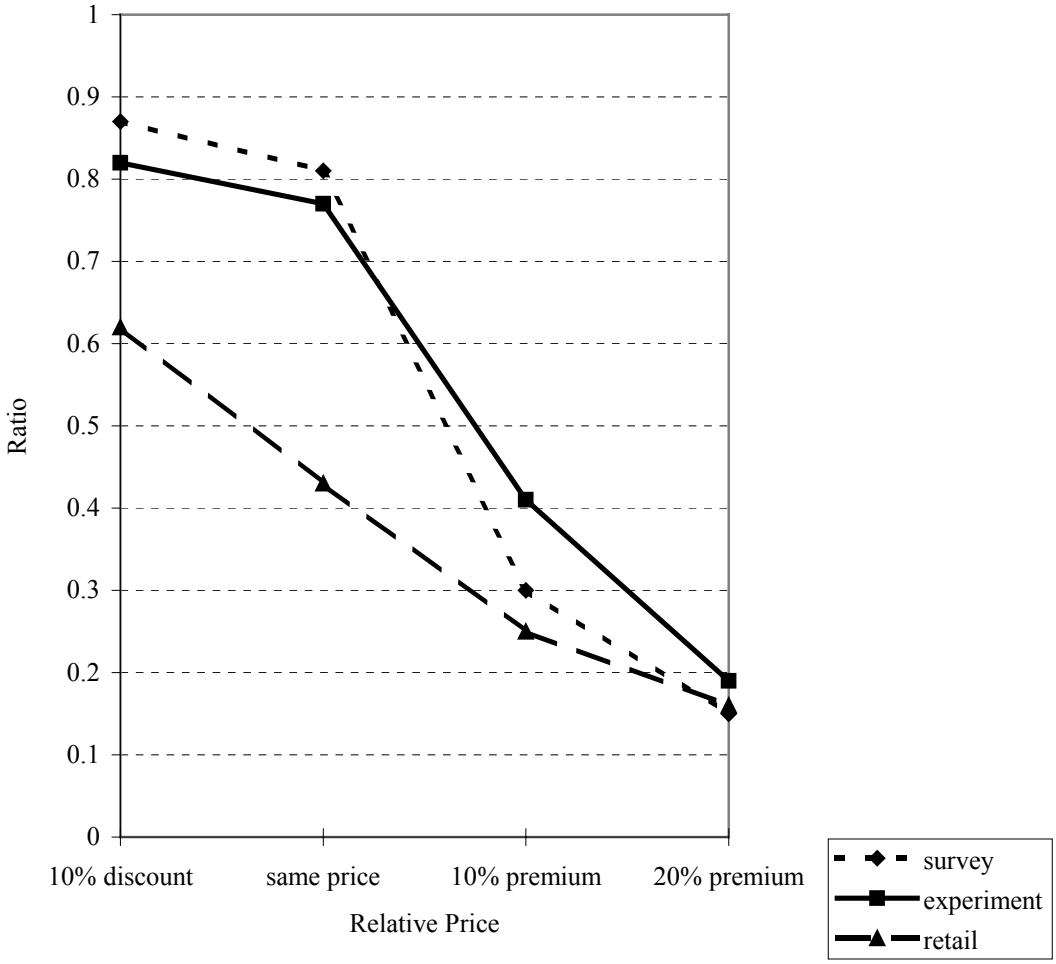


Figure 2 – Preference reversal rates in the market setting

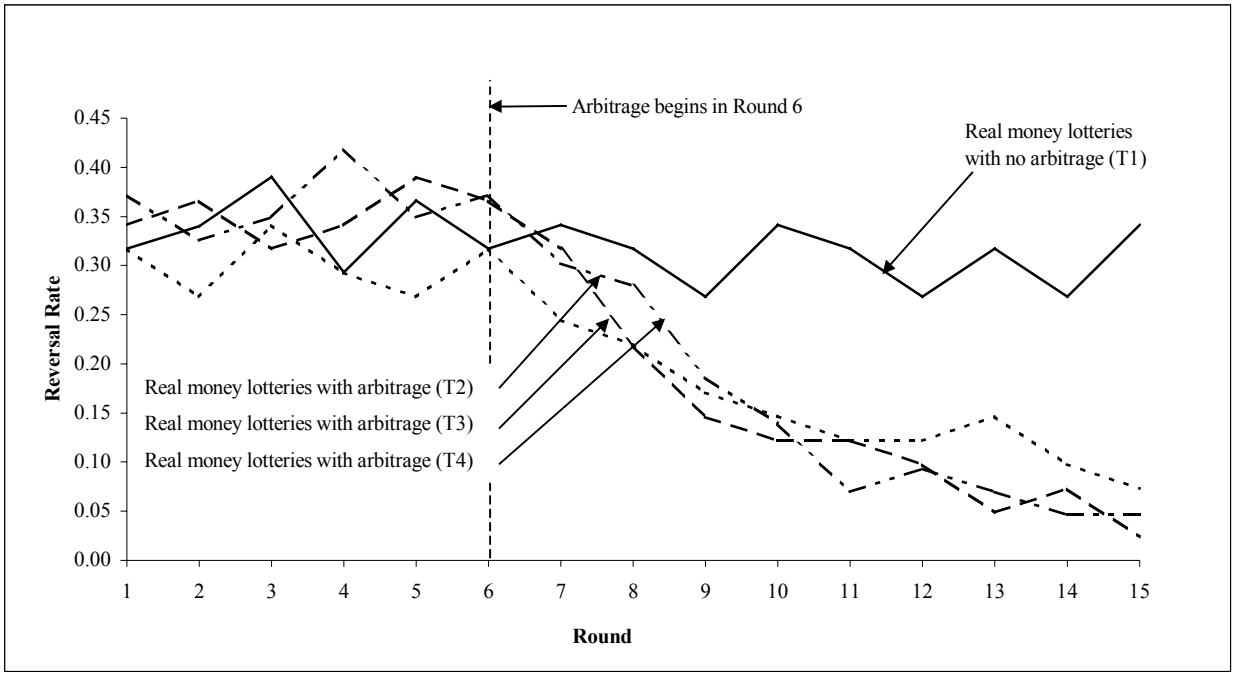


Figure 3 – Preference reversal rates in the nonmarket setting

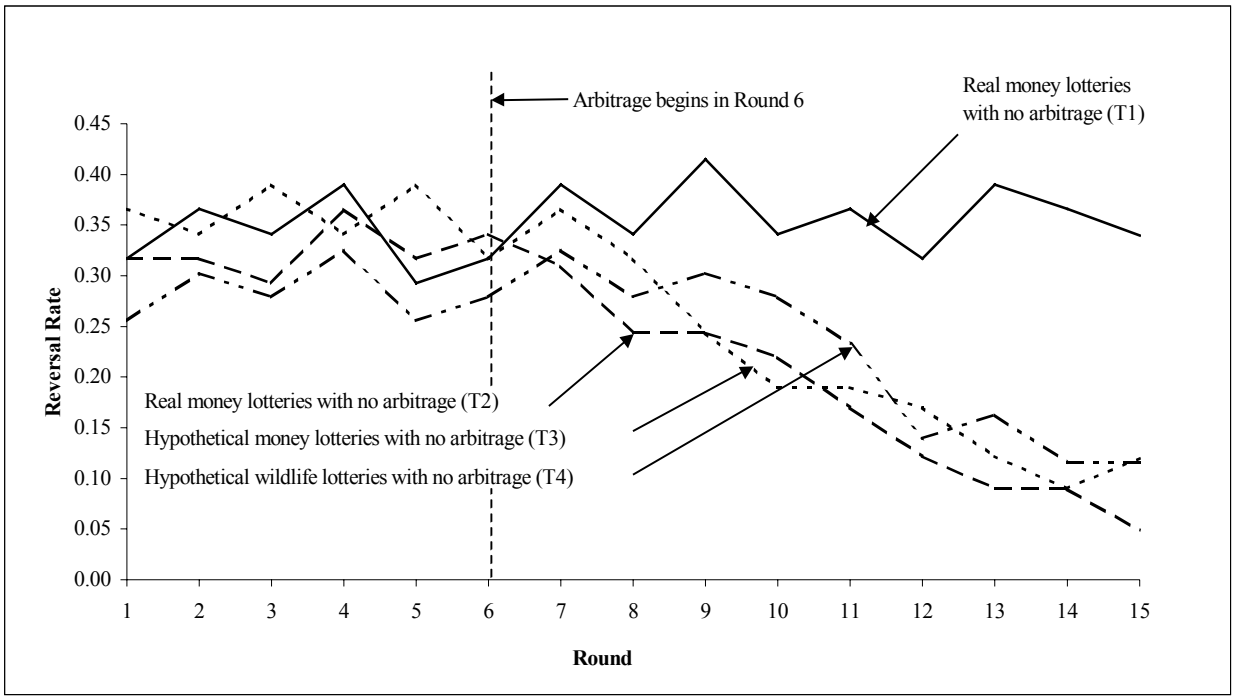
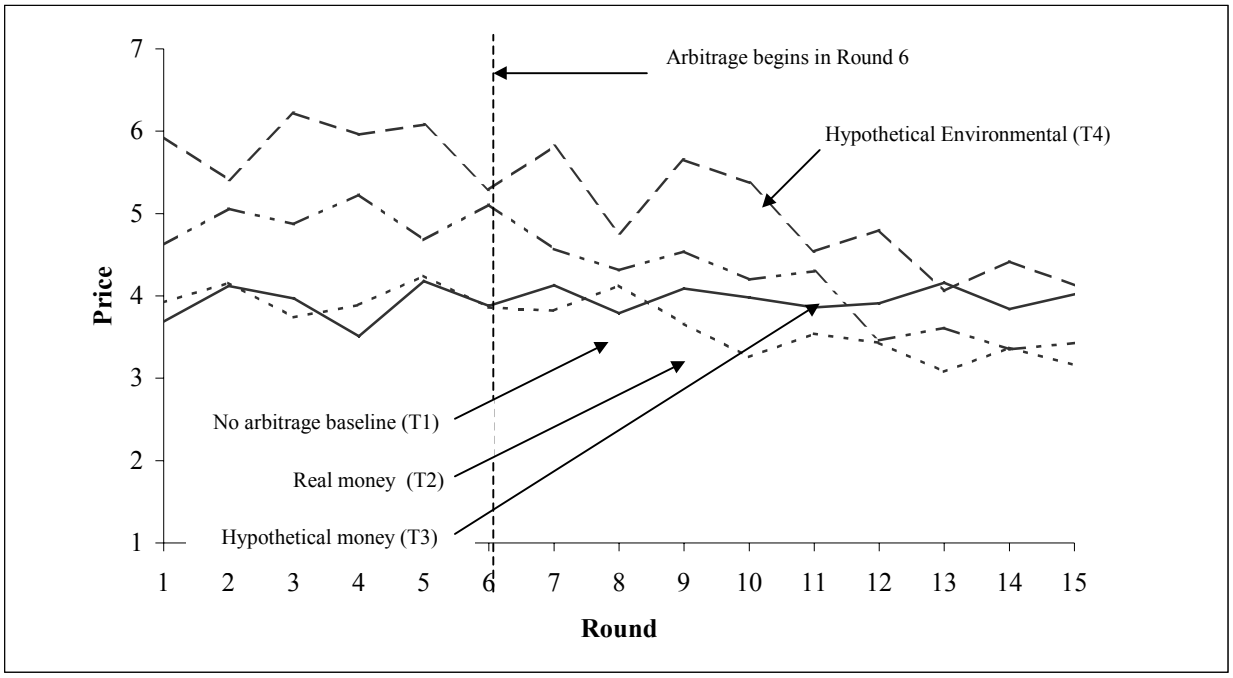


Figure 4 – Mean values for high-risk lotteries: Real versus hypothetical



Comments by Fred Kuchler (ERS) on

"Valuing Pathogenic Risk: Methods, Skill, & Rationality"

(by Jason Shogren, Tommy Stamland, Todd Cherry, and Thomas Crocker)

I'm very happy to be able to comment on the paper by Shogren and others. The paper is very provocative. In a few pages, it sweeps away the most important developments in estimating value of statistical life (VSL), the values we Federal bureaucrats have used routinely for valuing reductions in fatal risks. Shogren et al. (henceforth denoted Shogren) argue that the potential for bias in values we have been using is enormous. The likely direction of bias is that the values we have used are grossly inflated. By implication, that means that the policy guidance economists have offered on health and safety issues for at least the last 17 years has been misleading from a welfare or efficiency perspective.[1] That is, if he is right, we have sometimes said net benefits of proposed regulations are positive when they are decidedly negative.

I would like to confine my comments to practical issues of regulatory cost-benefit analysis rather than theory, but the two are not totally divorced. My comments will be structured as answers to three questions.

1. Does the proposed explanation of the relation between behavior toward risk and VSL make more sense than the explanation we rely on now?
2. Does the proposed explanation lead to something that we can estimate or is it simply a good theory?
3. If we can make this estimate, what will happen if we adopt Shogren's ideas in regulatory cost benefit analyses?

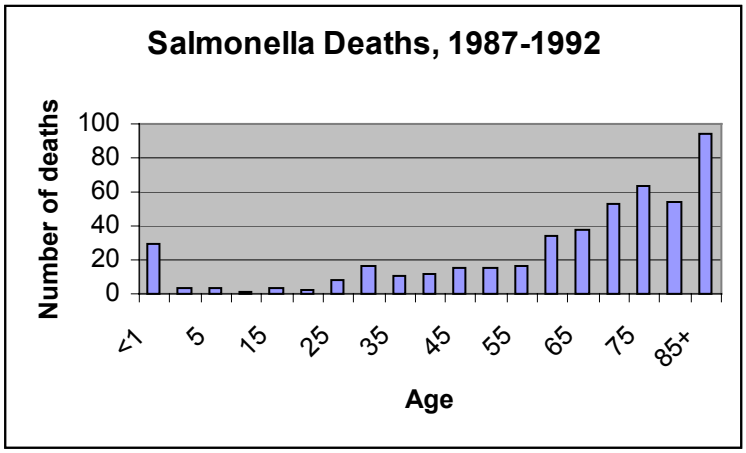
Answering the first question is easy. Our current explanation of behavior and prices doesn't hold up, especially for valuing reductions in foodborne risks. The paper by Shogren is a very different approach and is internally consistent.

Almost every agency involved in health and safety regulations either uses the $5 million value Viscusi (Viscusi, 1993) recommended or did roughly the same exercise he did to come up with a value of statistical lives. Viscusi arrayed the empirical estimates of VSL and put them on a common footing regarding assumptions. Then, he looked for a measure of central tendency. Most of these studies were wage-risk studies. EPA did an exercise similar in spirit to Viscusi's and came up with $4.8 million.

[1] Viscusi (1998) describes the transition in regulatory cost-benefit analyses from cost-of-illness to willingness-to-pay measures as occurring in 1983. The issue was a hazard communication regulation proposed by U.S. Occupational Safety and Health Administration. Initially, the regulation failed a cost-benefit test. But when benefits were valued using willingness-to-pay estimates, net benefits were positive, and the regulation was approved.

The estimates that are driven by results from wage-risk studies are very likely inappropriate ways to value foodborne risks. Principally, the people who are really at risk from the foods they eat are different and are likely to have different risk preferences than the people who make job choices based on wages and risks. Wage-risk studies reflect mostly preferences of middle-aged men in robust good health. That is, they are working and not home sick. Foodborne risks are primarily borne by the very young, the very old, and the immune compromised. The people who die by getting run over by a truck at work are not the same as those who die from foodborne illness.

Just to underline this point, I prepared a histogram of deaths in the United States from *Salmonella*. The histogram arrays deaths by age at death. These are deaths for which *Salmonella* was listed as the primary cause of death on death certificates. The 1987-92 data came from the National Center for Health Statistics (more recent data are not yet available). Although it is not shown on the histogram, the highest bars at the oldest ages are almost entirely women. At age 40, there are relatively few deaths.



So, transferring VSL estimates from wage-risk studies amounts to saying that middle-aged men's preferences reflect the way we value lives of children and elderly women. Viscusi, Magat, and Huber (1987) have studied values placed on reducing risks to children. They found much higher values for kids than adults. Cropper, Aydede, and Portney (1994) have studied values placed on reducing risks to the elderly. They found lower values for the elderly than for adults.

In effect, it makes little sense to think that one VSL will fit all at-risk populations and all risks (Golan and Kuchler, 1999).

Shogren has taken an entirely different approach. Instead of trying to transfer risk-dollar estimates from one set of individuals and risks to another set of individuals and another risk, he argues for starting with the individual and the full complement of risks each faces. Shogren argues it is both differences in risk preferences and differences in skill in mitigating health hazards that matters for value-of-life estimates.

Let's talk briefly about the bias in current estimates that Shogren identified. Current methods calculate VSL by dividing the marginal worker's wage differential by the statistical risk

differential. The latter is an average. The former is the highest wage differential among all workers. It is the worker who demands the highest compensation for his risk in the job. It is probably the worker who is least able to manage risk and the worker who is most concerned with risk. So, if workers differ in skill in managing risk and differ in risk tolerance, then VSL estimates overestimate benefits of risk reduction. Shogren's illustrative calculation suggests a factor of 5.

Reducing VSL estimates by a factor of 5 would have a clear impact on Federal cost-benefit analyses. Virtually none would pass a benefit-cost test.

Shogren shows in a formal way that we need individual value-of-life estimates for each risk. And he shows how to derive, in theory, those values. So, whether we should or shouldn't follow his suggestion, we have to pay attention to it.

My answer to the second question, raising practical estimation questions, is less certain. Shogren's analysis comes down to the following equation.

$$Vol_t = \frac{c_{it}}{\left(\rho_{it}^* - \underline{\rho_{it}}\right) x_i^*}$$

Here, he calculates value of life as an individual's willingness to pay to avoid risk of death. He divides individuals into classes, t. Each class is defined by ability to manage risk and risk tolerance. The denominator has two terms. The parenthetical is the difference in risk per unit of consumption between what the individual chooses and the lowest that is physically possible. This is like the risk of *E. coli* O157:H7 infection per hamburger, depending on how well you cook and clean. Microbiologists tell us that if we cook hamburgers to an internal temperature of 160 degrees and we use lots of chlorine bleach to reduce cross-contamination in the kitchen, we can drive the risk of infection to zero. Clearly, these averting behaviors are choices. The risk per unit is then multiplied by the number of units of risk, or hamburgers consumed, some proportion of which harbor *E. coli.*

Empirically getting at the denominator will be difficult, but is not necessarily impossible. Suppose that the epidemiologists and physicians come up with dose-response functions, relating exposure to pathogens to disease, and can do so for different types of people, distinguishing likelihood of infection by type of person (good health, elderly, child, able to control cross-contamination in the kitchen). Food consumption surveys might also tell us about x_i^*.

The impossible part to measure is the numerator. This is simply defined as the opportunity cost of activities that reduce risk. Some economists argue that opportunity cost is not something that an external observer can measure. I have copied a paragraph from James Buchanan's book, Cost and Choice (1969). He argues that opportunity cost is inherently unknowable.

> You face a choice. You must now decide whether to read this Preface, to read something else, to think silent thoughts, or perhaps to write a bit for yourself. The value that you place on the most attractive of these several alternatives is the cost

> that you must pay if you choose to read this Preface now. This value is and must remain wholly speculative; it represents what you now think the other opportunity might offer. Once you have chosen to read this Preface, any chance of realizing the alternative and, hence, measuring its value, has vanished forever. Only at the moment or instant of choice is cost able to modify behavior. (p. vii)

That is, opportunity cost is whatever a person thinks he is giving up by choosing a particular course of action. The result of a choice is one course that precludes all others. Thus, the other cannot exist. It was known to the person who did the choosing, but vanishes without a trace after the choice is made. Until we have a way of peering into the heads of people as they are making choices, the opportunity cost of their actions is necessarily unobservable. We certainly cannot directly estimate the values Shogren recommends.

Question 3—if we really could estimate individual values of life, that would raise some difficult ethical questions for economics. Suppose that we could accurately measure opportunity cost. Then our trouble would really start. We would have different values for different people. Some of the variation would be systematic. For instance, the opportunity cost rich people face would likely be much greater than that faced by poorer people, that is those with fewer opportunities. Chances are we would have relatively large values for the rich and small values for the poor.

The policy guidance offered by cost-benefit analyses would then depend on who was at risk. We would see relatively large benefits from putting in stop signs in rich neighborhoods and relatively small benefits in poor neighborhoods. This is a straightforward aspect of demand analysis--quantity demanded depends on relative prices and income. In our case, willingness to pay depends a lot on ability to pay. Some will say, "of course willingness to pay depends on ability to pay--it is worth more to the rich to be safe." Others will find this troubling, and will be really disturbed by policy guidance that gives greater attention to small risks in rich communities than to large risks in poor communities. I think economists would be better off recognizing this minefield before we walk into it.

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Rapporteur's Notes for

Valuing Risk Reductions Using Different Valuation Methods

Rapporteur: Jean C. Buzby

As we have seen throughout this conference, economists have developed several measurement techniques for valuing risk and nonmarket goods. Our breakout session discussed the general advantages and disadvantages of six techniques and their appropriateness for estimating the monetary benefits of policies or actions that reduce the risks of unsafe food. Benefit estimates from these techniques can be used as input in cost-benefit analyses for policies that reduce food safety risks.

In particular, we discussed six measurement techniques: cost-of-illness, contingent valuation, experimental auction markets, hedonic pricing, cost-effectiveness analysis, and health-health analysis techniques. The first four techniques provide estimates that are measured in dollar values, three of which (contingent valuation, experimental auction markets, and hedonic pricing) provide willingness-to-pay (WTP) estimates. Policymakers may feel more comfortable using benefit estimates in dollars instead of estimates of the number of lives lost or saved computed from techniques such as health-health analysis, but this is not always the case.

Cost-of-Illness Analysis

There was little enthusiasm in our group for the cost-of-illness (COI) method. The COI method 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 (Kuchler and Golan, 1999). For example, the annual costs of a specific health risk such as *Salmonella* in food can be estimated by adding together all of the estimated annual medical costs and productivity losses and other illness-specific costs, such as special education and residential-care costs, for all patients stricken with foodborne salmonellosis in a given year. Examples of COI studies for food safety include Buzby *et al.* (1996) for bacterial foodborne illness and Frenzen *et al.* (1999) for foodborne salmonellosis.

One advantage of the COI method is that it measures the economic impacts of a particular illness, and this accounting is useful to policymakers interested in the economic flows of public health regulations. COI is also meaningful to the health industry as it is interested in data associated with particular illnesses (*e.g.*, the number of days of hospitalization for an average salmonellosis patient). One disadvantage is that the COI analysis may not reveal the severity of illness. The analysis may also be complicated by our modern system of payment for health care where prices for medical care vary depending on how they are paid. Co-payments by ill individuals tend to be lower than total costs billed to insurance companies. This suggests that insurance co-payments are a far cry from the WTP notion and so the rationale that COI is a lower bound disappears (see appendix in Kuchler and Golan, 1999).

Contingent Valuation

The second technique that we discussed was contingent valuation (CV). CV surveys or interviews elicit consumers' WTP for a particular nonmarket good "contingent" on a given hypothetical scenario. There have been over 1,600 publications on contingent valuation and CV surveys have been increasingly used to measure consumers' WTP for food safety risk reductions. For example, CV surveys have elicited consumers' WTP for reduced risk from toxins in shellfish (Lin and Milon, 1995), nitrates in drinking water (Crutchfield *et al*., 1997), *Salmonella* in chicken and eggs (Henson, 1996), and pesticide residues in food (Buzby *et al.,* 1995 and 1998).

One advantage of the CV method is that it is grounded in the theory of welfare economics (people will pay more if they get greater utility or welfare). Another strength is that a hypothetical scenario can be built for any market of interest.

On the other hand, V.K. Smith discussed how CV studies may fail to be successful in eliciting true WTP in dealing with conditional probabilities, a concept that many consumers find difficult to understand. This concept is very relevant to valuing the benefits of a food safety risk reduction. For example, in describing a risk reduction for human illness from *Salmonella* in eggs, the CV survey must make it clear to respondents that there is both the probability of having an egg contaminated with *Salmonella* serotype *Enteritidis* (SE) and the probability of getting sick given that the egg was contaminated with SE.

Because of the hypothetical nature of the CV technique and because no money is exchanged, there are various biases that may be associated with CV estimates (see Mitchell and Carson, 1989). The hypothetical scenario in the CV surveys may not come across as relevant or realistic. And, because health and safety are normal goods, predicted changes in WTP values can be explained by changes in income, ceteris paribus.

Another weakness is that it may be difficult to ascertain the validity and implications of the results. Despite the detailed guidance for implementation of the CV technique provided by the 1990 National Oceanic and Atmospheric Association (NOAA) Blue Ribbon Panel, there is no standard which should be used to judge whether results are believable. We can however be more confident with the results if the prescribed sequence of events such as focus groups, pretesting, and so forth is followed. Of the techniques that we discussed, CV has the most detailed guidance for implementation because of this NOAA panel and because of the relatively extensive use of this technique. In general, researchers want and will use guidelines for applying a valuation technique if the guidelines are from a reputable source or consensus.

Conjoint Analysis

At this point, we went off on a brief tangent and discussed conjoint analysis which is another hypothetical market tool. Essentially, in the CV technique, the attributes are embedded whereas in conjoint analysis, the attributes are distilled. Our group generally felt that this technique should be explored further. Two advantages are that there is more design control with this

technique and that it is cheaper in the sense that the researcher can ask more questions for a given budget. One downside is that the resulting observations are dependent.

Experimental Market Techniques

The third technique that we discussed was the experimental market technique (or "experimental auction technique"), where individual choices made in constructed market situations reveal preferences for a good that usually cannot be directly purchased in the market. Food safety is a non-market good primarily because of high information costs and/or information asymmetry. Contingent valuation of food safety overcomes the information problem by providing objective assessments of health risk. Valuation of food safety in experimental markets attempts to go one step further – eliminating the informational deficiency and placing the good in something akin to a market situation where money actually changes hands. Examples of experimental market studies for food safety issues include studies on reductions in pesticide risk (Roosen *et al.,* 1997), bovine growth hormone in milk (Fox, 1995), and a series of studies on irradiated pork by Shogren, Fox, and others.

Valuation in the lab offers some advantages in valuing food safety risk reductions. First, although the choice situation is artificially created, the choices are real not hypothetical and force respondents to consider their budget constraints. Second, revelation of truthful values is encouraged through the requirement that the winner of the auction eats one of the "risky" food products being valued and through the use of an incentive-compatible auction mechanism. In one common auction mechanism, the Vickrey second-price auction, the person with the highest bid buys the good at the second highest price. This is incentive compatible because the bidders' best strategy is to bid their true WTP value. Third, Shogren states in his conference paper that because of the laboratory nature of this technique, researchers can replicate or repeat the experiments to isolate, control for, and understand the ramifications of a wide range of different auction or market settings. Fourth, Kuchler and Golan (1999) point out that as with the CV technique, the experimental auction technique incorporates the recognition that individual preferences are unique and that individual demands for risk reduction vary. Despite the advantages of this technique, according to Shogren, the results from experimental markets do not always fare better than results from contingent valuation studies, and there is clearly a great deal more to learn.

Hedonic Price Techniques

The fourth technique that we discussed was hedonic pricing. This technique estimates the value of each attribute of a good or service, including health-influencing attributes. The dominant application calculates compensating wage differentials or a "risk premium" revealed in labor markets through the higher wages employers must offer to induce workers to take riskier jobs. Some hedonic studies have focused on nutrition and other food-related issues such as fat content in milk, fiber in cereal, and organic versus non-organic. [1] Shogren mentioned one study that he

[1] Other studies have covered goods and issues such as seat belts, property values, smoke detectors, and highway speed.

did on the marbling, coloring, and size of pork chops.

In his conference paper, Shogren pointed out that some of the disadvantages of hedonic wage-risk studies include the presumption that workers know all the risks in the job and that they can change jobs costlessly. Another common criticism is that these studies focus on those who have a job and underrepresent other segments of our population such as seniors and children. One challenge is to fully understand the market and its consumers, with only price and quantity data.

Cost-Effectiveness Analysis

The fifth technique that we discussed was cost-effectiveness analysis, which is essentially a comparison of costs with the number of physical benefits. The ratio of dollar costs to physical benefits is the cost per physical benefit, and the program with the lowest cost per benefit is the most cost-effective (Kuchler and Golan, 2000). One advantage of this technique is that it uses real cost and outcome data. There are numerous Centers for Disease Control and Prevention (CDC) studies and studies by other health professionals that use this technique. However, to date, it has not been applied to food safety issues.

The cost-effectiveness method is becoming closer to the traditional cost-benefit analysis because of the trend toward monetization of quality-adjusted life-years (QALY) as we have seen in Josephine Mauskopf's presentation. Also, note that it is a short step from choosing a number for a QALY to having to choose a value of a statistical life for a study. On the downside, unless we measure the benefits in QALY's, the questions that can be answered with this method are fairly limited, and unless we monetize health benefits, the net benefits cannot be determined. Instead, only projects with identical outcomes can be ranked by their cost per physical benefit. This limitation may be fine if the research stays within one narrowly defined health outcome.

Health-Health Analysis

The sixth technique that we discussed was health-health analysis. In essence, 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 health and safety programs. One advantage of this technique is that it uses real markets and real tradeoffs. The premise is that if people pay for a policy that reduces a particular health or safety risk, their disposable income goes down, in effect reducing the amount that they can spend to protect themselves in other ways. This means that there could be an increase or decrease in their overall level of safety. One food safety example is the study by Kuchler *et al.* (1999) on oysters.

In cases where agencies are really averse to assigning dollars to a life, this is an alternate route that still maintains the spirit of cost-benefit analysis in that a net benefits figure can be calculated. It also provides some insight into income-risk tradeoffs. However, this approach acknowledges the general equilibrium nature of tradeoffs but then focuses on partial equilibrium tradeoffs.

Where Do We Go From Here?

The selection of a valuation technique for a particular research project depends largely on the goals of the project. And even when a particular valuation technique is selected, researchers will tailor the approach as necessary for the project. As previously mentioned, the 1989 NOAA panel provided guidelines and recommendations for contingent valuation. However, some of the other techniques are more broadly defined than contingent valuation and do not have similar guidelines.

The consensus of the breakout group was that we would like to see a panel discuss issues and come up with guidelines or recommendations about the different methodologies and about how to interpret the results. These guidelines could also cover the scope, role, and implementation of benefit-cost analysis. Perhaps a second panel could look at specific issues related to food safety and other similar health outcomes. We would like to see guidance for food safety but in a way that makes sense such as by identifying a class of risks. However, as a precursor to any panel, there needs to be a great effort made in organizing what is known about the methodologies to provide background for the panel to make their guidelines or recommendations. Also, the panel would benefit from a list of issues that need to be addressed.

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SESSION IV

VALUING RISK REDUCTIONS FOR DIFFERENT HAZARDS

Benefits Transfer and the Value of Food Safety

Alan Krupnick
Resources for the Future

Introduction

We take it as given that cost-benefit analysis (CBA) is a useful tool for choosing among alternative courses of action according to the criterion of social efficiency. It does this by providing a single, money metric that under certain assumptions indexes social welfare. Other things being the same, policies that would increase welfare as indicated by the metric would be preferred to policies that would reduce welfare, and policies that would increase welfare more would be preferred to policies that would increase welfare less.

The application of CBA in the food safety area is challenging for many reasons. Of most importance here, is the fact that benefits of food safety regulations or other interventions are primarily registered in improved health status. One can perform useful policy analyses by comparing the costs of various interventions per unit health improvements across the set of available interventions (a cost-effectiveness analysis), but to be able to aggregate across various types of health effects, and to be able to say something normative about the regulations or interventions being contemplated, requires estimating health benefits, i.e., placing monetary values on these health improvements.

But to successfully apply CBA in the food safety area means valuing an enormous range of possible diseases related to food safety – a task far beyond what the literature on health valuation in a food safety context can currently support. There are only three solutions to this problem. We can wait until the valuation literature catches up – not a very satisfying option; we can "retreat to defensible borders," in the sense of using medical cost information as a placeholder and lower bound for the more appropriate "willingness to pay" measures of value; or we can use techniques to modify the existing, non-food safety valuation literature to make it more appropriate for use in a food safety context. This last option is called benefits transfer.

In fact, there is a reasonably robust literature for valuing the respiratory effects of air pollution reductions, containing a significant and reasonably accepted number of studies valuing respiratory-related symptom-days and chronic respiratory disease cases. There is also a very large number of studies yielding values of statistical life (VSL) that, while not defining a policy context appropriate to deaths associated with air pollution (a discussion we will take up below), are typically used in CBA studies associated with air pollution regulation performed by the government and others. The question for this paper is: Should and can this literature be used to

help value food safety outcomes? A supplementary question is: What research needs are suggested by this analysis?

What is Benefits Transfer?

To be more formal about it, benefits transfer is the application of valuation results from a study performed for one policy context to another policy context (see Desvousges, et al., 1992, for a complete discussion in the context of recreation demand; see AERE, 1992, for many papers on this topic).

There are two types of results that can be used for benefits transfer—unit values and valuation functions. The first is more easily and more widely used. It involves the application of a value, say in terms of the willingness to pay (WTP) for a reduction in a health "unit," such as a symptom-day of a particular kind, being applied, after any needed adjustments, to epidemiological estimates of symptom-day reductions as a result of a food safety intervention.

The second approach allows the analyst to adjust the values for the policy context at the cost of placing a greater burden on the food safety analyst. There is an *ad hoc* approach to do this and one relying on statistical results. The *ad hoc* approach involves developing from information in the literature or the analysts' own judgment, various factors to adjust the WTP estimates from the study context. The statistical approach involves, first, finding an original study where statistical analyses explain variation in the WTP for, in this case, avoiding a symptom-day using a set of explanatory variables, such as severity of the symptom, income, sex, health status, etc. The outcome is a regression equation describing the contribution of each factor to WTP. The food safety analyst then takes the resulting regression equation and substitutes in the values for the factors in the regression that are appropriate to the food safety case. For example, suppose the regression shows that every year of life over age 40 results in a $1 reduction in the WTP to avoid a symptom-day. If the age of those affected by a food safety intervention averages 75 years, then this factor would drop WTP estimated from the other factors by $35.

Why Use Benefits Transfer?

Of course, if simple adjustments like those for age and income were all it took to perform a credible benefit transfer, they would be used much more frequently and with much less controversy. After all, a benefits transfer is far cheaper than performing an original research study. For instance, the cost of an in-person contingent valuation survey is at least $100 per completed survey, with a sample of about 1,000 fairly standard. Add to this the cost of developing the survey and analyzing it, and such a study, on one or at most a few health endpoints, could cost over $200,000. Moreover, a benefits transfer from an established set of unit values or functions carries with it instant professional and institutional legitimacy. The unit values appearing in EPA's recent study of the *Costs and Benefits of the Clean Air Act Amendments of 1990* (USEPA, 1999), for instance, have been reviewed by a special panel of economists and undergone review both inside and outside the Agency.

Unfortunately, the needed adjustments are not simple. The food safety context differs markedly from the air pollution context in several areas, some of which have so far not been very well addressed by researchers.

Available Unit Values

Above, we noted that the health unit values for the air pollution context are drawn from the most robust literature. Table 1 provides a small sample of the midpoint values typically used by practitioners of health benefits analyses in the air quality area, as well as ranges of these values. We picked the unit values for health endpoints chosen by four major studies or models in the United States, Canada, and Europe, ordered from highest to lowest based on the first of these studies--the U.S. study on the Costs and Benefits of the 1990 Clean Air Act Amendments (USEPA, 1999) --and put them in common currency and constant dollars.

The willingness to pay for reducing risks of mortality and chronic morbidity is expressed, for convenience, in terms of the value of a statistical life (VSL) and the value of a statistical case of chronic disease (VSC).[1] The table shows quite close agreement on the size of the best or midpoint VSL's and VSC's. The differences that do exist may be explained partly by currency conversions and partly by researchers' not always adjusting such values over time for inflation. Also, the rank ordering of values is found to be very similar across the studies, although not every study considers the same set of health endpoints. The low VSL's for the Tracking and Analysis Framework (TAF) (Bloyd, et al., 1996, which came from Lee et al., 1995) and the Air Quality Valuation Model (AQVM) (Stratus Consulting, 1999) result from adjustments to the VSL for the older age of those affected by air pollution relative to those included in the studies underlying the VSL estimates. ExternE (ExternE, 1999, originally from ExternE, 1996) makes a similar adjustment by converting the VSL to a value of a life-year for subsequent analysis. In other analyses, EPA (USEPA, 1999) and TAF have done the same thing.[2] These efforts have yielded values ranging from $50,000 to $300,000 per life year.[3]

In our judgment, this close agreement among the studies is the result of several factors, including replicability of findings in original studies in different locations (i.e., independent choices made

[1] It is important to note that these terms are merely a shorthand for the WTP for a given risk reduction divided by that risk reduction. This relationship is convenient because the VSL's or VSC's can be multiplied by estimates of the "lives saved" or "chronic cases saved" to obtain benefits.

[2] Other adjustments to VSL's have been made (or suggested) for latency (ExternE, 1999), for health status (basically the "harvesting" issue) (UKDH, 1999) and for a range of attributes, such as dread and voluntariness (USEPA, 2000).

[3] The ranges around these estimates are all somewhat different, seemingly without pattern. This result perhaps could be expected since there is no treatment of uncertainty that is universally accepted. The EPA mortality results are based on one standard deviation from the distribution (the Weibull) that best fits the mean WTP estimates from 26 studies. The Canada results are based on a representation of uncertainty as a three-point probability distribution, which includes expert judgment. The TAF distributions are Monte Carlo-based, assuming, unless otherwise indicated by the original studies, that errors about mean estimates are normally distributed, with variances given in the concentration-response and valuation studies relied upon for the underlying estimates. Bounds are defined as 5th and 95th percentile. Error bounds in the latest ExternE report (1999) are established as one-half (low) and twice (high) the geometric mean.

by different research teams), and the consensus reached by research teams on a common pool of studies, results, and interpretations. We believe that the social cost of electricity studies in the United States and the ExternE effort in Europe have something to do with this commonality. In addition, the Canadian studies have been informed by the AQVM model developed by Hagler Bailly (now Stratus Consulting) and others who have been active participants in the U.S. debate over the social cost of electricity as well (Hagler Bailly, 1995). Many U.S. studies pre-date and presage these efforts.

It is worth noting that the endpoints being valued are not all comparable to one another. The unit values for mortality risk, chronic lung disease risk, and acute symptoms all are derived from a willingness-to-pay approach that may be thought of as capturing, however imperfectly, the full value to the individual of reducing the risk or the symptom. The other values are only partial, mainly relying on cost of illness techniques. They are meant to capture the more severe manifestations of either acute events or chronic states and may, without proper adjustments, double-count WTP benefits or provide significant underestimates of the WTP to reduce such effects. Indeed, it is fairly common practice to adjust such cost of illness (COI) estimates by a factor to bring them up to a WTP estimate, so as to eliminate such underestimation. AQVM, for instance, recommends using a factor of 2-3 to make this adjustment. The evidentiary basis for the generality of this adjustment across endpoints is weak.

Example of Ad Hoc Adjustment of Unit Values

A recent attempt to adjust the VSL used by EPA in its cost-benefit analyses for the context of death from cancer (Revesz, 1999) is illustrative of an ad hoc approach to benefits transfer and the critique it received by the EPA's own Science Advisory Board is illustrative of its problems.

Revesz sought to develop a VSL for cancer for use in addressing alternative policies to control emissions of carcinogenic pollutants. He proposed to adjust the standard VSL used by EPA ($4.8 million in 1996 dollars, based on hedonic wage studies) for involuntariness of exposure, the lack of controllability of that exposure, and for the dread cancer causes in those facing it. Relying on some studies in the literature, Revesz suggested that the first two factors would lead to a doubling of the VSL, while the third would lead to another doubling.

The EPS's Science Advisory Board (2000) carefully reviewed the paper and concluded that the literature relied upon was not robust enough to justify adjusting the standard VSL.

Elements of the Policy Context

It is helpful to develop a taxonomy of the elements of the policy context. If a function were available that related each of these elements to WTP, then one could do a confident benefits transfer. Even though such a function is not available, we can use the taxonomy to compare the study context to the policy context to make judgments about how credible a benefits transfer would be.

There is no universally accepted list of all the elements of a policy context one needs to address for a conceptually complete benefits transfer. Table 2 gives one such list, listing four elements and various features for each element. This list does not attempt to distinguish what elements or

features *should* affect values, only those that have been shown or speculated to affect values. The nature of the risk refers to whether the risk refers to death or morbidity (either chronic or acute), the features of morbidity that might be relevant, and the qualities of both mortality and morbidity that might be relevant, such as dread and controllability (Slovic, 1987). While it might seem strange that morbidity and mortality are valued separately, in fact the health valuation literature is bifurcated in this way, probably more due to the difficulties of obtaining values on this more complex combined commodity than any other reason.

Referring back to table 2, the risk change element has three features. One is baseline risk, which refers to the risk of death or morbidity faced by the individual in the absence of a policy intervention. The timing refers to whether the intervention will have an immediate effect on risk or a latent effect. Size is the size of the risk change.

The only other element that needs clarification is "Other." Whether the good is provided privately, through markets or through an individual's actions, or publicly, say through the government to an entire class of individuals, may affect valuations directly. In addition, particularly in the public good setting, individuals may hold values for health improvements to other individuals, i.e., they may be altruistic. Whether altruistic WTP should be counted in addition to individual WTP depends on the type of altruism individuals hold. Paternalistic altruism is defined as one person's caring about another's health, to the exclusion of caring about other facets of the person's life, facets that might be affected by their wealth. In this case, there is reasonable agreement that the altruistic portion of WTP can be counted. If the altruism is non-paternalistic, however, in the sense that one individual cares about another's utility, then the cost of the policy to the other person should enter into the altruistic person's WTP. In this case, altruism would not be counted.

Avoidance behavior means the ability of at-risk individuals to reduce their health risks. A health intervention may reduce the need for avoidance behavior taken by an individual, without necessarily changing health risks. While this benefit is not strictly speaking a health benefit, it should be counted in a benefits analysis, and individuals would count such improvements as a benefit of an intervention. Looked at in another way, individuals may not be willing to pay much for an intervention that would reduce their chance of a headache where taking an aspirin (the averting behavior) costs 2 cents and it works immediately and without side effects. As a food safety example, WTP to reduce the risk of health effects from an outbreak of giardiasis would be limited by the cost of avoiding the contaminated water. Where avoidance behavior options are limited, this factor would not have to (or need to) be taken into account.

Finally, some researchers have speculated that the willingness to pay to reduce risks may be affected by the agent causing the health effect, e.g., that the WTP to reduce risks of a named disease (e.g., listeriosis) may be different than the WTP for avoiding a disease solely described by its symptoms. This effect may overlap with the disease quality feature discussed above.

Mortality Risk Valuation and Benefits Transfer

Table 3 provides the elements of the study context for the main literature used to value mortality risk reductions in governmental environmental cost-benefit analyses and compares them to the elements for the policy context for air pollution and health.

We have identified five approaches to estimating preferences for reducing mortality risks and expressing these preferences in monetary terms: the human capital approach, various revealed preference approaches (most importantly the hedonic labor market approach, but also the consumer products approach), and stated preference techniques that address health and those that do not.

The human capital approach is not a WTP measure. It seeks to estimate the productivity lost when a person dies prematurely. This approach is utilitized as part of the cost-of-illness methodology employed by ERS, for instance (Buzby et al., 1996). Without special adjustments, it ignores losses to society of nonworkers.

The hedonic labor market studies statistically relate wage differentials to mortality or morbidity risk differences across occupations and industrial/commercial sectors, under the theory that in competitive labor markets, workers in risky jobs should receive wage premiums equal to the value they place on avoiding increased mortality or morbidity risks. One study asks workers their perception of the death risks they face in order to address the issue of whether their behavior would be consistent with perceived risks rather than actual risks and that these two types of risks might diverge. These studies are numerous and form the foundation for most VSL estimates.

The stated preference approaches, of which contingent valuation and conjoint analysis are the two most prominent, are survey approaches that set up choice situations. These methods ask individuals to chose among various hypothetical choices. For instance, they ask whether individuals are willing to pay some amount, or to vote yes on a referendum, or to prefer one package of attributes over another, in order to acquire reductions in mortality risk. The ability of conjoint analysis to recover preferences is a matter of debate. Also, both of these approaches may suffer from a variety of their own biases, and their results have been shown to be very sensitive to question wording and ordering. They are capable of being molded to whatever population and context are appropriate, however. And respondents can be tested for their cognition and understanding of the issues being examined in the survey (see Hammitt (2000) for a detailed discussion of the CV-mortality risk valuation literature). Some of the best known CV studies for mortality risks (Jones-Lee et al., 1985; Hammitt and Graham, 1999) look at traffic fatalities.

The comparison between the study and air pollution policy context reveals that there is already a benefits transfer underlying valuation of mortality in the air pollution context and that there is a serious disconnect between the study context and this policy context. The main body of literature is the hedonic labor market studies and contingent valuation studies based on accidental fatality risk in mainly a transportation context. This literature focuses primarily on prime age, healthy individuals (mostly men) and involves “private” labor market or transportation choices, while the air pollution context involves a very different at-risk population and affects more the nature of a public good. The sizes of the risk reductions match fairly well, although some air pollutants may have latent effects on health, which the literature has not captured.

Is a benefits transfer from this literature to the food safety context any more credible than its use in an air pollution context? To answer this question, we first must define the "food safety context" For the purpose of this paper, we focus simply on the top four foodborne diseases

identified by the ERS/USDA/CDC: salmonellosis, campylobacteriosis, *Escherichia coli* diseases, and listeriosis. Box 1 provides summarizes key features of these diseases.

Turning to the last column of table 3 for food safety, we find that the diseases have a number of characteristics that are distinct from one another, making them difficult to classify according to table 2's taxonomy. Nevertheless, they do have in common that the unconditional mortality risks are very small, on the order of 1 in 100,000 or lower. And, they have conditional death risks that are considerably larger than those in the study context—anywhere from 1 in 1,000 to 1 in 5 annually. The latter is for listeriosis—a disease hard to contract but remarkably easy to die from. As estimated VSL's appear to be very sensitive to the size of the risk change (larger for smaller risk changes) and communicating conditional risk continues to be problematic in the literature, these differences are serious.

In addition, as in the air pollution context, but unlike the study context, effects are concentrated on the ill. Somewhat unique for the food safety context is that children, particularly very young children, are a significant fraction of the population at risk and that averting behavior after an outbreak is announced is a significant component of the behavioral response to risk. The upshot of this comparison is that benefits transfers for mortality valuation are probably more problematic for the food safety context than for the air pollution context.

Theory and Empirical Evidence for VSL

How important are the distinctions being made in the above section? If the differences in context do not amount to much empirically, perhaps such differences can be ignored. In fact, some differences matter more than others.

Table 4 (based partly on Hammitt, 1999) attempts to summarize both the theoretical and empirical literature to answer this question. Neoclassical welfare economics, in particular the life-cycle utility model, lies at the heart of the theoretical modeling. Its predictions about the effects of various factors on WTP are provided in the first row of the table. WTP should clearly increase with the size of the risk change; indeed, subject to some minor caveats, the life cycle model predicts a proportional relationship. This implies that the VSL would be constant for any risk change. The model also implies that the further in time any risk change begins, the lower WTP should be. The effect on WTP of baseline risk was studied by Pratt and Zeckhauser (1996), who show that those facing higher baseline risks should be willing to pay more for a given risk reduction (the "dead anyway" effect). Higher incomes or wealth should be related to higher WTP. The age effect varies depending on whether the individual can borrow against future earnings. With borrowing, the predicted relationship is an inverted U-shape, peaking, according to these studies, at around 40. Finally, the models do not make a prediction on health status.

These predictions have not always been matched by the model results. Table 4 provides some information on findings of empirical studies and rates the robustness of the results, ranging from "high," which means there is a body of literature in basic agreement, to "low," which means either a very thin literature, and/or a new literature, or a literature in disagreement.

Beginning with responsiveness to risk change, a perfectly responsive finding, where WTP moves proportionally with the size of the change, would imply a constant VSL. Rarely have most studies even

tested for sensitivity of the WTP for different risk changes provided to separate samples (the external scope test), let alone passed them. The recent CV study by Krupnick et al (2000) passes this test but fails the more stringent proportionality test, showing less than proportional responsiveness, and therefore a VSL that is higher for small risk changes. It is worth noting that the VSL's ranged from $1-$3 million (1999 dollars), still far lower than EPA's choice of $6 million, drawn from labor market studies.

The same study (as noted above) is the only one to test for the WTP for future risk reductions in a survey also testing the WTP for contemporaneous reductions. This study found the former—for average futurity of 15 years, and with an average perceived probability of making it to 70 (when the risk reduction would begin) of about 75 percent—to be about 40 percent of the latter.

The empirical studies have all found income effects as expected but have had difficulty separating baseline risk from age, because the two move together. Also, all studies have had very limited participation of older individuals. An exception is Krupnick et al. (2000) which had one-third of their sample over 60 years old (up to 75), finding no statistical difference in VSL across ages until age 70 and above, the latter VSL being lower than that for the 40-year-olds by a fraction similar to that of Jones-Lee at al. (1985) (about 33 percent) but at a much lower initial VSL. Indeed the VSL for those over 70 was only about $650,000 for a 5-in-10,000 annual risk change. Finally, only the Krupnick et al. study explicitly addresses the effect of health status on WTP, finding no effect of health status on WTP, except for those with cancer, who were WTP about 45 percent more to reduce their annual risks by 5 in 10,000 than their counterparts with the same characteristics who did not have cancer.

Summary of Four Foodborne Bacterial Diseases

The largest rate of food poisonings is from *Salmonella*.[1] Its symptoms range from mild abdominal discomfort to dehydration and vomiting and can cause secondary chronic illnesses, such as septicemia, which can lead to death. The most vulnerable populations are the very young (below age 5), the old (over age 70) and the immunocompromised. The incidence rate has been estimated to be between 1.7 percent and 8.3 percent, with 2 percent of cases resulting in hospitalization and death rates around 6 percent of this or about 1 in 10,000 in the population. *Salmonella* contamination occurs in undercooked poultry, raw eggs and beef, and other dairy products, such as ice cream, and even fruits and vegetables. Avoidance options are easily available in some cases, but not in others. Cost-of-illness estimates, which include medical costs and productivity losses (including losses of human capital from premature death), range from $0.60-$3.5 billion annually.

Campylobacter infections occur through the consumption of poultry and pork, as well as clams, raw milk, and untreated water. The symptoms are mostly diarrhea and at times very strong abdominal pain, and can last from a day to weeks—the latter in about 20 percent of the cases. Chronic conditions can follow in from 2-10 percent of cases, including meningitis, inflammation of the gall bladder, and appendicitis. The very young and people in their twenties seem to have the most cases. Case rates are about 1 percent, with 0.6 percent of these hospitalized and with 2-6 percent of these resulting in death, or about 1 to 4 in a million in the population. The costs of foodborne campylobacteriosis are $0.6 to $1 billion annually, using the cost-of-illness approach. Improved food handling could reduce cases, particularly in supermarkets.

Escherichia coli infections can be caused by a variety of foods, some cross-contaminated by bovine products. The bacteria can produce symptoms from mild diarrhea to death; some infections can cause hemorrhagic colitis, and some of these cases can result in hemolytic uremic syndrome (HUS), which can lead to death through kidney failure and other complications. There are a small number of cases throughout the U.S., only a rate of 0.004-0.008 percent. Of these, 18 percent are hospitalized, 20 percent of these turn into HUS, and 33-40 percent of these die, or from 5 per 100,000 to 1 in 10,000. The very young are most susceptible, followed by those over age 60. Cost estimates range from $0.2-$0.6 billion

Infection from *Listeria monocytogenes* (listeriosis) has a "bimodal distribution of severity, with most cases either mild or severe." Even the "mild" cases are characterized by fever, severe headache, and vomiting. Severe cases, which are experienced *in utero*, by infants, and some immunocompromised or pregnant adults can involve delirium, coma, and death. It survives refrigeration and can be present in high doses on underheated hot dogs, cheese, and pate. The reported number of cases is tiny, only 1,800 in 250 million. But all are hospitalized and of these about a quarter die, or 2 per million. The severity of this disease pushes costs to $0.2-$0.3 billion annually.

[1] All the information in this box is taken from Buzby et al. (1996).

Morbidity Valuation and Benefits Transfer

Table 5 takes the same format as table 3, but describes the study, air pollution, and food safety contexts for morbidity. The key studies here vary for whether the morbidity is chronic or acute. In general, the cost of illness approach breaks down the consequences of illness into its component parts and attempts to place values on each part. The ideal WTP measures would capture all the medical costs, pain and suffering, time loss, productivity loss and fear of an illness (see Harrington and Portney (1987) for the basic model). This approach has a welfare theoretic basis but is basically a stop-gap to use when other approaches fail. For instance, Hartunian (1985) uses a model of the progress of cancer and (separately) of respiratory disease to estimate the medical costs of these diseases over one's lifetime. Cropper and Krupnick (2000) have estimated the consequences of various chronic diseases on wages and labor force participation. Ultimately, such measures founder on their inability to capture the pain and suffering that are likely to arise from chronic illness. The approach has fared better with acute illness.

Considering the valuation of chronic illness, conjoint analysis has been used by two studies to value the WTP to reduce risks of developing chronic respiratory disease, and several studies have addressed the WTP to reduce cancer morbidity risks. Viscusi, Magat, and Huber (1991) and Krupnick and Cropper (1992) used conjoint analysis to examine the WTP to reduce the risks of chronic respiratory disease.

Considering acute health valuation, three contingent-valuation studies (Loehman et al., 1979; Tolley et al., 1986; Dickie et al., 1987) are the original studies of this type. They used bidding procedures to elicit estimated values for respiratory-symptom days, with average estimates ranging from $5 to $25, depending on the symptom, its severity, and whether a complex of symptoms is experienced.

All those studies have drawbacks, related mainly to their methodology--the CV studies were performed before many of the most important advances in CV techniques. But they offer consistent ranges of estimates for WTP to avoid a particular type of symptom.

Differences in the study and air pollution contexts are not very large because many studies have been designed with the air pollution context in mind. However, differences between these and the food safety context are more pronounced than those for mortality risks. Many foodborne illnesses have strange and serious symptoms, making reliance on studies of respiratory disease for benefits transfer questionable. In addition, some of these symptoms may be unfamiliar and dreaded, adding additional dimensions to the WTP. Furthermore, baseline risks are different. The foodborne disease risks may be in the 1 per 100 range—very large compared to the chronic disease in the air pollution context and smaller than respiratory symptom probabilities. And again, the ill and very young are at risk, and avoidance behavior is perhaps a major element of the behavioral response.

Conclusions and Recommendations

In comparing the study and policy contexts for valuing food safety, the clear conclusion emerges that reliable health values for food safety are not going to be found in the health valuation literature used in air pollution benefit-cost analyses. That literature has its own problems of credibility and reliability. But, more important, at least in the case of valuing mortality risks of air pollution, there is a serious disconnect between the study and policy contexts. While far from

a consensus has been reached, agreement is growing that there should not be one VSL for use in all cases. Where different groups are affected in different contexts, whether they differ by age, sex, race, health status, or other characteristics, it is their WTP that matters for valuation. *A priori,* there is no reason that each of these groups should hold the same willingness to pay for an equivalent risk, although Krupnick et al.'s findings on the lack of sensitivity of WTP to age (below 70) and physical health suggest that not all these characteristics may matter. In the context of food safety, where some diseases affect children, those with AIDS, and the elderly, these considerations suggest not only that benefit transfers would be unreliable but that VSL's will differ in different food safety contexts.

Moreover, as empirical evidence mounts that WTP changes less than proportionally with risk reductions (this in spite of the conceptual support for proportionality from the lifecycle model literature), the possibility grows that different VSL's would be used for different size risk reductions *experienced by the same groups.* Again, in the food safety context, risk reductions are either relatively smaller or relatively larger than the air pollution or labor market contexts, suggesting, again, that transfers are unlikely to be reliable and that more than one VSL may be appropriate, depending on the food safety context.

For morbidity valuation, the case against useful benefit transfers is clearer still. The symptoms associated with the major foodborne illnesses are specialized and varied far beyond the simple respiratory effects or diarrheal effects that have been valued in the health literature. Also, the high prevalence of foodborne diarrheal disease among children means that WTP estimates appropriate for this group are necessary; however, the state of the literature for deriving these values is embryonic.

The food safety context also has some unique elements affecting valuation relative to that of the air pollution context. Most important, for many foodborne illnesses there is a pre-outbreak period where damage is being done before people are aware of the cause and the need for averting action. This is followed by a post-outbreak period where averting activities can be taken. Values are needed that are associated with both periods, because WTP in the second period is conditioned on the cost of averting behavior while WTP for the first period is not.

Implications

If the conclusions of this paper are accepted, then, aside from the thin literature directly addressing valuation of foodborne health effects, there is not much of a literature available to use in estimating the benefits of food safety policy. What should the agencies with regulatory responsibilities in this area do in the mean time?

The first option is to do what the ERS in particular has been doing—use cost-of-illness estimates instead of WTP estimates. This may be viewed as a "retreat to defensible borders" because the COI approach has a long history in food safety, is transparent, and can be thought of as a lower bound on WTP. Another option is to use cost-effectiveness analysis rather than attempting to value health effects. Here the key decision is the health measure. Where one type of physical effect dominates, a measure of the reduction in this effect could be used—something like a health index measure. However, if the analysis is meant to compare cost-effectiveness measures

across diseases, there probably will not be a single "index" symptom to use. This obvious problem has led to the creation of various indexes for physical symptoms—the Quality of Well Being scale (Torrance), the Quality-Adjusted Life Year (QALY) (Neumann et al., 1997), and others.

This paper is not the place for an examination of the problems of these various measures as compared with one another and as compared with WTP measures. Suffice it so say that the assumptions needed for their equivalency as measures of utility in alternative health states are many, the empirical literature testing these assumptions shows that they are unrealistic, and the empirical literature shows a fairly consistent lack of association between these measures (O'Brien, 2000) within the same sample of individuals.

A third option is for the longer run and requires a sustained research effort: develop a literature based on food safety valuation and suitable to be used in benefit transfer exercises across the myriad food safety contexts. The idea would be to develop functional relationships applicable to a wide variety of food safety contexts. Such an approach would be less expensive than developing a catalogue of values for different risks and different populations, as suggested by Kuchler and Golan (1999), although it would be less accurate as well.

Beyond this broad agenda for research, our discussion of the food safety context brings out some more specific research priorities. These include:

- WTP applicable to children and household WTP. Research is beginning on building conceptual and testing empirical models appropriate to the valuation of children's health changes. None of the conventional approaches to valuation are applicable because (very young) children are not capable of valuing their own health in hypothetical situations and are not in situations to reveal it. Parent WTP is obviously a key element here. The prominence of children as a sensitive group to foodborne disease makes such research imperative.

  Equally important is research on the WTP of the household as a unit. Altruism within the household is a fact of human existence and economic decisions are often made as a household unit. Most valuation literature looks at *individual* WTP and tries hard to eliminate considerations of family. In the air pollution context, where averting behavior opportunities are minimal and contagion is not a serious issue, the individual valuation paradigm may be sensible. But for food safety, the above concerns loom far larger.

- WTP for combined improvements in mortality risk and morbidity. The health valuation literature is almost entirely bifurcated into studies of the WTP for mortality risks and the WTP for reductions in morbidity. This split is probably not defensible for the air pollution context any more than it is for food safety. Yet the problems in valuing lifetime, integrated health risk changes are so formidable that progress will be slow.

- Improving communication about small probabilities/conditional probabilities. The mortality risk valuation literature continues to struggle with how to communicate small probabilities effectively and to obtain sensitivity to scope. A smaller literature (Smith and Desvousges, 1987) has also tried to communicate conditional probabilities. In the food safety context,

where unconditional probabilities are very small (1 in 100,000 or less) but conditional probabilities can be startlingly large (1 in 5 for listeriosis!), progress will be needed.

- Altruism and WTP. The conceptual literature is reasonably in agreement about the conditions under which altruism (outside the family) can be counted and alternatively, results in double-counting. What is not known is the prevalence of these conditions and when one set or the other might apply. There is also only the smallest literature on how large altruistic values might be and no information on such values in a food safety context, where private actions can do so much to limit exposure that people may not hold significant altruistic values.

- Qualitative risk attributes and WTP. The ERS and CDC funded projects recently to examine whether attributes, such as the cause of the health effect (bacteria vs. virus vs. something else), the type of carrier (e.g., foodborne), the name of the disease, and dread, voluntariness, controllability, etc., have any independent effect on WTP for reduced health risks. More of this type of research will be needed if initial results show such sensitivity. Perhaps the results might be appropriately transferred to the air quality valuation literature, where virtually no information of this nature is available!

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Table 1. Comparison of unit values used in several major studies or models

Values	US EPA[1]			US TAF[2]			Canada AQVM[3]			Europe ExternE[4]
	Low	Central	High	Low	Central	High	Low	Central	High	Central
				1990 dollars						
Mortality	1560000	4800000	8040000	1584000	3100000	6148000	1680000	2870000	5740000	3031000
Chronic bronchitis	-	260000	-	59400	260000	523100	122500	186200	325500	102700
Cardiac hospital admissions	-	9500	-	-	9300	-	2940	5880	8820	7696
Resp. hospital admissions	-	6900	-	-	6647	-	2310	4620	6860	7696
ER visits	144	194	269	-	188	-	203	399	602	218
Work loss days	-	83	-	-	-	-	-	-	-	-
Acute bronchitis	13	45	77	-	-	-	-	-	-	-
Restricted activity days	16	38	61	-	54	-	26	51	77	73
Respiratory symptoms	5	15	33	-	12	-	5	11	15	7
Shortness of breath	0	5.3	10.60	-	-	-	-	-	-	7
Asthma	12	32	54	-	33	-	12	32	53	36
Child bronchitis	-	-	-	-	45	-	105	217	322	-

[1]The Costs and Benefits of the Clean Air Act Amendments of 1990. Low and high estimates are estimated to be 1 standard deviation below and above the -mean of the Weibull distribution for mortality. For other health outcomes they are the minimums and maximums of a judgmental uniform distribution.
[2]Tracking and Analysis Framework, developed by a consortium of U.S. institutions, including RFF. Low and high estimates are the 5% and 95% tails of the distribution.
[3]Air Quality Valuation Model Documentation, Stratus Consulting for Health Canada. Low, central, and high estimates are given respective probabilities of 33%, 34%, and 33%.
[4]ExternE report, 1999. Uncertainty bounds are set by dividing (low) and multiplying (high) the mean by the geometric standard deviation (2).

Table 2. Elements of the Policy Context

Elements	Features
Nature of risk	Mortality/morbidity For morbidity: Symptom type Severity Frequency Jointness Disease qualities Dread Controllability Etc.
Risk change	Baseline Timing Size
Population characteristics	Health status Age Income Education Race
Other	Public vs. private good Altruism Avoidance possibilities Causal agent

Table 3. Mortality Valuation and Benefit Transfers

Elements	Primary studies (hedonic wage/CV accident)	Conventional air pollution context	Food safety context
Nature of risk	Familiar, voluntary (?)	Familiar, involuntary	Varies
Timing	Contemporaneous	Contemporaneous and future	Contemporaneous and future
Size	X in 10,000	X in 10,000	X in 100,000 or smaller*
Affected population	Healthy (males); no young, few old	Ill, very old, very young (?)	Ill, very young, other
Public/private	Private	Mostly public	Mostly private
Averting behavior		Minor	Major

* Unconditional probability; conditional ~ 1 in 1,000 (salmonellosis); 1 in 4-5 (listeriosis)

Table 4. Theory and Empirical Evidence for WTP for Mortality Risk Reduction

	Risk change	Latency	Baseline risk	Income	Age	Health status	Dread
Life cycle model	+ proportional.	_	+	+	-, + then -	?	+
Wage compensation	+		_	+	+ then -		
CVM	+; not prop.	_	varies	+	varies	0, cancer +	+

Hammitt and Graham (1999) and author

Table 5. Morbidity Valuation and Benefit Transfers

Elements	Primary studies (primarily CV; context free)	Conventional air pollution context	Food safety context
Nature of risk	Acute: Mostly respiratory Chronic: respiratory; Familiar	Acute: Respiratory and cardiovascular (CA), Chronic: respiratory and CA; Familiar	Wide variety (GI), complex mixture of symptoms; Unfamiliar/dread
Timing	Contemporaneous	Contemporaneous and future	Contemporaneous and future
Size	Acute: Certain Chronic: x in 10,000	Acute: high Chronic: small	Varies: e.g., ~1 in 100
Affected population	Adults	Adults, asthmatics	Ill, very young
Public/Private	Private	Public	Private
Averting Behavior	Few	Minor	Major

Rapporteur's Notes for

Valuing Risk Reductions for Different Hazards

Rapporteur: Tammy Riggs, U.S. Dept. of Health and Human Services

The discussion began with the question, "Can we standardize methodologies across hazards?" This, however, led to the question, "What are the standard methodologies being employed by the different agencies?" The general consensus from this discussion was that the different agencies did employ different methods and that these differences needed to be identified before being able to conclude whether or not standardization was possible. Most people felt that, if possible, a single approach should be used by all the agencies to enable comparisons between policies.

Next, the group discussed how to begin this standardization process. It was noted that the OMB guidelines on cost-benefit analysis could be used as a starting point but that a needs assessment should be conducted to assess the differences in approaches between the agencies. This assessment could begin with the work that has already been done for this conference. This assessment would identify differences in approaches between agencies as well as the rationale for those differences. Then, an expert review panel would be beneficial to help resolve these differences and to make recommendations on the final methodology. It was suggested that epidemiologists also be involved in this process. Once the methodology was agreed upon, a multi-agency project to use this new methodology to actually measure consumers' willingness to pay to reduce certain risks would be beneficial to all the agencies, since no good measures seem to be currently available.

The final discussion went back to the first question about whether or not one would be able to standardize, given the way consumers view different types of hazards. Agreement was reached that willingness to pay (WTP) was the best approach to valuing these risk reductions. One suggestion was to create a single WTP function with a set of standard variables. For example, WTP = f(Dread, Unknown, Severity, Duration, Cost, Risk, etc.), but with a precise definition of each of the included variables and interpretation of terminology to reduce confusion. Some of these variables would be zero depending on the hazard. This seemed feasible but led to a discussion of what consumers were actually going to be asked to value. Should they be asked to value risk reductions in terms of the symptoms and sequellae caused by the hazards or in terms of the hazards themselves? There was some thought that certain hazards would have different WTP values than the sum of the WTP values of their associated symptoms. While a difference in the values would be easy enough to measure, which value would be the best value to use in a practical application? Moreover, if the difference was caused by misinformation, would it be best to better inform survey respondents before they answered any survey questions? Or are we then undervaluing the true societal benefits? If there is misinformation, could society simply benefit by better informing consumers in a general information campaign? These last few questions were left unresolved.