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Abstract

Most benefit-cost analyses of reductions in air pollutants and other pollutants carrying mortality risks rely on estimates of the value of reductions in such risks produced by compensating wage studies, or contingent valuation studies that value risk reductions in the context of transport or job-related accidents. As we argue below, these estimates are inappropriate when valuing risk changes produced by environmental programs. The objectives of this paper are to explain why these estimates are inappropriate and to describe an improved approach to valuing reductions in risk of death from environmental programs, especially programs to reduce air pollution. We have implemented this approach in a pilot study in Tokyo, Japan. The paper provides estimates of the value of a statistical life based on the pilot study and describes extensions of the approach based on test results.

Our preliminary results from the Tokyo pilot indicate that individuals are able to distinguish between different magnitudes of small changes in mortality risks and between the same change in these risks occurring at different times (although the latter has not yet been subjected to an external scope test). Changes to the survey and a big increase in sample size may improve performance on the internal validity tests and the results of the scope tests. Although the current results can only be considered suggestive, if they were to remain after administration of the survey to a larger sample and subject to some other caveats, they would imply that the VSL's currently used in benefit-cost analyses of environmental policies are significant overestimates.

Key Words: mortality risk valuation, contingent valuation, Japan

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MORTALITY RISK VALUATION FOR ENVIRONMENTAL POLICY

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I. INTRODUCTION

Much of the justification for environmental rulemaking rests on estimates of the benefits to society of reduced mortality rates. Reductions in risk of death are arguably the most important benefit underlying many of EPA's legislative mandates, including the Safe Drinking Water Act, CERCLA, the Resource Conservation and Recovery Act and the Clean Air Act. In two recent analyses of the benefits of air quality legislation, *The Benefits and Cost of the Clean Air Act, 1970 - 1990* (USEPA 1997a) and EPA's *Regulatory Impact Analyses for Ozone and Particulates* (USEPA 1997b), over 80 percent of the monetized benefits are attributed to reductions in premature mortality.

Most benefit-cost analyses (including the above) rely on estimates of the value of reductions in risk of death produced by compensating wage studies, or contingent valuation studies that value risk reductions in the context of transport or job-related accidents. As we argue below, these estimates are inappropriate when valuing risk changes produced by environmental programs. The objectives of this paper are to explain why these estimates are inappropriate and to describe an improved approach to valuing reductions in risk of death from environmental programs, especially programs to reduce air pollution. We have implemented this approach in a pilot study in Tokyo, Japan. The paper provides estimates of the value of a statistical life based on the pilot study and describes extensions of the approach based on test results.

II. WHY EXISTING ESTIMATES OF THE VALUE OF MORTALITY RISKS ARE INAPPROPRIATE IN AN ENVIRONMENTAL POLICY CONTEXT

A. The Nature of Mortality Risk Reductions from Pollution Control

Estimates of the mortality benefits from reducing pollution--in this case air pollution--come from two types of epidemiological studies.[2] Episodic studies measure the impact of

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[1] Respectively, the authors are with Resources for the Future, University of Colorado, University of Maryland and the World Bank, and the USEPA. Additional authors are with the Fuji Research Institute and MITI, Tokyo, Japan.

[2] The studies described here are those used to estimate the number of statistical lives saved by reducing air pollution in *The Benefits and Costs of the Clean Air Act, 1970-1990* and EPA's *Regulatory Impact Analyses for Ozone and Particulates*. Evidence from toxicological studies and cross-sectional epidemiological studies also support an association between air pollution and premature mortality.

short-term exposures to pollution on mortality rates, using daily time series data. Prospective cohort studies measure the impact of long-term exposures to pollution by following a cross-section of individuals over time. Both types of studies, which are described briefly below, suggest that most of the statistical lives saved by reductions in air pollution are persons 65 years of age and older.

Studies by Schwartz (1991,1993) and Schwartz and Dockery (1992a, 1992b) examine the association between daily mortality, by age and cause, and the criteria air pollutants. In Philadelphia, Schwartz and Dockery found a significant impact of total particulate matter (TSP) on deaths among persons 65 and over, but no significant effect of air pollution on deaths below the age of 65. The impact of particulates was greater for cardiovascular deaths and deaths due to chronic obstructive lung disease (COPD) or pneumonia than on all non-trauma deaths.

The prospective cohort study of Pope et al. (1995) followed 552,000 individuals in up to 151 U. S. cities. The study used a proportional hazard model to examine the effects of particulate exposure and other covariates on death rates. This model assumes that the impact of particulates is proportional to the conditional probability of dying at each age (given that one survives to that age), or the hazard rate.[3] The significant impact of particulates on the hazard rate implies that the benefits of reducing particulate exposure fall primarily on older persons, whose conditional probability of dying is higher than that of younger persons. Significant effects were observed for mortality only from heart and lung disease and lung cancer.

When using the Pope et al. study to estimate benefits from reducing air pollution it is usually assumed that a reduction in annual average PM concentrations (both PM2.5 and sulfates) will immediately reduce the hazard rate. This implies that a given reduction in PM will save a certain number of statistical lives. As the preceding paragraph implies, these statistical lives will be concentrated among older persons. This point is made explicit in Table 1, which shows the age distribution of statistical lives saved as a result of reductions in particulate exposures achieved by the Clean Air Act, based on Pope et al. (1995). These estimates show that three quarters of the statistical lives estimated to be saved in 1990 are persons 65 years of age and older.

This has two implications for valuing morality risks. For older persons, the correct valuation concept is what an individual would pay today for an immediate reduction in his risk of death. For younger persons, who will not experience significant risk reductions until they are older, the correct valuation concept, assuming that the costs of pollution control are incurred today, is what a person would pay today for a future risk reduction.

[3] The study finds that mortality rates decrease 0.7 percent for every $\mu g/m^3$ change in sulfates.

Table 1. Distribution of Premature Mortalities Avoided by the Reductions in PM2.5 under the Clean Air Act, for 1990

Age Group	Remaining Life Expectancy	Deaths Avoided
Under 65	25	45,000
65-74	14	43,000
75-84	9	54,000
>84	6	41,000

Source: EPA, *The Benefits and Costs of the Clean Air Act, 1970 to 1990*, draft report prepared for Congress, July 1997.

B. Current Approaches to Valuing Mortality Risk Reductions

Epidemiological studies suggest that reducing air pollution lowers death rates primarily among persons over 65. These benefits, furthermore, are more likely to accrue to people with chronic heart or lung disease and may occur with a lag. In spite of these findings in the medical literature, the dominant approach for valuing these reductions in death risks is simply to transfer estimates from compensating wage studies or contingent valuation studies that value risk reductions in the context of transport or job-related accidents.

1. <u>Labor Market Studies</u>

The main shortcoming of labor market studies is that they measure compensation received by prime-aged men for immediate reductions in risk of death. Since older people have fewer life-years remaining than prime-aged males, the compensation received in labor market studies may overstate the value of risk reductions to persons over age 65. Secondly, compensating wage studies measure compensation for a reduction in risk of death over the coming year, whereas exposure to air pollution (and to carcinogens) can result in delayed effects. When evaluating an environmental program today that will not reduce risk of death until the future, policy makers must know what people will pay today for future risk reductions.[4]

Attempts have been made to adjust estimates of risk reductions from the labor market literature for age and latency. Under certain strong assumptions, one can convert the value of a statistical life from a labor market study (or other source) into a value per life-year saved. The value of a life-year can then be multiplied by discounted remaining life expectancy to value the statistical lives of persons of different ages. The justification for these adjustments

[4] The delay in the realization of risk reductions could occur either because the installation of pollution control equipment today will not benefit young people until they become susceptible to the effects of pollution (the air pollution case described above), or because the program reduces exposure today to a substance that increases risk of death only after a latency period (e.g., asbestos).

is the life cycle consumption-saving model with uncertain lifetime (Yaari, 1955; Shephard and Zeckhauser 1982; Cropper and Freeman 1991; Cropper and Sussman 1990). According to this model, WTP for a reduction in the probability of dying over the coming year equals the present value of expected utility of consumption over the remainder of one's life, divided by the marginal utility of income.[5] In the special case in which utility of consumption at age t is constant for all t, WTP is proportional to discounted life expectancy. In this case, it is meaningful to speak of a value per life-year saved, which can be computed by dividing WTP by discounted life expectancy.[6]

To illustrate this calculation, suppose that the value of a statistical life based on compensating wage differentials is $5 million, and that the average age of people receiving this compensation is 40. If remaining life expectancy at age 40 is 35 years and the interest rate is zero, then the value per life year saved is approximately $140,000. If, however, the interest rate is 5 percent, then *discounted* remaining life expectancy is only 16 years, and the value per life-year saved rises to approximately $300,000.[7]

Computing a value per life-year saved clearly hinges on very restrictive assumptions, even if one believes the life-cycle consumption-saving model. It is also very sensitive to the choice of discount rate. Moore and Viscusi (1988) have used labor market data to infer the rate at which workers discount future utility of consumption; however, their models make very specific functional form assumptions in order to infer a discount rate from a single cross section of data.

2. Contingent Valuation Studies

Difficulties in measuring the impact of age and latency on WTP using labor market data have led to the use of stated preference methods to value a change in risk of death. In a contingent valuation study persons of different ages can be asked to value an immediate reduction in risk of death, and each respondent can be asked what he would pay today to reduce his risk of dying in the future. Before such approaches can be used, however, it must be demonstrated that valuation questions can be posed in a manner that is meaningful to respondents. Existing contingent valuation studies of mortality risks suffer from two problems: (1) They ask people to value small changes in their risk of death, which are expressed in units unfamiliar to most people, e.g., a 1-in-10,000 reduction in risk of dying over the coming year. (2) They ask people to attach a value to a commodity (e.g., a 1-in-10,000

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[5] If an individual can save via actuarially fair annuities and borrow via life-insured loans, then one must add to this expression the effect of a change in the conditional probability of dying on the budget constraint.

[6] Formally, let j be the individual's current age and let $q_{j,t}$ be the probability that the individual survives to age t, given that he is alive at age j. The individual's remaining life expectancy is the sum of the $q_{j,t}$'s from j to T, the maximum age to which humans live. The individual's discounted life expectancy weights each $q_{j,t}$ by the discount factor $(1+r)^{j-t}$ before summing.

[7] Similar adjustments can be made to account for the effect of latency periods. According to the life-cycle model, a 40-year-old's WTP to reduce his probability of dying at age 60 should equal what he would pay to reduce his current probability of dying at age 60, discounted back to age 40.

reduction in risk of dying) that they have never purchased, or at least are not used to thinking about in this way. This has led to inconsistencies in responses to many contingent valuation surveys.

a. Problems in Comprehending Quantitative Risk Changes

To elaborate on the first problem, people appear to have difficulty perceiving small risk changes. This may result, in part, from an inability to handle fractions.[8] In a recent study of the value of mortality risks in the U. S. (Hammitt and Graham, 1998), 32 percent of respondents did not know that 5/100,000 was a smaller number than 1/10,000. One way to circumvent this problem is to use visual aids--to darken squares on a sheet of graph paper to show the size of a risk change or to place risks on a risk ladder.[9]

Even when care is taken to communicate the size of small risk changes, however, people often do not distinguish the magnitude of these changes. Evidence of this is the fact that, in many surveys, people's WTP for reductions in risk of death does not increase with the size of the risk reduction. In a survey of WTP for reductions in risk of death in the context of highway safety (Jones-Lee, Hammerton and Philips, 1985), there was no statistically significant difference in the amount people would pay for a 1 in 100,000 reduction in risk of death during a bus trip versus a 7 in 100,000 reduction. Presumably, both numbers were perceived as "small." Similar problems were encountered by Smith and Desvousges (1987) in a study of WTP to reduce exposure to hazardous waste. Respondents were told their current risk of exposure to hazardous waste (R) and their probability of dying from the waste (after a 30-year period) given that they were exposed (q). WTP for reductions in probability of exposure (holding q constant) were insensitive to the change in R. Hammitt and Graham (1998) encountered similar problems in their survey of WTP for air bags. The WTP for a 10 in 10,000 risk reduction was estimated to be only 23 percent larger than WTP for a 5 in 10,000 risk reduction. When respondents were presented with larger initial risks and risk reductions of 15 in 10,000 and 10 in 10,000, the differences in WTP were even smaller (only 6 percent).

b. Problems in Valuing Quantitative Risk Changes

Even if people are able to understand the magnitude of a risk change, it may be difficult for them to place a dollar value on it. This is because people are unaccustomed to purchasing quantitative risk reductions. There are two problems here. People are often aware

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[8] According to our research, this is a difficulty that can be largely avoided if surveys express risks in the same units of the denominator.

[9] Another way to avoid the problem of small probabilities is to describe programs that will reduce the number of deaths in a population. For example, a road safety program in one's state could reduce the number of motor vehicle deaths from 1,000 to 900 per year. The problem with this approach is that the value a person places on such a program is likely to reflect his WTP to reduce risk of death to others as well as to himself. The appropriate welfare measure for evaluating life saving programs is what all affected individuals would pay to reduce risks to *themselves alone* (Jones-Lee, 1991).

of the risk factors associated with a given cause of death and may actually engage in risk averting or risk reducing behavior; however, they are unlikely to know the magnitude of the risk reductions resulting from these behaviors. For example, people will state that they wear seat belts to reduce risk of injury and death in an auto accident, but it is difficult for them to quantify the benefits of wearing a seat belt. Secondly, as in the seat belt example, many of the activities people engage in to reduce their risk of death do not cost them money. This is true of most behavioral changes (diet, smoking, exercise) and even of the purchase of medical services (cancer screening tests) when they are paid for by health insurance.[10]

CV surveys have been occasionally used to place a value on the mortality risk reductions associated with environmental, transportation safety or health programs (Mitchell and Carson, 1986; Smith and Desvousges, 1987; Jones-Lee et al. 1985; Hammitt and Graham, 1998). These studies found that while many respondents report positive WTP amounts to secure such risk reductions, a considerable fraction of the respondents is likely to have WTP equal to zero. Some respondents fail to grasp the basic notions of probability, and others ascribe similar WTP amounts to grossly different risk reductions. With few exceptions (Mitchell and Carson; Smith and Desvousges), most of these studies dealt with accidental death risks, as opposed to risks involving latency or late-in-life risk.

The most recent exception is Johannesson and Johansson (1996), who report on the first study we know of that values extensions to life expectancy. They conducted a telephone survey of a random sample of adult Swedes, asking respondents to report their willingness to pay for a new medical technology that would extend the remaining duration of their lives, assuming survival to age 75. The WTP question was worded as follows:

> "The chance for a man/woman of your age to become at least 75 years old is X percent. On average, a 75-year-old lives for another 10 years. Assume that if you survive to the age of 75 years you are given the possibility to undergo a medical treatment. The treatment is expected to increase your expected remaining length of life to 11 years. Would you choose to buy this treatment if it costs SEK C and has to be paid for this year?"

Respondents were to give yes or no answers to this question.

Based on the over 2000 completed surveys, Johannesson and Johansson fit a logit model predicting the likelihood of a positive response to the WTP question as a function of the amount C stated to the respondent, respondent age, income, educational attainment and

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10 Studies that have obtained "reasonable" WTP values for risk reductions (values of the same magnitude as compensating wage studies) often provide implied value cues to which respondents can anchor their answers. In the Jones-Lee et al. (1985) study, for example, people were told that they were given £200 to spend on the bus trip and were asked how much of this they would spend to travel on the safer bus. It is also the case that the researcher can, by altering the size of the risk reduction valued, help guarantee a "reasonable" value of a statistical life. If the risk reduction valued is small (on the order of 1 in a million) a WTP of only a few dollars will generate a value of a statistical life in the range of values found in compensating wage studies.

gender. They found results consistent with economic theory, in that WTP increases with respondent age. Predicted WTP was, however, relatively low, due to the large number of responses consistent with very low, or zero, WTP.

Despite the novelty of its approach, in many respects the Johannesson and Johansson study leaves much to be desired. First, it was conducted via telephone, which many researchers find an inadequate means of communicating complex, hard-to-understand commodities, such as mortality risks, and precludes the use of visual aids. Second, although the goal of the survey was to value a change in life expectancy, the commodity respondents were to value was not well-defined, in the sense that respondents could have easily interpreted it to be a year added on to the end of life. Third, the published article is silent about the survey development work, and respondent debriefing. Finally, the risk change respondents are to value is extremely large, to the point of being implausible when the risk reduction is to be delivered by an environmental policy.

III. IMPROVING ON THESE APPROACHES

Our goal is to design a survey to estimate WTP for reductions in mortality risks that can be used to evaluate the benefits of environmental programs. This requires that we ask older persons to value an immediate reduction in their risk of dying and younger persons to value a future reduction in their risk of dying. It also requires that we address problems--in particular, insensitivity to scope--that have been encountered in previous surveys. We describe our survey instrument below. The instrument has been developed over a period of several years, as a result of extensive one-on-one interviews in the United States, and pretests in the U.S. and Japan. We describe the results of the Japanese pretest and modifications to the survey that we have made subsequently. The modified survey will be administered in Canada, in Japan and in the United States later this year.

The survey instrument that we have developed differs from previous efforts in several important respects:

- First, the current target population is persons 45 to 75 years old. This is appropriate in light of the goal of the survey, but also necessary if we are to meaningfully discuss reductions in mortality risks outside of the context of transport accidents. It is only in middle age that risks of death from cardiovascular disease, respiratory illness and cancer become significant in industrialized countries.

- Second, we discuss mortality risks in 10-year intervals. Extensive use of focus groups and one-on-one interviews convinced us that most people find it easier to imagine a positive probability of dying over a ten-year interval than over a one-year interval. The use of 10-year intervals also allows us to represent risks in terms of chances per 1,000, which can be shown on graph paper.

- Thirdly, we ask people to pay for a product that will reduce their risk of dying over a ten-year interval by 5 in 1,000 and 1 in 1,000. These risk changes correspond to *annual* risk changes of 5 in 10,000 and 1 in 10,000, respectively, which are of the magnitude estimated to occur from air pollution reductions.[11] As noted above, some surveys deal with risk changes so small that a WTP of a few dollars generates a value of a statistical life in the $5-$10 million-dollar range.

- Finally, we note that the method of delivering risk reductions in our survey is a private good, not covered by health insurance. Although we believe that our estimates can be used to value the benefits of environmental programs, we believe that it is inappropriate to presents respondents with risk reductions *delivered by* environmental programs. Environmental programs usually reduce the risk of dying for all people in an exposed population; hence, it is difficult for the respondent to separate his own risk reduction from that of others.

A. Survey Description

Throughout our survey, we are motivated by two important concerns: (1) that respondents find the commodity to be valued understandable and meaningful, and (2) that they accept that mortality risks can be mitigated at a cost and that many people, if not themselves, perform such mitigation as part of everyday life.

The first section introduces probability of dying and probability of surviving and proposes simple practice questions to familiarize respondents with these concepts. The main task of this section is to clearly communicate probabilities and test for comprehension, eschewing tests of mathematical ability. First we describe two cities, City A and City B. The cities are identical in every way, except that in one city 10 persons out of every 1,000 of the respondent's age and gender will die over the next 10 years, whereas in the other, only 5 persons out of every 1,000 of the respondent's age and gender will die. Then we show the subject a graph of the risks for one of the cities and ask him or her to identify which city it is. Finally, we ask: "If you had to move to one of two cities, which city would you prefer, or are you indifferent between them?" (The risks in each city are represented using colored grid squares to convey probability.

Another major element that increases the understandability of the commodity is to state all probabilities in terms of chances per 1,000. After extensive one-on-one interviews and focus group testing, we concluded that the use of grids with more than 1,000 squares (i.e., 10,000 or 100,000) results in reduced cognition and a tendency to ignore small risk changes as being insignificant. Because we wanted annual risk changes to be smaller than 1 in 1,000, however, we expressed the commodity as a risk change over 10 years *totaling* x per 1,000. Baseline risks and payment schedules were also put in 10-year terms.

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[11] They are also of the magnitude of risk changes that are observed in labor market studies.

The second section presents respondents with age- and gender-specific leading causes of death and introduces common risk-mitigating behaviors, illustrative risk reductions, and illustrative costs. As noted above, one difficulty in asking people to value quantitative risk reductions is that, although people often engage in risk-reducing behaviors (e.g., cancer screening tests, taking medication to reduce their blood pressure or cholesterol levels), they have no idea how much these actions reduce their risk of dying. We present results from cost-effectiveness studies that quantify the reductions in risk of dying (over 10-year periods) from common risk-reducing behaviors.

The third section communicates baseline risks for someone of the respondent's age and gender and asks them to accept this risk as their own for the purpose of the survey (the acceptance of the baseline risk is tested in debriefing questions). To fix this baseline in the respondent's mind, he or she is asked to create their own baseline risk graph by marking squares on a blank grid.

The fourth section elicits information about WTP for risk reductions of a given magnitude, occurring at a specified time, using dichotomous choice methods. In one subsample, respondents are first asked if they are willing to pay for a product or action that, when used and paid for over the next ten years, will reduce baseline risk by 5 in 1,000 over the 10-year period (WTP5); in the second WTP question, risks are reduced by only 1 in 1,000 (WTP1). In another subsample, respondents are given the 1 per 1,000 risk change question first. This design permits both internal and external scope tests. To impress the risk change on the respondents, we ask that they erase the appropriate number of squares from their personal baseline risk graph.

Our final series of dichotomous choice questions focuses on future risk reductions. The WTP questions are preceded by a question concerning the respondent's perceived chance of surviving to age 70. This question encourages the respondent to think about his future. A variety of surveys have shown that individuals are reasonably good at estimating future survival probabilities (Hamermesh, 1985; Hurd and McGarry, 1996) and are able to value risk changes occurring in the future (Johannesson and Johansson, 1996). The respondent is then told his gender-specific chance of dying between ages 70 and 80 and is asked, through dichotomous choice questions, his WTP each year over the next ten years for a future risk reduction beginning at age 70 and ending at age 80 *which totals* 5 in 1,000 (WTP5_70). The respondent is reminded that there is a chance he may not survive to age 70, making a payment today useless. He is then given the opportunity to revise his bid. During an extensive debriefing section of the survey, the respondent is asked whether he thought about his health state during this future period.

In sum, our WTP questions differ from those in earlier CV surveys in six respects: (1) the timing of the risk reductions, (2) the timing of the payment, (3) the tailoring of baseline risks to age and gender, (4) the extensive use of visual aids, (5) the addition of questions to gauge the strength of a respondent's conviction in his WTP responses, and (6) the abstract nature of the commodity and payment vehicle.

Although keeping the risk reduction scenario abstract may depart from the recent CV literature and the NOAA panel recommendations (Arrow et al., 1993), we argue that, according to the discounting human lives literature, respondents are willing and able to make choices among abstract life-saving programs (Hurd and McGarry, 1996, Cropper, Aydede, and Portney, 1994). In addition, we argue that being specific about the attributes of the risk and mitigation approach may lose as many people as it gains because some respondents will not believe that the specifics apply to them. While we do provide the respondent with some examples of mitigating activities that could produce the risk reductions in question, we emphasize that the activity could take any number of forms, allowing respondents to focus on the size of the risk reduction itself.

IV. TOKYO PILOT SURVEY

Thus far we have developed and refined the mortality risk questionnaire based on a total of 27 personal, "think-aloud" interviews lasting approximately one hour each and have completed a 60-person pre-test of the survey instrument in the U.S. This survey development, plus a similar number of personal "think-aloud" interviews in Tokyo, led to a 316-person pilot study administered in Tokyo with our partners, the Fuji Research Institute. The Fuji Research Institute is a non-profit research group that has received funding for this project from Japan's Ministry of International Trade and Industry (MITI).

A. Sampling and Survey Administration

316 adults were recruited in Tokyo during February and March of 1998. Three age groups were sampled: 30 to 44, 45 to 54, and 55 to 64.[12] We focused on respondents aged 30 and older to ensure that the respondents' baseline mortality risk would be large enough for the 5 in 1,000 risk reductions to be meaningful--i.e., that a risk reduction of 5 in 1,000 would result in a positive mortality risk for the respondent.[13] With the cooperation of ten companies, we recruited 80 participants from employee rosters, most of them male. We recruited the rest of the participants from Tokyo by random telephone calls. Interviewers made appointments with the participants and conducted the interviews in the participants' residence or place of business. Participants were randomly assigned to two subsamples. Subsample I (161 people) received the WTP5 question first. Subsample II (155 people) received the WTP1 question first.

The Japanese questionnaire uses a dichotomous choice format with two follow-up questions. The yen bids assigned to the respondents were varied within each subsample, as shown in Figure 1.

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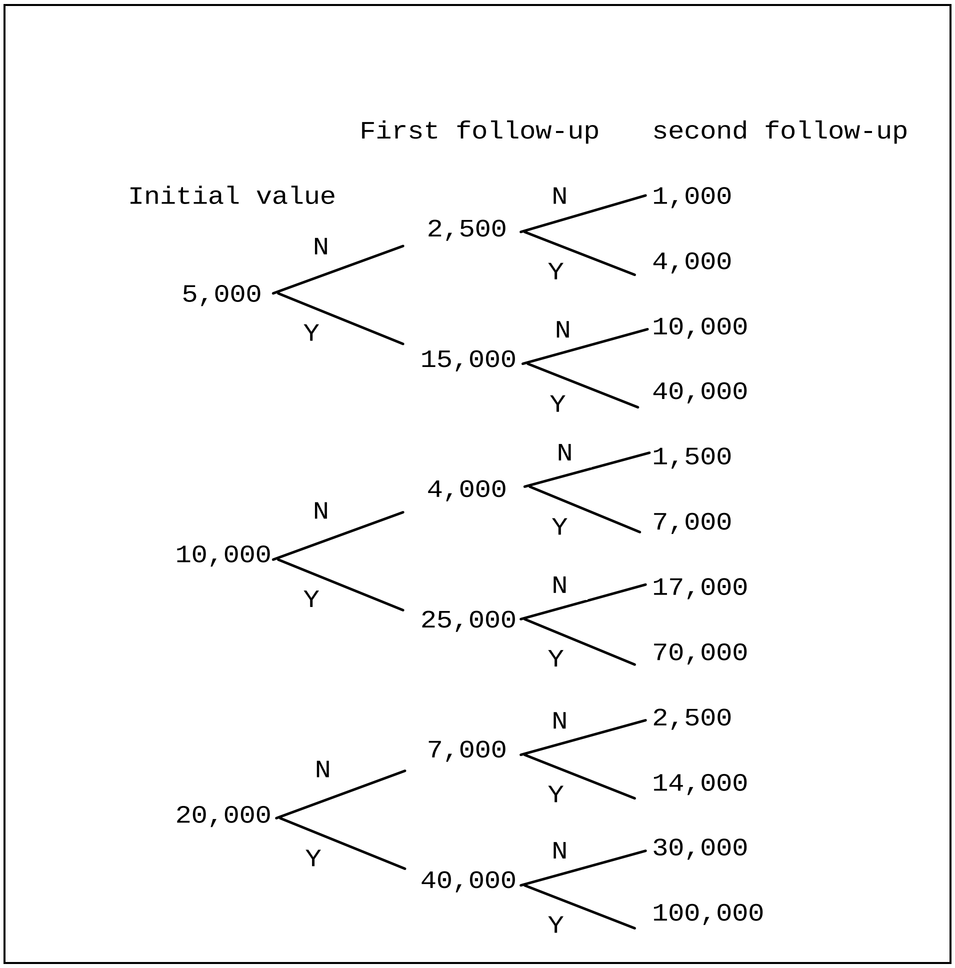
[12] As noted above, our current focus is persons 45 to 75 years old.

[13] The mortality risk of Japanese women under the age of 35 is less than or close to 5 in 1,000. A risk change of 5 in 1,000 would result in a chance of death equal to zero.

Figure 1. Bidding Structure (yen)



B. Descriptive Statistics

Table 2 provides descriptive statistics for the entire sample. The average age of respondents is 47 years old, with 8 percent of the sample above 60. Most of the women in the sample are housewives, although housewives comprise only 20 percent of the population. Mean household income is $63,000, which is above the Tokyo average of $54,000. Forty percent of the sample has attended some college.

The remaining statistics in the table relate to baseline risk of dying (see below) or are taken from the debriefing section of the survey and are used as covariates explaining WTP. The high fraction of individuals who thought of effects to others when answering the WTP questions (47 percent) has an unclear interpretation. It is possible that these people thought of the impact of their own death on loved dependents; alternately, they may have erroneously assumed that the risk reduction for which they were paying would accrue to other people as well as to themselves. No respondents answered our probability test incorrectly, but 14 percent and 36 percent were indifferent to whether they lived in City A or City B when the mortality risk difference was 5/1000 and 1/1000, respectively.

Table 2. Summary of respondent characteristics

RESPONDENT CHARACTERISTICS	MEAN	Standard deviation
Sex (% female)	53.8	
Age (years)	47.4	8.9
Age Distribution (%)		
30-34	13.3	
35-39	9.5	
40-44	14.9	
45-49	21.5	
50-54	17.7	
55-59	15.5	
60-64	7.6	
Housewife (%)	43	49
Self-employed (%)	31	46
Employed by others (%)	26	44
Household Income (million yen):		
Mean	8.31	4.10
Median	6.84	
College (%)	40	49
Perceived probability of surviving until age 70	0.66	0.22
Baseline risk	0.039	0.035
Percentage risk reduction	29	28
Respondent did not think risk was his own (%)	23	42
Respondents thought of effects to others when answering payment question (%)	47	50
Respondent thinks it is unwise to start paying now for risk reduction to be incurred over ten years (%)	47	50
Respondent did not think of his or her own health in answering payment questions (%)	64	48
Currently in good health and not hospitalized over the last 5 years (%)	76	42
Percent indifferent to City A/City B choice when mortality risks differ by:		
5/1000	14	
1/1000	36	

The raw responses to the WTP questions for contemporaneous risk reductions are provided in Tables 3a and 3b. "Version" indicates the three starting bids. The typical bimodal distribution of responses is observed, although there are many bids in the interior of the frequency distribution.

Table 3a. Frequency of response for WTP5 (subsample I)

Version	NNN	NNY	NYN	NYY	YNN	YNY	YYN	YYY	Total
1	10	4	2	0	5	5	16	8	50
2	8	4	7	2	9	4	11	10	55
3	13	5	8	1	6	4	9	10	56
Total	31	13	17	3	20	13	36	28	161

Table 3b. Frequency of response for WTP1 (subsample II)

Version	NNN	NNY	NYN	NYY	YNN	YNY	YYN	YYY	Total
1	11	6	5	0	7	7	10	5	51
2	12	4	8	1	5	5	9	10	54
3	9	12	7	4	3	7	6	2	50
Total	32	22	20	5	15	19	25	17	155

C. Estimates of WTP

To estimate mean or median WTP, it is first necessary to combine the responses to the initial and follow-up payment questions and obtain the lower and upper bounds of the interval around each respondent's WTP amount. Next, assuming that WTP follows a specified distribution *F*, we estimate the distribution's parameters, θ, by maximum likelihood techniques. Formally, the log likelihood function is:

$$\log L = \sum_{i=1}^{n} \log[F(WTP_i^H;\theta) - F(WTP_i^L;\theta)] \tag{1}$$

where WTP^H and WTP^L denote the upper and lower bounds around respondent i's unobserved WTP amount.

We experimented with Weibull, log normal, exponential, logistic and log logistic distributions for WTP, assuming that the WTP variables for each of three risk reductions are independent of one another.[14]

[14] Statistical theory suggests that treating our variables as independent is unlikely to affect much the point estimates of the parameters and the predicted mean or median WTP values. Standard errors, however, may be biased when one ignores the potential correlation between WTP for the different risk reductions. See Farhmeir and Tutz (1994).

Results for the best fitting distributions are reported in Table 4, along with the implied value of a statistical life, based on a discount rate of 3 percent.

Table 4. Annual WTP and VLS (pooled subsamples)

All WTP figures are annual payments for 10-years, expressed in US dollars.

Commodity	Median WTP (Mean WTP)	Standard Error	Best Fit	Implied VSL (000) (r=3%)
5 in 1,000 risk change over the next 10 years (WTP5)	\$113 (323)	\$13	Weibull	\$193 (\$551)
1 in 1,000 risk change over the next 10 years (WTP1)	\$50 (148)	\$6	Weibull	\$427 (\$1,262)
5 in 1,000 risk change from age 70 to age 80 (WTP5_70)	\$22 (169)	\$4	Weibull	\$38 (\$288)

As shown in Table 4, the estimated median WTP for decreases in mortality risk of one (WTP1) and five (WTP5) in one thousand are \$50 and \$113 per year, respectively. The implied value of statistical life (VSL) for WTP1 is \$427,000 using a discount rate of 3 percent. The VSL for WTP5 is \$193,000. However, the WTP falls to only \$38,000 when the risk change is experienced between ages 70 and 80 (WTP5_70).

As is expected in these types of surveys, mean responses are considerably higher than the median responses, leading to a tripling of the VSL for contemporaneous risk reductions and more dramatic increases for the future risk reduction case. Still, these estimates are far below those reported in labor market studies, which average around \$5 million 1990 USD.

A two-follow-up question format was used to obtain these estimates; however, this did not yield dramatic differences in WTP compared with WTP estimates computed from responses to the first follow-up question. Median WTP5 for the entire sample was \$123 with the latter approach, compared to \$113 with the two question follow-up approach. Median WTP1 was \$69 for the one follow-up approach compared to \$50 for the two follow-up question format.

Because of possible ordering effects, we provide WTP estimates for each subsample. Table 5 shows that respondents given the 1 in 1,000 risk change as the first commodity to value (subsample II) have higher median WTP5 values than respondents who valued the 5 in 1,000 risk reduction first (subsample I). The same ordering effect can be observed for WTP1 and WTP5_70. We therefore focus on WTP estimates from the first WTP question seen by respondents.

The results reported in Table 5 can also be used to perform internal and external scope tests. Internal scope tests formally show that, within a given subsample, larger risk reductions command greater WTP (holding constant the time horizon for the risk reduction), while a risk reduction of the same size is valued more highly if it starts immediately, as opposed to when the respondent reaches age 70.

Table 5. Annual median and mean WTP: Separate samples
All figures expressed in US dollars, and all calculations based on the Weibull distribution.

Commodity	Median WTP (Standard Error)		Mean WTP	
	Subsample I	Subsample II	Subsample I	Subsample II
WTP5	109 (17)	118 (17)	337	310
WTP1	36 (5)	72 (11)	106	194
WTP5_70	14 (3)	34 (7)	113	231

The external scope test compares median WTP for the first risk reduction valued by respondents, which differs between subsamples I and II) using a Wald test. The WTP figures to be compared are those displayed in the shaded cells of Table 5. The Wald test statistic is equal to 3.45, and falls between the 5 percent and 10 percent confidence levels. A larger sample size would be likely to improve on this result.

The sensitivity of WTP to scope is not altered significantly by deleting the responses of individuals who: (i) are indifferent between living in city A and city B; (ii) think it "unwise" to begin to pay now for a risk reduction to be realized 10 years into the future; (iii) do not believe that the baseline risk is their own; or (iv) think that the intervention might affect others.

The CV literature (Hammitt and Graham, 1998) suggests that results can be affected by limiting observations to respondents who indicate that they are certain of their WTP responses. We found that 32 percent of our complete sample were "certain" of their responses to the WTP5_70 question, 52 percent were "somewhat certain," and only 16 percent were "not certain at all." However, the WTP estimates and scope test results were virtually identical after dropping individuals who were "not certain at all."

D. Relationship of WTP1 and WTP5 to Risk Measures

Earlier theoretical and empirical work has focused on whether WTP depends on baseline risk, on the absolute or relative size of the risk change, and on the individual's age. To explore these relationships, we fit a number of alternative regression models, as reported in Table 6. The underlying econometric model in all cases is:

$$\log WTP_i^* = \mathbf{x}_i \beta + \varepsilon_i \qquad (2)$$

where WTP* is true willingness to pay, ε is a normally distributed error term, the vector **x** contains a measure of baseline risk or risk change (or a transformation of them) and β is a vector of coefficients. We choose to work with a log normal distribution for WTP to keep the interpretation of the coefficients straightforward. In practice, the fit afforded by the log normal distribution is very close to (and only slightly worse than) that of the Weibull distribution, and results are robust to replacing one distribution with the other.

Table 6. WTP5. Log normal distribution (T statistics in parentheses)

	A	B	C	D
Intercept	9.3161 (35.99)	93.95 (13.31)	9.5096 (37.12)	9.3165 (18.86)
Baseline risk	2.8431 (0.55)			
Log(baseline risk)		0.1001 (0.51)		
Relative risk reduction			-0.3043 (-0.46)	
Respondent is a male				0.6485 (1.86)
Age 35 to 39				-0.3604 (-0.50)
Age 40 to 44				-0.4757 (-0.74)
Age 45 to 49				0.4508 (0.77)
Age 50 to 54				-1.3572 (-2.01)
Age 55 to 59				0.1941 (0.29)
Age 60 to 64				-0.4504 (-0.52)
σ	2.0896 (12.68)	2.0895 (12.68)	2.0894 (12.70)	1.9984 (12.71)
Log likelihood	-314.05	-314.07	-314.09	-307.48

Table 6 shows that WTP5 increases with the baseline risk and decreases with the relative risk reduction, but not in a statistically significant fashion. The predictions for WTP offered by specifications (A), (B) and (C) are very similar, despite the different functional form for the regressor. Depending on the specification, WTP is about $82 for the 10-year risk change experienced by a person in the 30 to 34 years old age group, increases to about $94 for a 40-to-45 year-old, and is between $107 and $114 for the oldest respondents in the sample, the 60-to-64 year-olds.

However, when baseline risk and the percentage risk change variables are replaced with a gender dummy and dummies for the respondent's age group, the relationship between age and WTP appears to be non-monotonic, while males bid more. We refrain from drawing firm conclusions on the age effect, because most of the coefficients in the latter model are statistically insignificant and the sample (161 people) is small.

The results for WTP for a 1 in 1,000 risk change reveal a qualitatively similar story. The magnitude of the coefficients of baseline risk and the relative risk change is (in absolute terms) are generally larger than the corresponding coefficients in Table 6. The age effects (relative to the 30-35 age group) are consistently (if insignificantly) positive; i.e., older people are WTP more for a given risk reduction than younger people.

E. Relationship of WTP5 and WTP1 to Other Regressors

In addition to log baseline risk we added dummy variables to capture certain aspects of survey participants' understanding of the survey and their acceptance of the scenario. Specifically, we created dummies to indicate whether the respondent (i) did not believe the baseline risk was his or her own; (ii) took into account effects to others when answering the WTP questions; (iii) deemed it unwise to start paying today for the risk reduction; (iv) did not consider his or her future health in answering the WTP questions; and (v) was indifferent between city A and B.[15]

We found that all coefficients have the expected signs, except for the dummy indicating that the respondent thought about effects on others when answering the WTP questions. Most of the coefficients are insignificant. The variable that has the strongest association with WTP is the dummy for whether the respondent deems it unwise to start paying at this time. Its coefficient is negative and significant at the 1 percent level, and implies that respondents holding such an opinion have median WTP values that are about 75 percent to 70 percent--depending on whether we refer to WTP for 5 in 1,000 or 1 in 1,000 risk reduction--lower than those of other respondents. This finding is robust to dropping regressors from the right-hand side of the model. We do not have a ready explanation for why respondents who took into account effects on others should report lower WTP. We note, however, that the presence of a bequest motive may lower WTP (Cropper and Sussman (1988).

We also examined the effects on WTP5 and WTP1 of income, a college dummy, occupational dummies, a dummy (HEALTHY) denoting whether the respondent currently does not have serious health problems, nor has been hospitalized in the last five years, plus log baseline risk. Few individual characteristics turned up significant in the regressions. Most likely, this is due to the small sample sizes. Only the occupational dummies are significant in the

15 When we estimate the model for WTP for a 1 in 1,000 change, we form a dummy that takes on a value of one if the respondent declared himself or herself indifferent between city A and city B, when city A was described to have a mortality rate of 3 in 1,000, and city B of 2 in 1,000. When the estimate the model for a 5 in 1,000 change, we focus on indifference between city A and city B, when one has a mortality rate of 5 in 1,000 and the other of 10 in 1,000.

equation for WTP5, but these variables do not appear to significantly influence WTP1. Although insignificant, the income elasticity of WTP is in line with that from earlier studies (0.3).

F. Relationship of WTP5_70 to Other Regressors

In Table 7, we report some of the results of regressions explaining WTP for a risk reduction beginning at age 70. The regressors include a gender dummy, dummies for the respondent's age group, the respondent's self-assessed likelihood of surviving to age 70, and a dummy variable indicating whether the respondent believes it "reasonable" ("wise" in Japanese) to start paying now for a risk reduction to be delivered starting from age 70.

Table 7. WTP for risk reduction starting from age 70

Variable	Subsample I	Subsample II
Intercept	6.2084 (7.00)	6.9135 (9.72)
Male	-0.3984 (-0.97)	-0.2058 (-0.52)
Age group 35 to 39	0.7805 (0.92)	0.3827 (0.47)
Age group 40 to 44	0.1953 (0.26)	-0.2650 (-0.36)
Age group 45 to 49	0.4526 (0.66)	1.5758 (2.37)
Age group 50 to 54	-0.1081 (-0.14)	0.2959 (0.46)
Age group 55 to 59	0.8672 (0.11)	0.6306 (0.87)
Age group 60 to 64	0.3822 (0.38)	0.7435 (0.92)
Chance of surviving to age 70	0.0106 (1.08)	0.0045 (0.52)
Wise to pay now for risk reduction beg. at age 70	2.4620 (4.67)	2.6876 (5.90)
σ	2.1644 (10.60)	2.2179 (11.12)
Log likelihood	-245.95	-258.58

Table 7 shows that WTP is not explained by respondent age and gender, and that even the variable measuring the probability of surviving to age 70 does not have a statistically significant coefficient. However, as in earlier regressions, the belief that it is wise to start paying now for a risk reduction to be delivered starting at age 70 *is* positively and significantly associated with WTP.

V. FURTHER EXTENSIONS

The analysis of the pilot study results in Tokyo, together with the results of a small U.S. pre-test suggested a number of modifications of the survey instrument. Planning for the full-scale surveys to be conducted in Canada and the U.S., plus a follow-up survey in Japan suggests still other modifications. The most important are noted below:

1. To save money and standardize the survey, we have made the survey fully self-administered on a computer. Ancillary benefits are many, including: facility in targeting graphics and questions to the age and gender of the respondent; better graphics than are realistically possible with hardcopy; better comprehension of information presented by reinforcing the written text with voiceovers, so that respondents will both see and hear the questions. This last point is particularly important given point 2 below.
2. We will enlarge our sampling frame to include the 65-75 year age group. This age group was excluded in the Tokyo survey due to concerns about communicating probabilities and other concepts to this group. We have now heavily tested the survey with individuals in this age group with good success. Subjects in this group will be asked only the WTP questions for contemporaneous 10-year risk changes.
3. We will be including more extensive health status questions in the survey. These variables were rudimentary in the Tokyo survey, which may account for their lack of significance. We plan to use standard questions to describe the quality of life to aid in the estimation of a health status index in the literature.
4. We have developed additional education screens on the meaning of probability and risk of death. Specifically, we have added a series of questions to reinforce the time dimension of the risk changes, what we mean by risk of death and how risk changes with age, among other things.
5. Finally, our budget will permit the further development and administration of a CV survey identical to the one described in this section, but expressing mortality risk changes in terms of life expectancy changes. A comparison of results for both surveys should reveal which format is superior in eliciting internally and externally consistent responses.

VI. CONCLUSIONS

Mortality risk reductions associated with reduction in pollution are not easily valued. These mortality risks are generally realized later in life or by older people. Only one study to date (Johannesson and Johansson, 1996) has been able to incorporate the futurity characteristic and none have heavily sampled older people. In addition, CV studies of mortality risk present convincing evidence that small changes in probabilities are not being successfully communicated to respondents. Our work may eventually overcome these difficulties. Not only have we developed a survey instrument that focuses on mortality risks realized in the future, but the questionnaire is administered in-person with extensive use of visual aids. Tests of cognition are imbedded in the instrument. The new survey will be administered to seniors as well as younger people.

Our preliminary results from the Tokyo pilot indicate that individuals are able to distinguish between different magnitudes of small changes in mortality risks and between the same change in these risks occurring at different times (although the latter has not yet been subjected to an external scope test). Changes to the survey and a big increase in sample size may improve performance on the internal validity tests and the results of the scope tests. Although the current results can only be considered suggestive, if they were to remain after administration of the survey to a larger sample and subject to some other caveats, they would imply that the VSL's currently used in benefit-cost analyses of environmental policies are significant overestimates.

Examples of other caveats include the effect on WTP of involuntary exposure to risk and altruism. One could argue that our scenarios already involve involuntary exposure because a person's baseline risk is based on his age and gender (over which he obviously has no control) and then he is given the opportunity to take steps to reduce those risks. As for altruism, including the effect of altruism on willingness to pay would no doubt increase WTP above our estimates. However, including what is termed benevolent altruism (where an individual cares about other's utility) would lead to serious double counting of benefits, while including paternalistic altruism (where an individual cares about other's consumption) would not. Here one possible line of argument is that individuals view individuals outside of the family benevolently and view those inside the family paternalistically. In this case, our VSL estimates might be underestimates of adult VSL because their altruistic feelings towards other family members are not included.

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