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The Effect of Risk Characteristics on the Willingness to Pay for Mortality Risk Reductions from Electric Power Generation

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Abstract. The objective of this study is to estimate willingness to pay (WTP) for the reduction of mortality risks caused by fossil fuel (natural gas, coal and oil) versus nuclear electric power generation systems and to examine the influence of risk characteristics involved with electric power generation on WTP. A choice experiment was conducted to achieve these objectives. The attributes for nuclear risks in the experiment included the probability of disasters and the expected losses if a disaster occurs. We find evidence of (i) a baseline effect (where WTP is sensitive to hypothetical versus actual baseline expected mortality); (ii) a 'labeling effect,' where, surprisingly, the term 'nuclear' has no effect on WTP, but the term 'fossil-fueled power generation' results in lower WTP; and (iii) disaster aversion, meaning that people focus on the conditional loss from a nuclear disaster, not the probability. We also find that the WTP for reducing deaths from a nuclear disaster is about 60 times the WTP for routine reducing fossil-fuel generation-related deaths.

Key words: choice experiment, coal-fired generation, mortality, nuclear power, risk characteristics, willingness to pay

1. Background

To formulate policy in the electric power sector, it is necessary to take the 'external costs' of electricity generation into account. These are damages caused by the use of energy not reflected in the market price of electricity. In Japan these concerns may well influence the choice between nuclear and fossil fuel (natural gas, coal and oil) generation as the major options for new power systems. Not only do these technologies have very different production costs, but their external costs – both estimated and perceived – could be very different as well. In choosing to add new capacity, differences in such external costs would obviously play a major role.

Several large research projects have examined the external costs of electric power generation in monetary terms [e.g. Oak Ridge National Laboratory and Resources for the Future (1994) in the United States, Extern-E (1999) in Europe]. These studies show that most of the external costs of power generation systems arise from risks to health, especially mortality risks, arising in the generation stage. The willingness to pay (WTP) for mortality risk reductions used in the calculation of external costs dominates the cost categories.

The Value of Statistical Life (VSL) (which is the willingness to pay for risk reductions divided by the risk reduction) used in the U.S. and Europe is in the range of 100–1000 million yen, which is generally applied uniformly to any change in mortality risk. However, there is considerable debate about this practice and suggestions in the literature that VSLs (and therefore, WTP) should be heterogeneous, varying with risk characteristics, such as the size of the risk change, the voluntariness of the risk, and the dread associated with the risk, as well as population characteristics, such as the age of the individual and their health status (Slovic 1987; Slovic et al. 1979; Krupnick et al. 2002).

With respect to electric power generation, this debate translates into one about whether differences in the size of the mortality risks posed by nuclear and fossil fuel power generation (both actual and perceived) and the dread that may be attached to nuclear power result in different WTPs. This topic has not been researched in Japan or anywhere else to our knowledge. There have been a number of studies examining risk attitudes towards nuclear and fossil fuel generated power (e.g. Slovic 1987), but no head to head comparisons of WTP for mortality risk reductions from these technologies.

2. Objectives and Methods

The main objectives of this study are:

(i) to estimate the WTP for reduction of mortality risks caused by fossil fuel power generation versus mortality risks caused by nuclear power generation,

(ii) to examine the influence of risk characteristics involved with electric power generation on WTP, specifically, the effect of alternative baseline risks and the effect of the nuclear power label, and

(iii) to examine an effect we call ‘disaster aversion,’ by which individuals base choices on losses if a disaster occurs and ignore the probability of a disaster. Specifically, do individuals process based on expected deaths, on the probability of preventing deaths and the number of deaths prevented, or on one or the other?

A survey designed as a choice experiment was conducted to achieve these objectives. To address (i) above, this survey presents respondents with alternative mortality risk reduction programs based on reductions in nuclear disaster risks and routine fossil fuel generation mortality risks (from air pollution). The nuclear risks are specified as the probability change, the change in the size of the loss if the disaster happens, and the expected reduction in loss, while the fossil fuel reduction is specified in terms of a reduction in lives lost.

Concerning baseline risks ((ii) above), we think this is an important issue because, as the nuclear industry often asserts, when the huge death toll from a catastrophic event is multiplied by the extremely small probabilities associated with that event, the resulting product is far less – several orders of magnitude less – than the death toll from the smaller, but much more likely effects from burning fossil fuels. This difference in baseline risks leads, according to the valuation literature, to the hypothesis that the sector with the higher baseline risk will have the higher WTP for a risk reduction, other things being equal. Since there may be a huge divergence between perceived and actual risks, however, it is not clear if in the public's mind nuclear or fossil fuel power has the lower risks. At the same time, because of the well-known difficulties people have in processing small probabilities and their tendency to overweigh them, WTP for nuclear risk reductions may be overstated.

We tested this hypothesis by developing information treatments using the actual baseline risks and a treatment with a hypothetical, much larger baseline risk for nuclear power and smaller risks for fossil fuel power. To avoid confounding the nuclear risk perception issue with the baseline issue, this hypothetical risk treatment was conducted without labeling the source of the risks.

Concerning the labeling effects, with the legacy of nuclear war in Japan, many in the public doubtlessly make a connection – between nuclear power and nuclear bombs. They may also be concerned about deaths from radiation being more horrible than deaths by other means. Thus, the 'nuclear' label may carry with it weight – dread and fear that would not be present if an equivalent catastrophe were to possibly occur, but with a cause not so named (Krupnick et al. 1993). We hypothesize that just the use of the term nuclear will raise the WTP to avoid generation from this source, compared to the same scenario without a named cause. One can also hypothesize that the label 'fossil fuel' power has either no effect on WTP (when compared to an otherwise identical scenario where fossil fuel power is not mentioned) or perhaps a smaller negative connotation than that for the nuclear power label. Therefore, we developed information treatments that present actual baseline risks, but are unlabeled as nuclear or fossil fuel sectors, to compare with the treatments where the actual risks are labeled.

Finally, to address disaster aversion in (iii) above, we note that the events in Chernobyl and Three Mile Island have firmly fixed catastrophe (or disaster) in the public's mind when the subject of nuclear power comes up. At the same time, it is probably fair to say that fossil fuel power bears none of this concern. Rather, the concern about fossil fuels is that conventional pollutants that are harmful to health and the environment will be emitted on a daily, continuing and routine basis.

A priori, it is not clear if the public would prefer a technology with extremely low probability of disaster to one with on-going, significant and not at all uncertain health damages. We hypothesize, however, that there is a special preference for avoidance of a disaster at a nuclear power plant to an avoidance of routine damages from a fossil fuel power plant. It may manifest itself in assuming that the probabilities of such an event are higher than scientists say, that the catastrophe will be larger than they say, or both, or in a focus on the qualitative aspects of risks noted above. Evidence of such outcomes is discussed in Adler (2003) and evidence that individuals overstate low probability events can be found in Hakes and Viscusi (2004).

We examine a special version of this effect, which we refer to as 'disaster aversion,' in which individuals process on the basis of losses if a disaster occurs and ignore the probability of disasters. The existence and strength of this effect is examined econometrically by testing various models including or excluding the probability of disaster, the size of the consequences and the expected consequences.

3. Summary of Results

We find evidence of (i) a baseline effect (where WTP is sensitive to hypothetical versus actual baseline expected mortality); (ii) a 'labeling effect,' where, surprisingly, the term 'nuclear' has no effect on WTP, but the term 'fossil-fueled power generation' results in lower WTP; and (iii) disaster aversion, meaning that people focus on the conditional loss from a nuclear disaster, not the probability. We also find that the WTP for risk reduction from a nuclear disaster is about 60 times that for routine fossil-fuel generation-related deaths. Finally, we find significant heterogeneity in the preferences of the respondents based on age and education.

4. Survey Design

4.1. PRESENTING MORTALITY RISK REDUCTIONS

Survey-based estimates of WTP are typically identified by asking individuals what tradeoffs they are willing to make between money and changes in their own risk of death (e.g. Krupnick et al. 2002). However, for the case of risk reductions in the generation of electric power, it is difficult to conceive of a scenario in which this risk reduction could be made specific to an individual, i.e., made 'private' In other words, the risk context for the case of power generation is a public risk where the respondent and other individuals will be simultaneously affected by any risk reductions. Therefore in our survey the impact on society of mortality reductions is shown – a public benefit.

Presenting risk reductions in the public goods context introduces at least two challenging issues. First, the values expressed will depend on the size of population affected or the size that the individual is thinking about when making the tradeoff decision (see Green et al. 1994). Thus the scale of the assessment (e.g. national, regional) should affect the WTP. We present the risk reductions as national scale programs. Second, individuals have preferences for their own exposure to risks as well as the level of exposure to others (family members, etc.). The issue of altruism in the value of public programs for risk reduction is a topic for further research.

In any hypothetical survey instrument one is concerned about the degree to which respondents will answer as if they are actually making choices in a market or salient context. In this survey effort was made to make the survey as consequential as possible. The policy issues and scenarios were realistic and the respondents were told that the responses would be important for policy formation. Design features such as uncertainty questions after the valuation questions, checks for processing and attentiveness were incorporated into the survey. These design features have been used in the past to develop surveys that generated hypothetical choices that closely corresponded to choices made in market-like contexts.

4.2. STRUCTURE OF THE QUESTIONNAIRE

The questionnaire opens with demographic questions. The next section explains in a general way the concept of expected lives lost in a disaster (explaining probability and its multiplication by lives lost if a disaster occurs), giving numerical examples, and contrasting this concept to routine lives lost. The respondent is also asked about whether he or she has any preferences for avoiding an equivalent number of deaths from routine and disastrous sources.

At this point, the survey is developed into three versions. In Version 1 (see Table I) descriptions are presented of nuclear and fossil fuel power generation in Japan, complete with pie charts, maps and figures showing how these activities can cause mortality. The actual baseline death rates, probabilities, and estimated deaths in a disaster are also presented. The effect that the small annual probability of a disaster (30 per million) coupled with an estimated 4000 deaths from such a disaster has on expected deaths (0.12 lives lost per year) is shown graphically (see http://www.rff.org. for a draft of the survey). Comparison of expected deaths from nuclear power generation, fossil fuel power generation and many other causes of deaths are then made using a logarithmic risk ladder. This is followed by a question about whether the respondent believes the baseline information and, if not, is asked to assume it is true for the duration of the survey.

Table I. Versions of the questionnaire and features of choice experiment questions

Version		1	2		3	
Sample size		285	303		322	
Number of choice tasks per respondent		Six	Six		Six	
Choice tasks		Six	First three →	Second three	First three →	Second three
Context		Labeled*	Unlabeled**	Labeled	Unlabeled	Labeled
Baseline mortality risk		Actual†	Hypothetical‡	Actual	Actual	Actual
Nuclear/disaster risks	Probability of a disaster per year	30/1 million	50/10,000	30/1 million	30/1 million	30/1 million
	Lives lost if a disaster happens (persons)	4000	20,000	4000	4000	4000
	Lives lost per year (expected, persons)	0.12	100	0.12	0.12	0.12
Fossil fuel/ routine risks	Lives lost per year (persons)	1000	100	1000	1000	1000

*'Labeled' stands for the context labeled by power generation activities.
**'Unlabeled' stands for the context of abstract activities (not mentioning power generation activities).
†Actual baseline refers to the best estimates of Japanese mortality risk by power generation activities.
‡Hypothetical baseline sets the expected lives lost per year by disaster risks equal to lives lost per year by routine risks. This is not an actual estimate of the risks generated by power production.

The next section describes the choice experiment. Each respondent faces seven choice experiment tasks, although the first task is a practice question where there is a dominant choice. If the person gets this choice wrong they receive further explanation about why their choice is not appropriate.

The respondents are then presented with six choice experiments, each followed by a question about the degree of certainty the respondent had about their choice. A typical choice screen is presented as Figure 1. Respondents are presented with three options or alternatives concerning mortality risk caused by nuclear and fossil fuel electricity generation: staying with the current situation, implementing program 1 to reduce risks or implementing program 2 to reduce risks. Each alternative contains a description of the post-program attribute levels and changes that would occur, including, for nuclear, the probability of an accident (a nuclear disaster) and the lives lost if a disaster occurs, as well as the expected number of deaths and for fossil, the number of lives lost annually from 'routine' pollution. The respondent is also provided with the expected number of deaths for the entire program.[1] Finally, the cost of each program – in terms of increased taxes per household – is provided on the line above the choice line. A fractional factorial design is used to construct the design points and to use attribute levels that are orthogonal. Our data are repeated choice observations for each individual (6 each). Repeated choice data are elicited from respondents to increase the information content in each survey response. In the analysis discussed below we address issues surrounding use of these repeated data.

The last section of the survey contains debriefing questions on the reasons for the vote, such as whether the respondent thought their own mortality would fall as a result of the program, whose mortality they considered (allocating 10 points to one's self, one's family members, and the community in general), why they voted the way they did, whether they believed the effects of the programs, and if they didn't believe the baseline, how large they thought the effects were. Respondents were also asked attitudinal questions about the risks posed by these power sources, whether they prefer additional generation that comes from burning fossil fuels or nuclear energy, and several socio-demographic questions of a more sensitive nature (about health and income).

Returning to Table I, Version 2 presents two abstract activities, one causing death from disaster, the other from routine operations, although the expected deaths from these two activities are equal in the baseline. This is followed by three choice questions involving these abstract activities. Then, the discussion of power generation in Japan appears, along with the appropriate baseline information, followed by three more choice questions, of identical format to Figure 1 above.

Versions 3 is identical to Version 2 – in that abstract, unlabeled activities appear in the choice experiment first, followed by labeled activities. However,

		Attributes	Current situation	Program 7	Program 8
PRODUCT	Break-down of effects of Nuclear power sector	(a) Annual probability of a severe accident	30 / 1 million	30 / 1 million [No change]	30 / 1 million [No change]
		(b) Lives lost <u>if a severe accident happens</u>	4000 persons	1500 persons [2500-person reduction]	1500 persons [2500-person reduction]
	Nuclear power sector	(c) Lives lost per year Calculatedby(a)*(b)=(c)	0.12 person	0.05 person [0.07-person reduction]	0.05 person [0.07-person reduction]
SUM	Thermal power sector	(d) Lives lost per year	1000 persons	990 persons [10-person reduction]	998 persons [2-person reduction]
	Total reduction of lives lost per year		**0**	**10.07-person reduction**	**2.07-person reduction**
	More tax per household per year (Costs for new public policies)		**0**	**8000 yen**	**2000 yen**
	Which one of these three options would you vote for?				

1000 yen per year = About 80 yen per month

Figure 1. Choice experiment question (an example choice set).

the baselines initially given for the abstract activities are the actual baselines for the nuclear and fossil fuel generation.

By comparing results from Version 1 to Version 3 (unlabeled) we can test for the labeling effect. By comparing Version 2 (unlabeled) to Version 3 (unlabeled) we can test for the baseline effect. By examining whether the probability, the lives lost or the expected lives lost are important attributes we can test for the disaster effect as well as examine how people process this kind of information. WTP information can be derived from the 'clean' test in Version 1 or the possibly ordering-biased results from Versions 2 or 3, or by pooling all the power generation results.

4.3. SURVEY DESIGN PROCESS

To design the survey, six focus groups with six to seven participants each were held. We originally thought that information about morbidity would influence respondents' choices and, therefore, the questionnaire described respiratory disease and cancer cases. Participants in the focus groups generally disregarded the information about illnesses, focusing instead on deaths. Hence, we removed discussion of morbidity from the survey.

We also were interested in respondent reaction to disaster risk from fossil fuel generation and routine risks from nuclear generation. We realized that fossil-fueled generation systems pose a very small risk of a major disaster relative to nuclear generation systems. At the same time, emissions from nuclear generation systems may cause health effects from routine operations, as fossil fuel generation does. However when we presented this information to focus groups, participants were confused and disregarded the information because these effects were very small and unexpected. Thus, the survey focuses only on disasters in the nuclear sector and 'routine' losses in the fossil fuel sector.

The resulting version of the survey, which was basically version 1 of the finalized questionnaire, was pre-tested on an 87-person convenience sample. Based on the results of pre-tests we made minor changes to the questionnaire and then implemented the final version of the survey.

5. Implementation of the Survey

5.1. ADMINISTRATION OF THE SURVEY

The sample of respondents was drawn through random sampling of the general public aged 20 or older living in the Tokyo Metropolitan region or in Gifu City in the midland of Japan. This sampling was conducted using the Basic Resident Registers in each area of local governments, which list all residents. Surveys were hand delivered to respondents and were picked up by the survey firm the following day. Approximately 1500 Tokyo residents and 1000 Gifu city residents were sampled with responses from 910 and 603, respectively, resulting in response rates of 60% in Tokyo and 58% in Gifu City. Respondents were instructed not to jump ahead, but to answer questions in the order they were presented.

5.2. CHARACTERISTICS OF RESPONDENTS

Table II provides the descriptive statistics for the entire sample as well as for each regional sub-sample. Forty-six percent of the respondents are female, which is less than the national average of 52%. The Gifu City subsample has more female respondents (53%) than that of the Tokyo metropolitan area (43%). On average, the Gifu subsample respondent (51 years old) is a little older than that of the Tokyo metropolitan area respondent (47 years old). The sample has more members per family (3.6 persons) than the national average (2.7). However, for households where at least one person is employed, the average family size is 3.5 persons. The average income of the sample is close to the national average. In total, our sample is relatively representative.

Table III provides additional descriptive statistics from attitudinal and behavioral questions asked in the survey and roughly in the order they appear. As would be expected most people state that they avoid engaging in risky behavior. In the beginning of the survey people were asked whether they prefer reducing mortality that occurs on a routine basis or that occurs through disasters. About half had no preference, but of those that did only one-third preferred reducing deaths from routine activities. This is in

Table II. Descriptive statistics ($N = 910$)

Respondents' characteristics		Unit	Tokyo + Gifu N = 910	Tokyo Metropolitan area N = 603	Gifu City N = 307
Proportion Female [national average: 51.5**]		%	46.3	43.0	52.8
Age	20–29 years old	%	15.2	17.6	10.4
	30–39 years old		16.8	15.9	18.6
	40–49 years old		19.1	20.1	17.3
	50–59 years old		23.3	24.5	20.8
	60–69 years old		17.9	16.4	20.8
	70–79 years old		6.4	4.8	9.4
	Over 80 years old		1.3	0.7	2.6
	Average	Years old	47.9	46.5	50.6
Average number of persons in household [national average of all households: 2.74† national average of labor's households: 3.47‡]		Persons	3.6	3.43	3.85
Proportion of respondents currently married		%	73.0	79.8	69.5
Average number of children in household*		Persons	1.4	1.4	1.4
Average years of education*		Years	13.0	13.3	12.5
Share of respondents' occupation	Company employee	%	33.6	37.1	26.7
	Self-employed		16.2	13.9	20.5
	Engaged in agriculture/ forestry/fishery		0.2	0.2	0.3
	Public officer/teacher		7.3	7.3	7.2
	Homemaker		17.1	15.6	20.2
	Student		2.7	3.8	0.7
	Part-time job		10.5	10.4	10.7
	Unemployed		12.0	11.4	13.0
Percentage of respondents who live in Gifu City		%	33.7	–	–
Total combined household income*	~200 million yen	%	8.6	8.6	10.7
	~400 million yen		21.4	23.5	22.8
	~600 million yen		22.2	21.5	29.0
	~800 million yen		15.4	17.9	14.5
	~1000 million yen		12.6	15.5	10.3
	~1500 million yen		8.9	9.9	9.3
	~2000 million yen		2.1	2.0	2.8
	Over 2000 million yen		0.9	1.1	0.7
	Average [national average of all households: 602.0† national average of labor's households: 661.4]	Million yen	632.8	644.8	610.2

Table II. Continued

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*Blank answers are omitted from the calculations.
**Reference: Statistics Bureau, Ministry of Public Management, Home Affairs, Posts and Telecommunications 2002. 2000 Population Census of Japan.
†*Reference*: Statistics and Information Department, Minister's Secretariat, Ministry of Health, Labour and Welfare. 2004. 2002 Comprehensive Survey of Living Conditions of the People on Health and Welfare.
‡'Labor's household' means the household whose head is a laborer. Reference: Statistics Bureau, Ministry of Public Management, Home Affairs, Posts and Telecommunications 2002. 2001 Family Income and Expenditure Survey.

qualitative accordance with the small amount of literature on this topic (see Jones-Lee and Loomes 1994). Further, these responses may be compared to those of a similar debriefing question, which asked for preferences for nuclear versus fossil-fueled generation plants. To this question, two-thirds preferred the fossil-fueled plants, remarkably consistent with the answers to the earlier question.

Beliefs in the baseline death rates and accident probabilities are important to gauge because they affect the credibility of the survey results. Only 17% of the sample did not believe the nuclear baselines, while 13% did not believe the fossil-fuel mortality baseline. Of these, there was a tendency to believe that the baselines were too low for nuclear disaster probability and mortality and were too high for fossil-fuel mortality. The most important health and environmental concerns people listed for these technologies also bears on the credibility of the survey. We would like to see such concerns focused on the attributes being examined in the choice experiments. In fact, these attributes do rate highly, relative to others, such as morbidity and plant location. However, effects on the environment, which are not mentioned or listed as an attribute in any of our programs, are the most prevalent effect mentioned by the sample. We note, however, that these environmental concerns come up equally for both technologies. Hence the relative rankings in the choice experiments may not be biased.

Finally, respondents were asked whose mortality they were thinking about when they answered the choice questions. Each respondent was asked to allocate 10 points to him or herself, their family members, and others. While each category received roughly the same number of average points, heterogeneity in responses is masked by this statistic. In fact, almost 70% of the sample gave the majority of points to one of the three categories, with, for example, 44% of the sample allocating 6–10 points to either themselves or to their family (and a much larger fraction (about 67%) allocating most points to these two categories together). The upshot is that most people were not assigning much importance to mortality reductions to those outside of their family.

Table III. Descriptive statistics for attitudes and behavior

Question	Mean
Engage in risky behavior (%)	8
Avoid risky behavior	23
Prefer reducing routine mortality over reducing mortality from disaster (all else equal) (%)	33
Do not believe nuclear baseline (%)	17
Respondent probability relative to baseline probability	
Much higher	5.2
Higher	8.5
Lower	2.5
Much lower	1.0
Respondent lives lost relative to baseline lives lost	
Much higher	5.1
Higher	9.6
Lower	1.6
Much lower	1.0
Do not believe thermal baseline (%)	13
Respondent lives lost relative to baseline lives lost	
Much higher	1.0
Higher	5.7
Lower	3.2
Much lower	3.6
Prefer new thermal plants to new nuclear plants	64
Most important concerns about externalities from nuclear generation (mark all that apply from list) (% of people checking the following)	
Environment	62
Effects on future generations	48
Probability of accident	45
Lives lost if accident occurs	43
Morbidity from cancer	28
Location of plants	15
Number deaths per year	13
Most important concerns about externalities from thermal generation (mark all that apply)	
Environment	65
Effects caused by routine operation	33
Number deaths per year	28
Morbidity	20
Location of plants	16
Whose mortality mattered? (points out of 10 points distributed)	
Own	2.8
Family	3.8
Other	3.4

Table III. Continued

Question	Mean
% sample with over 5 points to	
Own	12
Family	32
Other	24

5.3. SELECTION OF RESPONDENTS FOR ANALYSIS

We 'cleaned' the sample based on answers to up to two practice choice questions and debriefing questions. Everyone faced a practice question that included a *dominant* program, one that is more beneficial than the other program and costs less. The second practice question is only for respondents who chose the *dominated* option and is designed to allow individuals who chose the dominated program to correct this error. Twenty-two individuals chose the *dominated* program in the first practice question while only seven of these chose it again, and were dropped from further analysis.

We also removed respondents according to their justification for voting for the *status quo* in all six questions. We dropped those who said: 'Programs might be important but I don't like the idea of paying for the programs by raising taxes,' 'I don't believe the effects of the programs,' or 'Other types of programs are necessary.' Among those who chose a program, those who chose the reason, 'I didn't consider the effects of the program but I believe it is a good thing to pay for the programs about power stations' or 'I think it stimulates the energy industry by paying for the programs of power stations' were also dropped. Twenty-nine percent of the sample choose *status quo* for all their choices with 16% dropped because of their justifications. An additional 13% were dropped whose reason for choosing a program was listed above. The total sample in the rest of the analysis was thus 639 of 910 respondents in total.

6. Methods and Results

6.1. METHODS

The data generated in the choice tasks are responses to scenarios based on cost (a tax increase), deaths in the nuclear sector (based on the probability of a disaster in the nuclear sector and the number of lives lost if a disaster occurs) and deaths in the fossil fuel sector. First coefficients of variables in the profile of alternatives, or marginal utilities, are estimated with a conditional logit model assuming that preferences are homogeneous over respondents.[2] Several model specifications are examined. Second, we estimate mixed logit models (random parameter logit models) assuming a distribution for the coefficients of the attributes, and conditioning on selected demographic variables, to examine sample heterogeneity.

The random utility model is assumed to express overall utility U_j when selecting profile j as

$$U_j = V_j + \varepsilon_j = \beta \cdot x_j + \varepsilon_j \quad (j = 1, 2, \ldots, J)$$

V_j is the observable part of utility, ε_j the unobservable or stochastic part, x_j a vector of attributes in profile j, and β a parameter vector. Assuming that the error term follows a Gumbel distribution (Type 1 extreme-value distribution) and fixing the scale parameter to be unity, the probability P_j of selecting profile j is as follows:

$$P_j = \frac{\exp(V_j)}{\sum_k \exp(V_k)}$$

Here, k is the number of alternatives or profiles presented at once. Maximum likelihood estimation is used to generate estimates of the β parameters. In the mixed logit model we assume that the β parameters are distributed normally over the individuals. In this case the means and variances of these parameter distributions are estimated using simulated maximum likelihood (Train 2003).

6.2. SPECIFICATION OF THE UTILITY FUNCTIONS

Five attributes related to mortality are presented in the choice experiment. However, those attributes result in only three truly independent parameters because 'Expected lives lost per year in the nuclear power sector' is a product of 'Probability of a disaster at a nuclear power plant' multiplied by 'Lives lost if a disaster happens at a nuclear power plant' and 'Total of expected lives lost' is a summation of 'Expected lives lost per year in the nuclear power sector' and 'Lives lost per year in the fossil fuel power sector.'[3]

The following three models arising from combinations of the set of attributes are examined.

Specification 1: $V = \beta_C * Cost + \beta_{EL} * EL$
Specification 2: $V = \beta_C * Cost + \beta_{NL} * NL + \beta_{TL} * TL$
Specification 3: $V = \beta_C * Cost + \beta_P * P + \beta_L * L + \beta_{TL} * TL$
V: utility function.
β_i: coefficient of attribute i
$Cost$: amount of additional tax
P: probability of a disaster in the nuclear power sector
L: lives lost if a disaster happens in the nuclear power sector
EL: total of expected lives lost in the nuclear sector and the fossil fuel sector
NL: expected lives lost per year in the nuclear power sector
TL: lives lost per year in the fossil fuel power sector

An alternative specific constant (ASC) is added to each specification to account for utility separate from the attributes that are captured in the *status quo* (current situation) choices. Specification 1 is the simplest model including only the total expected lives lost in the nuclear power sector and fossil fuel power sector, assuming expected values are used in choosing an alternative. In Specification 2 the mortality risks of a profile of alternatives are divided into two parts 'Expected lives lost per year' in the nuclear power sector and those in the fossil fuel power sector. In Specification 2, it is assumed that the 'Expected lives lost per year' in the nuclear and fossil fuel power sectors are considered separate goods. This allows for the examination of different WTP for risk reduction in the two sectors. Specification 3 includes parameters for 'probability of a disaster' and 'Lives lost if a disaster happens' in the nuclear power sector separately. This model assumes that utility is not based on expected values but arises separately from the probability of a disaster and the lives lost if a disaster occurs. Note that while the utility function is specified as depending on deaths in each sector, the marginal WTP measures presented are those for the value of reducing one death per year.

6.3. CHOICE OF A UTILITY SPECIFICATION: HOW RESPONDENTS DIFFERENTIATE RISKS

To assess the performance of the various specifications and limit the number of models to test, we tested whether a pooled model over all versions and choice tasks with actual baseline risks and labeling is significantly different than the individual version unrestricted models. A test of the hypothesis that the pooled model is not significantly different from the individual unrestricted models cannot be rejected at a 5% level (e.g. for Specification 2 this test yields a chi-squared value 13.58, 8 degrees of freedom). Therefore, where appropriate, we use the pooled model below.

We apply Specifications 1, 2 and 3 to pooled data on the labeled sections of all versions and we examine the ability of the different specifications to explain the choices of the respondents. The estimated coefficients are shown in Table IV.

The likelihood value is the largest for the specifications with expected losses in the nuclear sector and fossil fuel sector separately entering the utility function (2 and 3). These specifications are an improvement relative to the model in which the total expected lives lost is used. Clearly, the utility of reducing lives lost in the two sectors appears to be quite different. The model that contains the probability of a disaster and the lives lost if a disaster occurs in the nuclear sector (Specification 3) performs as well as the model with expected lives lost in the two sectors (Specification 2) although the probability of disaster parameter is not significant.[4] Nevertheless, the model using expected deaths in each sector appears to be a parsimonious and well

Table IV. Three conditional logit model specifications of preferences for risk reductions [pooled sample of labeled sections (all versions, $N = 639$ respondents[a])]

Specification	1		2		3	
Parameter	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
ASC for status quo	−0.431**	[0.000]	−0.117	[0.218]	−0.228**	[0.007]
Annual tax increase per household (yen)	−1.34E − 04**	[0.000]	−1.40E − 04**	[0.000]	−1.37E − 04**	[0.000]
Nuclear/probability of a disaster					−2.78E − 03	[0.384]
Nuclear/lives lost if a disaster happens					−1.12E − 04**	[0.000]
Nuclear/annual lives lost (expected)			−4.37**	[0.000]		
Fossil fuel/annual lives lost			−7.29E − 02**	[0.000]	−7.21E − 02**	[0.000]
Total lives lost (annual, expected)	−7.20E − 02**	[0.000]				
Log likelihood	−2564.115		−2553.078		−2552.236	
Rho-squared	0.06958		0.07340		0.07352	

**1% significant, *5% significant.
[a]Each respondent faced 6 choice tasks in their survey. See Table I for details.

performing statistical model that facilitates welfare analysis.[5] Based on these results we do not use Specification 1 in any further testing. We now turn to a discussion of analyses from the separate surveys and return to the pooled model later.

Table V provides the conditional logit model estimates as well as marginal WTP values for utility Specification 2, for both labeled and unlabelled contexts and for both hypothetical and actual baselines. This table is constructed along the same lines as the flow of the survey, with version 1 providing estimates based on the actual baseline and labeled case, version 2 first providing a set of estimates from the hypothetical baseline, unlabeled case and then the actual baseline labeled case and version 3 providing estimates of the actual baseline unlabeled case and then the actual, labeled case. The final column in Table V provides the pooled model for the actual baseline, labeled case.

Examining the lower half of Table V first, focusing on actual baselines and labeled cases, a reduction in the lives lost per year in the fossil fuel sector generates very different values than reductions in the nuclear sector. Furthermore, observing the marginal WTP for mortality risk reduction in Table V, it can be seen that reductions of disaster-type risks generally have a higher marginal WTP than those of 'routine' risks. The marginal WTP for risk reductions in the fossil fuel sector is approximately 500 yen while a similar risk reduction in the nuclear sector is valued at more than 30,000 yen. The latter is about 60 times the former. The risk context significantly affects the valuation results. Further examination of these effects of risk characteristics is described below. It is noteworthy that the coefficients on tax and deaths in the two sectors are quite robust across versions with only version 3 producing estimates for the losses in the nuclear sector that differ from the other models.

6.4. EFFECTS OF RISK CHARACTERISTICS

6.4.1. *Baseline effects*

The effect of changing the baseline risk levels can be seen in Table V by comparing the unlabeled model with the hypothetical baseline to the model with the actual baseline. In the hypothetical baseline case the baseline risk for the 'disaster' is changed to be comparable to the annual mortality case. In other words, the expected lives lost per year are designed to be identical between the fossil fuel and nuclear sectors. The disaster and routine risks now have similar marginal values associated with risk reductions, 291 and 433 yen, respectively. The marginal WTP for mortality reductions in the 'disaster' case is reduced by orders of magnitude relative to the labeled/actual baseline cases. This suggests that when faced with similar expected values

Table V. Estimates of parameters in utility Specification 2 (conditional logit model) and marginal WTP measures

	Parameter		Version 1 (N=198)[3]	Version 2 (N=204)[3]	Version 3 (N=237)[3]	All Versions (N=639)[3]
Unlabelled	Baseline			Hypothetical	Actual	
Unlabelled	ASC for Status Quo			-0.385* [0.016]	-0.507** [0.004]	
Unlabelled	Increase in tax per household per year (Yen)			-1.63E-04** [0.000]	-1.36E-04** [0.000]	
Unlabelled	Mortality rarely occurs (disaster mortality)	Lives lost per year		-4.74E-02** [0.000]	-0.664 [0.695]	
Unlabelled	Mortality rarely occurs (disaster mortality)	Marginal WTP [95% confidence interval[2]		291 yen 【139 to 458】	- 【-】	
Unlabelled	Mortality occurs every year (routine)	Lives lost per year		-7.06E-02** [0.000]	-0.104** [0.000]	
Unlabelled	Mortality occurs every year (routine)	Marginal WTP [95% confidence interval]		433 yen 【224 to 630】	760 yen 【543 to 1,028】	
Unlabelled	Log likelihood			-611.5216	-712.1009	
Unlabelled	Rho-squared			0.08749	0.08578	
Labeled	Baseline		Actual			
Labeled	ASC for Status Quo		2.30E-03 [0.987]	-2.16E-02 [0.912]	-0.391* [0.026]	-0.117 [0.218]
Labeled	Increase in tax per household per year (Yen)		-1.41E-04** [0.000]	-1.63E-04** [0.000]	-1.22E-04** [0.000]	-1.40E-04** [0.000]
Labeled	Nuclear sector (disasters)	Lives lost per year	-6.24** [0.000]	-5.67** [0.003]	-0.321 [0.850]	-4.37** [0.000]
Labeled	Nuclear sector (disasters)	Marginal WTP [95% confidence interval]	44,327 yen 【25,786 to 61,844】	34,681 yen 【13,823 to 58,750】	- 【-】	31,144 yen 【18,345 to 44,543】
Labeled	Fossil fuel power sector (routine)	Lives lost per year	-7.16E-02** [0.000]	-7.24E-02** [0.000]	-7.53E-02** [0.000]	-7.29E-02** [0.000]
Labeled	Fossil fuel power sector (routine)	Marginal WTP [95% confidence interval]	508 yen 【352 to 669】	443 yen 【267 to 652】	619 yen 【393 to 923】	520 yen 【416 to 639】
Labeled	Log likelihood		-1205.4910	-608.5962	-732.0632	-2553.078
Labeled	Rho-squared		0.07480	0.09186	0.05882	0.07340

[1] *P* values are in parentheses.

[2] Confidence intervals of marginal WTP are calculated by Monte Carlo simulation based on the estimated parameters and the variance–covariance matrix of the estimated parameters ($N = 1000$).

[3] These are the numbers of respondents. Each respondent faced 6 choice tasks (see Table I for details).

[**] 1% significance level; [*] 5% significance level.

between disasters and routine outcomes, individuals appear to value the outcome similarly. Comparing this baseline to the actual baseline unlabeled case (Version 3) shows that the routine WTP values are similar (marginal value of 760 yen and the confidence intervals overlap). The disaster marginal value in the unlabeled actual baseline case is not significant.

6.4.2. *The WTP premium for disaster reduction*

Table VI follows the same format as Table V but is generated using Specification 3, in order to observe the preferences for reductions in deaths in the

Table VI. Estimates of parameters in utility Specification 3 (conditional logit model)

Parameter			Version 1 (N=198) [2]	Version 2 (N=204) [2]	Version 3 (N=237) [2]	All version (N=639) [2]
Unlabeled (Abstract context)	Baseline			Hypothetical	Actual	
	ASC for Status Quo			-0.413** [0.009]	-0.529** [0.001]	
	Increase in tax per household per year (Yen)			-1.56E-04** [0.000]	-1.34E-04** [0.000]	
	Mortality rarely occurs (disaster mortality)	Probability of a disaster per year (1 / 1 million)		-4.26E-02[1] [0.244]	5.38E-03 [0.367]	
		Lives lost if a disaster happens		-3.04E-04** [0.000]	-5.37E-05 [0.207]	
	Mortality occurs every year (routine)	Lives lost per year		-6.75E-02** [0.000]	-0.101** [0.000]	
	Log likelihood			-610.5139	-710.8976	
	Rho-squared			0.08825	0.08668	
Labeled (Context of power generation)	Baseline		Current situation			
	ASC for Status Quo		-0.124 [0.319]	-0.160 [0.355]	-0.460** [0.004]	-0.228** [0.007]
	Increase in tax per household per year (Yen)		-1.38E-04** [0.000]	-1.64E-04** [0.000]	-1.18E-04** [0.000]	-1.37E-04** [0.000]
	Nuclear sector (disasters)	Probability of a disaster per year (1 / 1 million)	-4.74E-03 [0.306]	-1.22E-02 [0.069]	7.62E-03 [0.196]	-2.78E-03 [0.384]
		Lives lost if a disaster happens	-1.75E-04** [0.000]	-8.99E-05 [0.052]	-2.45E-05 [0.569]	-1.12E-04** [0.000]
	Fossil fuel power sector (routine)	Lives lost per year	-7.08E-02** [0.000]	-7.56E-02** [0.000]	-7.24E-02** [0.000]	-7.21E-02** [0.000]
	Log likelihood		-1202.238	-609.7179	-731.0011	-2552.2360
	Rho-squared		0.07691	0.08944	0.05953	0.07352

P values in parentheses. ** 1% significance level; * 5% significance level.
[1]Version 2: this coefficient expresses the value of 1/10,000 reduction probability of a disaster per year in the unlabeled case.
[2]These are the numbers of respondents. Each respondent faced 6 choice tasks (see Table I for details).

fossil fuel or 'routine' sector versus reductions in probabilities of disasters and reductions in lives lost if a disaster occurs. The parameters on the probability of disasters are not significant explanators of choice. Respondents seem to focus on the number of lives affected by the policy and not the probability of the event. These results hold for the labeled and unlabeled cases and for hypothetical or actual baselines. The pooled model results are quite striking in this regard. Even though the coefficient on the probability of an accident is 'nearly significant' in Version 2, the pooled model with much more data generates an insignificant probability coefficient. In addition to focusing on deaths if an accident occurs, it may be that probability changes at a 1/1 million level are beyond the range of what a person can actually process. The insignificant coefficient estimates on the probability of a disaster could be reflecting this inability to process risk. This result should be tempered somewhat though by the fact that these models assume preference homogeneity. We relax this assumption later in the paper.

6.4.3. *Labeling effects*

In order to consider labeling effects we examine combinations of the unlabeled version with the actual power generation baseline with three versions that have nuclear and fossil fuel labels and the actual baseline. We compare the unlabeled version with labeled version 1 which constitutes a 'pure' external test since these are split samples unaffected by any question ordering biases. We also compare the unlabeled version with the labeled version from the same group of respondents (within sample test) and with the pooled sample of all labeled versions. We conduct a statistical test using Specification 2 and dummy variable for labels and introduce interaction terms of a label dummy and lives lost in each power sector. The estimated coefficients and the results of statistical tests are shown in Table VII.

As shown in Table VII, there are label effects but they are not as we had expected. The nuclear dummy variable is not significant in any of the models, providing evidence that there is no bias against nuclear power beyond its quantitative risk attributes. The fossil fuel label has a positive and statistically significant influence on the utility of mortality, indicating that the disutility of lives lost is decreased when these are labeled as arising from routine fossil fuel sector impacts. The results suggest a 38–42% reduction in WTP associated with a fossil fuel label. This may be interpreted as respondents feeling closer to and accepting the mortality risk of having the existing (fossil fuel power generation) label, rather than an abstract mortality risk occurring every year. However, this phenomenon does not occur in the nuclear power generation case. This may be because of the difference in familiarity between the nuclear power and fossil fuel power systems. This suggests that a nuclear label itself does not generate the significant difference in preferences or values, rather,

Table VII. Examination of label effects in conditional logit models using utility Specification 2

Parameter	< External test > Pooled sample of Ver.3-Part2 (non-labeled) and Ver.1- Part3 (labeled) N = 435[a]		< Internal test > Pooled sample of Ver.3-Part2 (non-labeled) and Ver.3-Part3 (labeled) N = 237[a]		< Joint test > Pooled sample of Ver.3- Part2 (non-labeled) and Part3 of all versions (labeled) N = 639[a]	
	Estimate	P-value	Estimate	P-value	Estimate	P-value
ASC for status quo	−0.191	[0.079]	−0.449**	[0.000]	−0.204*	[0.015]
Tax	−1.39E−04**	[0.000]	−1.29E−04**	[0.000]	−1.39E−04**	[0.000]
Disaster losses	−3.23*	[0.015]	−0.775	[0.581]	−3.14**	[0.010]
Nuclear label dummy	−1.39	[0.283]	0.573	[0.693]	−0.486	[0.677]
Routine losses	−0.114**	[0.000]	−0.103**	[0.000]	−0.113**	[0.000]
Fossil fuel label dummy	4.82E-02**	[0.003]	2.66E-02	[0.146]	4.33E-02**	[0.003]

	Nuclear		Fossil fuel	
	Changes by label	Is the change statistically different?	Changes by label	Is the change statistically different?
External test	43% up	No	42% down	Yes**
Internal test	74% down	No	26% down	No
Joint test	16% up	No	38% down	Yes**

**1% significant, *5% significant

[a]These are the numbers of respondents. Each respondent faced 6 choice tasks (see Table I for details).

Note: NL = lives lost in nuclear sector, TL = lives lost in fossil fuel sector. Changes of Nuclear estimate by Label = NL − LB/NL, Changes of Fossil fuel estimate by Label = TL − LB/TL.

the presence of small probability risks and large losses if a disaster occurs seems to be the driving force behind the differences.[6] However, it is also the case the nuclear power and fossil fuel power are probably viewed as substitutes and thus one could interpret our results as respondents having *relatively* lower WTP for risk reductions in the fossil fuel sector compared to the nuclear sector.

6.4.4. *Accounting for heterogeneity*

In order to analyze observed and unobserved heterogeneity, utility Specifications 2 and 3 are examined in a mixed logit framework (Tables VIII and IX respectively).[7] The mixed logit models are panel models accounting for the repeated choice nature of the data (Train 2003). The coefficients of the two types of mortalities, associated with nuclear and fossil fuel, as well as the probability of a disaster for specification 3, are assumed to follow a normal distribution over the individuals in the sample (Model 1). In both tables one model is presented with only random parameters and a second is presented in which the random parameters are expressed as conditional on age, income and education to capture the effect of these observable variables on the distribution of the parameters.

Examining Table VIII, there is a significant degree of unobserved heterogeneity as reflected in the significant standard deviations of the parameters in either model 1 or model 2. In addition, number of years of education is significant in both the nuclear and fossil fuel cases implying that more education increases the WTP for risk reductions. Age is significant in the fossil fuel case, implying a reduced WTP for fossil fuel risk reductions by older respondents. Income is not significant in these models but this may be a result of collinearity between income and education.

In Table IX the mixed logit results are presented for Specification 3. Model 2 in Table IX adds the effects of the demographic variables as shifters in these distributions. Model 1 shows that there is significant heterogeneity among the respondents over the attributes. Surprisingly, in Model 1, the mean of the probability of disaster is *positive*, implying, on average, a preference for increased chances of disasters. The standard deviation over the sample for this parameter is quite large indicating a large degree of 'disagreement' over the size and sign of this variable in our respondent sample. This peculiar result is somewhat explained in Model 2. Education is negative and significant (at a 10% level) as a shift variable indicating that higher educated respondents have a more negative preference for probability of a disaster. This result, we believe, supports the notion that individuals have difficulty processing the probability information and only those with higher levels of education can incorporate this factor into their choices in a fashion somewhat consistent with expected utility. Note that the parameter on

Table VIII. Mixed logit models to assess heterogeneity and demographic factors affecting utility Specification 2

Attributes		Model 1			Model 2		
		Coefficient	Standard error	P-value	Coefficient	Standard error	P-value
ASC for status quo		−0.832**	0.119	0.000	−0.814**	0.127	0.000
Tax increase per household per year		−0.218**	1.22E-02	0.000	−0.214**	9.56E-03	0.000
Lives lost per year in the nuclear sector	Parameter mean	−2.56	1.86	0.167	27.8*	13.7	0.042
	Age	–	–	–	3.74E-02	0.117	0.750
	Income per person	–	–	–	−1.50E-02	1.26E-02	.233
	Number of years of education	–	–	–	−2.14**	0.831	0.010
	Standard deviation	31.7**	2.18	0.000	31.4**	2.44	0.000
Lives lost per year in the fossil fuel sector	Parameter mean	−0.105**	1.39E-02	0.000	−5.84E-02	0.112	0.603
	Age	–	–	–	2.73E-03**	1.02E-03	0.008
	Income per person	–	–	–	−7.10E-05	1.12E-04	0.526
	Number of years of education	–	–	–	−1.19E-02	6.98E-03	0.088
	Standard deviation	0.196**	2.24E-02	0.000	0.197**	2.22E-02	0.000
Log likelihood		−2163.741			−1985.235		
Rho-squared		0.21439			0.22144		
N		639[a]			590[a]		

**1% significant; *5% significant.

[a]These are the numbers of respondents. Each respondent faced 6 choice tasks (see Table I for details).

Table IX. Mixed logit models to assess heterogeneity and demographic factors affecting utility Specification 3

Attributes		Model 1 Coefficient	Model 1 Standard error	Model 1 P-value	Model 2 Coefficient	Model 2 Standard error	Model 2 P-value
ASC for status quo		−1.20**	0.128	0.000	−1.15**	0.136	0.000
Tax increase per household per year[a]		−0.277**	1.65E − 02	0.000	−0.269**	1.45E − 02	0.000
Lives lost in the nuclear sector	Probability of a disaster per year (1/1 million)[b]						
	Parameter mean	0.222**	7.34E-02	0.003	1.01	0.556	0.070
	Age	–	–	–	2.81E − 03	4.76E − 03	0.555
	Income per person	–	–	–	−4.74E − 04	5.05E-04	0.348
	Number of years of education	–	–	–	−6.25E − 02	3.42E − 02	0.067
	Standard deviation	1.20**	9.77E − 02	0.000	1.10**	9.83E − 02	0.000
	Lives lost if a disaster happens (persons)[c]						
	Parameter mean	−0.152**	5.33E − 02	0.004	0.339	0.412	0.411
	Age	–	–	–	1.34E − 03	3.65E − 03	0.714
	Income per person	–	–	–	−2.81E − 04	4.10E − 04	0.493
	Number of years of education	–	–	–	−3.74E − 02	2.48E − 02	0.131
	Standard deviation	0.903**	7.98E − 02	0.000	0.823**	7.70E − 02	0.000
Lives lost in the fossil fuel sector	Parameter mean	−0.108**	1.95E − 02	0.000	4.03E − 02	0.147	0.785
	Age	–	–	–	3.15E − 03*	1.41E-03	0.025
	Income per person	–	–	–	−7.22E − 05	1.59E-04	0.649
	Number of years of education	–	–	–	−2.14E − 02*	8.93E-03	0.017
	Standard deviation	0.318**	2.67E − 02	0.000	0.320**	2.74E − 02	0.000
Log likelihood		−2186.487			−2004.341		
Rho-squared		0.20582			0.21310		
N		639[d]			590[d]		

[a]This variable has been rescaled to facilitate analysis (tax increase per household per year/1000).
[b]This variable has been rescaled to facilitate analysis (probability of a disaster per year/10).
[c]This variable has been rescaled to facilitate analysis (lives lost if a disaster happens/1000).
[d]These are the numbers of respondents. Each respondent faced 6 choice tasks (see Table I for details).
**1% significant; *5% significant.

probability was quite fragile over specifications, also an indication of the difficulty that respondents had in processing this information. Other demographic factors are generally not significant in Model 2 except for increased age reducing the WTP for fossil fuel risk reductions and higher education increasing the WTP for fossil fuel mortality reductions.

7. Conclusions

In this research a public goods-type scenario for mortality reduction is presented to respondents and their trade-offs are assessed using a choice experiment. Using the estimated models the WTP for reducing lives lost in the fossil fuel and nuclear sector are found to be very different. The WTP to reduce deaths caused by a disaster in nuclear power generation is about 60 times the WTP for risk reductions in the routine operation of fossil fuel plants.[8]

Support for the difference between nuclear and fossil fuel program WTP is provided by the qualitative data collected in the survey. Respondents did, on average, indicate that they were most concerned about reducing the chances of nuclear mortality effects and they supported fossil fuel generation over nuclear generation for new power capacity. Risk perceptions, overstating the low probability risks, likely contribute to the high nuclear WTP. It is also possible that concerns about environmental effects arising from nuclear incidents are embedded in our WTP estimates, overstating them somewhat.

In addition to the differences in value we also find evidence of baseline, 'disaster aversion' and labeling effects. We find that in the absence of labels, using a hypothetical, larger baseline mortality rate for nuclear disaster results in very similar WTP to routine mortality reductions from fossil-fuel generation.

We also find that with relatively high probabilities individuals appear to assess tradeoffs using expected values and the marginal values between the routine and disaster loss cases are quite similar. However, when the probabilities of disasters are very low they seem to ignore the probabilities and focus on the losses, resulting in what appears to be 'disaster aversion.' At least part of this effect appears to be due to an inability to process probabilities of the size relevant to the analysis of nuclear sector disasters. The addition of nuclear and fossil fuel labels to unlabeled cases shows no significant label effects for the nuclear sector but a 38–42% reduction in WTP for the fossil fuel sector.

A variety of questions for future research are raised by our analysis including further examination of the effect of baselines on expected utility processing and further assessment of routine versus disaster risks. The choice experiment conducted here is a type of risk within risk analysis tool in which respondents assess risky choices in the nuclear disaster programs and consider the degree to which they, and their family members, are willing to pay to reduce the risks associated with either the fossil fuel or nuclear sector.

Finally, this research illustrates some of the challenges in valuing mortality risk reductions in a public goods or public program context. Given that many policy questions pertain to public programs a better understanding of valuation in such contexts is required. The degree to which private values of risk reduction apply to public goods/programs is an important question.

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Notes

1. The attributes and levels in the choice experiment design for the actual baseline are (1) tax increase in yen per year (2000, 4000, 8000, 15,000); (2) annual probability of a severe nuclear accident in chances per million (30, 27, 15, 5); (3) lives lost if a nuclear accident occurs (4000, 3600, 2500, 1000); and (4) live lost in the thermal sector per year (1000, 998, 995, 990). All other information in the choice experiment (expected lives lost in the nuclear sector and total lives lost) is calculated from these attributes and levels. The attributes and levels for the hypothetical baseline are (1) tax increase in yen per year (2000, 4000, 8000, 15,000); (2) annual probability of a severe accident in chances per 10,000 (50, 48, 47, 45); (3) lives lost if an accident occurs (20,000, 19,500, 19,000, 18,000); and (4) live lost in routine losses per year (100, 98, 95, 90).
2. This form of analysis also ignores the panel or repeated choice nature of the data and assumes that observations are independent. This limitation is removed in the mixed logit model in which a panel data estimator, essentially a form of random effects model, is used (see Train 2003). The mixed logit model also controls for unobserved heterogeneity, but assumes a particular form of distribution of parameters. Order effects, such as respondent fatigue over the set of choice tasks, are not controlled for by the mixed logit model. Strategies to control for such effects are discussed in Train (2003) and Swait and Adamowicz (2001).
3. Note that respondents are presented with both the levels of the attributes (for the *status quo* and the two programs and their changes (for the two programs) in each choice screen. In this paper we refer to the levels because that is what enters into the utility functions. However, respondents had information on changes as well.

4. Additional specification tests (available from the authors upon request) examine models with expected deaths in the two sectors, probabilities of disasters and lives lost if a disaster occurs jointly. This model shows that respondents do not process on an expected utility basis. Also, a model with the logarithm of deaths if a disaster occurs and the probability of a disaster was used to test for expected utility processing. A test of equality of coefficients on the probability and losses if a disaster occurred variables was rejected, implying that respondents do not process on an expected utility basis for this specific form of utility function.
5. Respondents were also asked 7 point scale 'certainty questions' that identified how certain they were that they would actually choose the program they identified. About 42% of the sample stated that they were relatively uncertain about their responses (categories 1–3) while about 26% of the sample stated that they were reasonably certain (categories 5–7). Models were estimated in which respondents were removed from the sample if they responded with varying degrees of uncertainty, starting by removing those responding with category 1. As uncertain respondents were removed the model fit improved, but the marginal values of the attribute remained relatively unchanged. Therefore, we use the full sample in the remaining analysis.
6. The effects of labels were also examined using regression analyses and interactions terms with demographic characteristics. The fossil fuel label dummy is significant in these models while the nuclear label is not. In this case the presence of a fossil fuel label reduces WTP for mortality risk reduction (i.e. VSL) by approximately 34%.
7. The effects of other attributes were also examined using a conditional logit model for Specification 2 and introducing various demographic characteristics as interaction terms. These results are available from the authors upon request. A regional dummy shows that Gifu City has a smaller WTP for nuclear mortality reduction by about 60% relative to that in other regions. This may be due to an income difference between Gifu City and the other regions, but other factors may be at play as well. Income per family member is positively related to marginal WTP for nuclear mortality reduction but does not affect fossil fuel mortality reduction. Age is negatively related to WTP for fossil fuel mortality reductions but does not significantly affect nuclear mortality reductions.
8. Although the WTP estimates in this paper all translate into values of statistical life, readers will note that our emphasis has been on comparing WTP responses across different scenarios. Probably because the risk reductions presented are so small (as low as 30 in a million in the nuclear case), the VSLs are in some cases very large and, in our view, are generally unreliable for use in valuing mortality risk reductions.

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