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# A Reference Lottery Metric for Valuing Health

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This study utilizes reference lotteries on life and death to establish a death-equivalent metric for valuing long-term health effects. We use a computer-based survey approach to elicit choices among residential locations that pose different risks of chronic disease and dying in an automobile accident. From paired choices between different locations, we infer their rates of trade-off between reducing the risks of chronic diseases and the automobile death risk. The values of reducing the risks from two diseases, a nerve disease (peripheral neuropathy) and lymphoma (cancer of the lymph system), are measured in terms of both trade-off rates with the risk of an automobile death and with dollars.

While the use of reference lotteries for monetary outcomes to establish a utility metric is well established for monetary outcomes, our results suggest that reference lotteries on life and death can also be applied with decision-makers facing realistic choices to construct a utility metric for valuing health status. The results were corroborated by a strong positive correlation between the risk-risk trade-off values and relative aversion scores for the different health outcomes, as well as by the relative values of avoiding the three diseases in our study.

*(Benefit Valuation; Health; Utility)*

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## 1. Introduction

One of the most daunting and important tasks in the assessment of individual preferences pertains to health outcomes.<sup>1</sup> For a variety of psychological reasons, standard utility assessment techniques for monetary outcomes are difficult to apply to this task. This may be in part because of the fundamental relationship between one's health and one's welfare. Experimental subjects may, for example, find it difficult to respond in a meaningful way to hypothetical lotteries involving potential risks of death and monetary payoffs. The methodology developed in this paper is designed to address both the methodological and the practical concerns by using a

death risk lottery metric to value health effects rather than a lottery on monetary outcomes.<sup>2</sup>

The standard decision analysis approach is a utility metric derived from probabilities for hypothetical reference lotteries, where the high and low payoffs are monetary.<sup>3</sup> Our technique is analogous except that payoffs for the reference lotteries are two health outcomes—good health and death.<sup>4</sup> We are able to use non-expert decision makers by systematically educating

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<sup>1</sup> See Acton (1973); Hammerton, Jones-Lee and Abbott (1982); Jones-Lee (1976, 1989); Viscusi and Magat (1987); Magat, Viscusi and Huber (1988); Viscusi, Magat and Huber (1991); and Viscusi (1992).

<sup>2</sup> Consequently, our paper focuses on the development of a utility metric for health outcomes. See Howard (1980); Keeney (1980a, b); Keeney and Raiffa (1976); Pliskin, Shepard and Weinstein (1980); Shepard and Zeckhauser (1984); Torrance (1987); and Torrance, Boyle and Horwood (1982).

<sup>3</sup> See Raiffa (1968), Farquhar (1984), and McCord and deNeufville (1986).

<sup>4</sup> See, for example, Howard (1984).

them about health outcomes and then presenting them with choices analogous to those they often make. Thus, our results are potentially testable with real choices.

Use of this technique makes health rather than money the currency of interest. Depending on the ultimate use of these valuations, one could define all impacts associated with a decision in terms of death risk equivalents or, using evidence on the monetary value of statistical lives, convert the death risk scale into a monetary value.

Eliciting individual responses pertaining to their valuation of health risk reductions is often difficult, particularly to the extent that individuals are asked to think about low-probability events that they do not normally encounter. Using hypothetical reference lotteries to elicit valuations of risk will only be successful to the extent that people can process the probabilistic information accurately. Since these probabilities tend to be small for severe health outcomes, a potential danger of the lottery approach is that the valuations will be distorted by perceptual biases, thus affecting the estimate of the implicit value of the health outcomes.

Use of pairwise choices involving risk lotteries are shown to ameliorate this problem.<sup>5</sup> Rather than being forced to make tradeoffs among potentially incommensurate attributes, such as health and money, respondents equate risks of a similar class. The lotteries also involve understandable probabilities that are presented to respondents as numbers of cases per million to enable individuals to process the lottery. Furthermore, the comparisons are structured to avoid tradeoffs between different modalities, for example, the cost-of-living differences and mortality risks in different areas.<sup>6</sup>

Thus, our approach facilitates understanding in two ways. First, the two lotteries used in the pairwise comparisons each involve risks of comparable magnitude with identical denominators so that the relative risks will be apparent. Second, the tradeoffs involved entail

thinking in a single dimension—health status—rather than equating monetary changes to health lotteries. Although the hypothetical reference lotteries used in the decision analysis literature (e.g., see Raiffa 1976) frequently involve equating a monetary amount to a lottery, in the usual case lottery payoffs are also monetary. If instead these payoffs involve health status, the cognitive demands on respondents will be greater to the extent that these types of tradeoffs are unfamiliar and possibly unpleasant to make.

Our focus is on two different diseases thought to be related to exposure to various environmental contaminants, peripheral neuropathy (nerve disease) and lymphoma (cancer of the lymph system). The former disease is nonfatal in most cases and not related to cancer, while the latter disease is a form of cancer that occurs in both a form that is fatal and one that has a high probability of recovery. Thus, the health metric spans moderate discomfort to imminent doom.

Section 2 introduces the general methodological approach that is used, while §3 describes the survey methodology as well as the character of the health risks to be considered. Section 4 presents estimates of the benefits of reducing the risk of these diseases in terms of a rate of trade-off with another health risk, specifically, the risk of dying in an automobile accident. The risk-risk trade-off rates can be translated into dollar values by assigning values to death avoidance, for example, through hedonic wage studies.

Finally we measure each subject's rating of his or her aversion to eight characteristics of lymph cancer and ten characteristics of nerve disease. These relative aversion scores are useful as a method of checking the extent to which the lottery values accurately measure individual values of the health risk reductions and thus serve to corroborate our experimental results.

## 2. A Utility-Theoretic Model of Risk-Risk Trade-off Rates

The trade-off rates between the *risk* of disease and the *risk* of an automobile accident allow us to establish a von Neumann-Morgenstern utility metric for the degradation in health status (from a state of good health) caused by each of the three diseases considered in this

<sup>5</sup> See Viscusi, Magat and Huber (1991).

<sup>6</sup> It is beyond the scope of this paper to empirically compare the use of monetary lotteries with lotteries on life and death. Beyond the cognitive problems with the use of monetary lotteries, highly structured approaches such as multi-attribute utility theory require assumptions about the functional form of the utility functions that our approach avoids. See Keeney and Raiffa (1976) and Kleindorfer, Kunreuther and Schoemaker (1993).

paper. In particular, health outcomes are assessed using a probability-of-death metric.

Consider, first, the case of the nerve disease. As described in more detail later, we ask respondents to choose between two different areas in which to live that differ on two dimensions, the risk of contracting a disease (in this case, nerve disease) and the risk of dying in an automobile accident. Suppose that individuals have utility functions defined on three health-based states of the world, good health ( $H$ ), nerve disease ( $N$ ), and death in an automobile accident ( $D$ ). Then for an expected-utility-maximizing individual to be indifferent between Areas  $A$  and  $B$ , the probabilities and utility values in the two areas must be such that the two locations offer the same expected utility. Thus, for the situation in which the adverse health outcome under consideration is nerve disease, we have

$$p_A^N U(N) + q_A U(D) + (1 - p_A^N - q_A) U(H) \\ = p_B^N U(N) + q_B U(D) + (1 - p_B^N - q_B) U(H), \quad (1)$$

where  $U$  is the utility function,  $p_A^N$  and  $p_B^N$  are the probabilities of contracting nerve disease in Areas  $A$  and  $B$ , respectively, and  $q_A$  and  $q_B$  are the probabilities of dying in an automobile accident in Areas  $A$  and  $B$ . If we define the utility of death equal to zero, with no loss of generality, Eq. (1) can be rewritten as

$$\frac{U(N)}{U(H)} = 1 - \left( \frac{q_B - q_A}{p_A^N - p_B^N} \right), \quad (2)$$

or equivalently,

$$\left( 1 - \frac{U(N)}{U(H)} \right) = \left( \frac{q_B - q_A}{p_A^N - p_B^N} \right). \quad (3)$$

This equation shows that the percentage degradation in the utility of good health caused by contracting nerve disease (the left hand side  $\times 100$ ) equals the trade-off rate between the automobile death risk difference (between the two areas) and the nerve disease risk difference (between the two areas). Our empirical results will provide estimates of this trade-off rate.<sup>7</sup>

<sup>7</sup> In describing equations such as Eq. (3), we used the terminology of percent degradation in utility caused by the disease. It should be recognized that all the utility values in this paper are von Neumann-Morgenstern ratio-scaled utilities that must be interpreted within the

For the case of terminal lymph cancer (TLC), an analogous derivation leads to the result that

$$\left( 1 - \frac{U(\text{TLC})}{U(H)} \right) = \left( \frac{q_B - q_A}{p_A^T - p_B^T} \right), \quad (4)$$

where the probabilities of death from terminal lymphoma yielding indifference between the two locations are indexed by a superscript  $T$ . Thus, the percentage of the utility of good health lost due to terminal lymphoma is equal to (100 times) the trade-off rate between the automobile death risk difference and the terminal lymphoma risk difference which makes the individual indifferent between the two areas.

For the case of curable lymph cancer (CLC), we need to define a fifth health state that can occur, namely, contracting lymphoma, experiencing the pain and suffering of the disease, and eventually recovering. We label this state LR for "lymphoma recovery." Let  $z$  be the probability that a person contracting curable lymphoma will die. Then at the point of indifference between Areas  $A$  and  $B$ ,

$$p_A^c [z U(\text{TLC}) + (1 - z) U(\text{LR})] + q_A U(D) \\ + (1 - p_A^c - q_A) U(H) \\ = p_B^c [z U(\text{TLC}) + (1 - z) U(\text{LR})] + q_B U(D) \\ + (1 - p_B^c - q_B) U(H), \quad (5)$$

where the superscript  $c$  on the probabilities refers to curable lymphoma. Again setting the utility of an automobile death to zero, Eq. (5) yields an expression equating the *expected* percentage degradation in the utility of good health caused by contracting curable lymphoma to the trade-off rate between the difference in automobile death risks in the two areas and the difference in the curable lymphoma risks in the two areas:

context of lotteries rather than being viewed as additive valuation amounts. For example, suppose that the utility of good health is ten, the utility of nerve disease is five, and the utility of death is zero for a respondent. In our terminology, nerve disease results in a percentage degradation of utility of 50 percent from a day of being healthy. What the results mean is that respondent is indifferent between nerve disease and a 50:50 lottery between good health and death. The lottery scaling and all interpretations regarding the percentage degradation phrasing consequently must be always recast within a lottery framework.

$$\left(1 - \frac{[zU(\text{TLC}) + (1 - z)U(\text{LR})]}{U(H)}\right) = \left(\frac{q_B - q_A}{p_A^c - p_B^c}\right). \quad (6)$$

Since each respondent provided (automobile risk) trade-off rates both for terminal lymphoma and for curable lymphoma, Eqs. (4) and (6) provide an estimate of the percentage degradation in utility of good health caused by contracting lymphoma and *recovering* from the disease. This trade-off rate is a weighted average of the two trade-off rates, where the weights are functions of the probability of dying from lymphoma:

$$\left(1 - \frac{U(\text{LR})}{U(H)}\right) = \left(\frac{1}{1 - z}\right)\left(\frac{q_B - q_A}{p_A^c - p_B^c}\right) - \left(\frac{z}{1 - z}\right)\left(\frac{q_B - q_A}{p_A^T - p_B^T}\right). \quad (7)$$

Thus, the risk-risk trade-off rates for the three diseases measure the degree of utility loss (from a state of good health) caused by contracting each of the diseases. In addition, a weighted average of the risk-risk trade-off rates for curable and terminal lymphoma measures the fraction of utility that would be lost by an individual who contracted a nonfatal form of lymphoma, or equivalently, the morbidity component of lymphoma.

### 3. Empirical Methodology

#### 3.1. Sample

The sample of 727 adults was recruited from a blue-collar mall in Greensboro, North Carolina, a city which is often used in survey research because its citizens are fairly representative of the United States population. About 56 percent of the sample were women, average family size was about 2.7, respondents averaged 31.5 years of age (all were over 20 years old), income averaged \$35,800, the average respondent had completed 1.4 years of college education, and 58 percent were married.<sup>8</sup>

<sup>8</sup> Appendix 1 in Magat, Viscusi and Huber (1994) lists the mean, standard deviation, minimum, and maximum values of all the demographic questions asked of the respondents, as well as their responses to questions about their familiarity with the diseases under study. The questions about respondents' familiarity with nerve disease and lymph cancer were included as possible correlates with the valuation responses and to increase the respondents' involvement with the disease description parts of the questionnaire.

Most respondents were unfamiliar with the consequences of contracting the two diseases under study, requiring us to include a long section at the beginning of the questionnaire that educated respondents about these disease characteristics. We interspersed questions about familiarity with the two diseases with these descriptions in order to reinforce the information about the diseases as well as to increase respondents' involvement with the questionnaire. Written descriptions of the diseases were given to each respondent to read. In addition, all key attributes of the disease were described and respondents were asked questions to test their absorption of this information and force them to relate the diseases to their own lives.<sup>9</sup>

#### 3.2. Research Design

Our primary mechanism for eliciting health risk reduction valuations was the use of paired choice questions about a familiar choice, namely, a residential location decision.<sup>10</sup> In each question, respondents were asked to choose between two locations that differed along two dimensions, the risk of contracting the disease (either nerve disease or lymph cancer) and another familiar risk (specifically, the risk of dying in an automobile accident in that location). Their responses to these paired choice questions allowed us to infer the individual's rate of trade-off of automobile death risk reduction for a reduction in the risk of contracting the disease.

The survey informed respondents that the two new locations in each question were identical in all other respects to where they now live, and that the risks of contracting the disease or dying in an automobile accident were *lower* in both of the new locations than where they

<sup>9</sup> Although there are many potential causes of peripheral neuropathy, it is thought by some researchers to be linked to environmental pollutants such as lead (e.g., from smelters and batteries), acrylamide, organophosphate pesticides (such as parathion), industrial compounds (such as hexane 2 hexanone), and solvents (such as carbon disulfide). Lymphoma is closely related to leukemia (blood cancer), which has been thought to be one possible consequence of exposure to high levels of toxic chemicals such as formaldehyde and benzene, and toxics such as methylene chloride, dioxin, and acrylamide are also thought to cause various forms of cancer.

<sup>10</sup> The paired choice, or paired comparison approach is a familiar one in decision sciences, psychology, and marketing. See, for example, Saaty (1980) and Kleindorfer, Kunreuther and Schoemaker (1993).

currently lived. This context allowed them to ignore the many other attributes which enter into a location decision and focus on the health and automobile death differences between the two locations.<sup>11</sup> It also avoided the extreme reaction which often occurs when people are asked to accept increases in health risks (see Viscusi and Magat 1987).

The questionnaire was administered on a personal computer using an interactive program that adjusted the questions asked of each respondent based on his or her previous answers. This approach has been successfully used by the authors in several previous studies, most recently Viscusi, Magat and Huber (1991). By tailoring the questions to each respondent, fewer questions need to be asked of each respondent, thus economizing on the time available with each respondent. As well, this approach avoids potential problems with interviewer bias, induces respondents to more honestly reveal their preferences, and generates a higher response rate to sensitive questions such as income level. The use of a computer also tends to engage respondents better than when the same questions are asked by interviewers, yielding results which reflect a higher level of attention paid by the respondents to the interview task.<sup>12</sup>

Professional marketing interviewers introduced the respondents to the survey and to the use of the personal computer. In addition, the interviewers assisted in educating the respondents about the consequences of contracting the two diseases, since most of them were not familiar with the exact consequences of the diseases. The interviewers provided the short descriptions of the diseases and read this description out loud.<sup>13</sup> As described above, the computer program reinforced this initial education by asking a series of about twenty questions about each of the conse-

quences of contracting the disease (e.g., Did you know that nerve disease does not affect life expectancy?). Because respondents first listened to (and read) the disease descriptions, then the computer program repeated each attribute of the disease and asked the respondent a question about that attribute, we can be reasonably confident that the respondents understood the consequences of the diseases relevant to the locational choices they made.<sup>14</sup>

For each separate experimental treatment, respondents saw a series of paired choice questions and for each were asked to indicate on a nine-point scale whether they preferred Area A, they preferred Area B, or they were indifferent between the two areas. See, for example, the initial question displayed at the bottom of Part A of Table 1 which was asked of respondents trading off the risk of lymph cancer and the risk of an automobile death. Specifically, at the bottom of the screen posing this choice between the two areas they were asked "Which place do you prefer? Choose the number that best explains how you feel" (on a nine-point scale with five labeled as "about the same," one labeled "strongly prefer Area A," and nine labeled "strongly prefer Area B").

If the respondent preferred Area A on a question, the subsequent question was designed to modify one of the risks in Area A or Area B to make Area A less attractive. Similarly, if the respondent preferred Area B on a question, the subsequent question modified the risks to make Area B less attractive. This process continued until the risks in the two locations made the respondent indifferent between them (i.e., marked five on the scale). From this indifference point we then inferred the respondent's rate of trade-off between the two risks.<sup>15</sup>

<sup>11</sup> Even if respondents did consider other attributes relevant to the location decision, they were invariant across the pair of questions and so were factored out of the choice in the same way as in a fixed effects model. This is one of the well established advantages of using paired comparison questions.

<sup>12</sup> We make this judgment based on observation of respondents during the interview, the questions they asked, their responses to questions asked of them after the interview, and the fact that few people left the interview before completing the survey.

<sup>13</sup> See Appendices 2 and 3 in Magat, Viscusi and Huber (1994).

<sup>14</sup> Even more reinforcement of the education about disease characteristics occurred in the extensive set of questions eliciting relative aversion scores for each characteristic (see §4.2).

<sup>15</sup> Based on pre-testing with several different values of the risks in the initial question, we chose values for that question which corresponded to the likely median responses of respondents. In this way we were able to minimize the number of iterations of the question before reaching the point of indifference, thus economizing on interview time and reducing any effects on respondents' responses of the iterative process used to find their points of indifference.

## 4. Results

Our valuation results can be divided into two parts, those using the risk-risk lottery metric and those using the relative aversion scores for different generic disease characteristics. In addition, we analyze the correlations between the responses to these two methods of inferring values for environmental risk reductions as one form of validity check for the accuracy of the health-risk/death-risk trade-off responses.

### 4.1. Risk-Risk Estimates of the Death Risk Metric for Health Losses

As explained above, we asked respondents to select between two locations that differed, first, in the risk of one disease, either lymphoma (cancer of the lymph system) or the peripheral neuropathy (nerve disease), and, second, in the risk of dying in an automobile accident. Table 1 provides trade-off rate results on two forms of lymphoma, "curable" lymph cancer, which has a 90 percent chance of complete recovery if detected early, and "terminal" lymph cancer, which, as the name implies, is always fatal. Part A displays the curable lymph cancer results, Part B gives the terminal lymph cancer results, and Part C lists the within-respondent rates of trade-off between the two forms of lymph cancer. The mean trade-off rates are always larger than the median rates because of the existence of large values for some respondents and the lower bound of zero for all responses. For this reason, the medians provide a more useful summary statistic than the means of the entire distribution of trade-off rates.<sup>16</sup>

The median respondent was willing to trade off a reduction in the risk of curable lymph cancer of 1.6/1,000,000 for a 1/1,000,000 increase in the risk of an automobile death, which implies that a one in a million reduction in the risk of curable lymph cancer is comparable to a 0.625 in a million reduction in the risk of an automobile death. Thus, referring to Eq. (6), the median re-

spondent expects to suffer a 62.5 percent reduction in utility by contracting curable lymphoma, i.e.,

$$\left(1 - \frac{[zU(\text{TLC}) + (1 - z)U(\text{LR})]}{U(H)}\right) = 0.625.$$

Upon rearranging this equation, the expected utility of contracting curable lymph cancer is given by

$$[zU(\text{TLC}) + (1 - z)U(\text{LR})] = 0.375U(H).$$

For this median respondent, the expected utility of curable lymph cancer is equivalent to a lottery with a 0.375 probability of good health and a 0.625 probability of death (with utility normalized to equal zero), which we call a death risk equivalent of 0.625. Sixty-three percent of the respondents valued reducing the curable lymph cancer risk less than reducing the auto death risk, 8 percent were indifferent, and 29 percent of the respondents indicated that they place a higher value on reducing the risk of curable lymph cancer than on reducing the risk of an automobile death.

These results on the median respondent and on the percentages of respondents preferring the two diseases' risk reductions appear to capture the respondents' preferences for reduction in the two risks. Consistent with our results, we would expect that for most people curable lymph cancer would be a serious disease, but less onerous than certain and immediate death because the probability of dying is well below one and death, if it occurs, is not immediate. Due to the dread associated with cancer, some people may well prefer to lower their risk of lymph cancer, even the curable type, than to lower their risk of a fatal automobile accident by an equal amount.<sup>17</sup> Others may be so averse to their perceptions of the pain and suffering associated with a long, drawn-out case of cancer, even one with a high chance of recovery, that they prefer the instant death from an automobile accident. Part of the dispersion of values may also be caused by differences in what the respondents perceive as their own risks and those described in the questions, despite the fact that the questionnaire asked them personal characteristics, such as driving mileage and skill, and emphasized that these characteristics were used to estimate the respondents' own risks. Unfortunately, we did not ask respondents to

<sup>16</sup> The tables in Magat, Viscusi and Huber (1994) also provide separate results for respondents who answered the questions about *curable* lymph cancer before responding to the questions about terminal lymph cancer and for respondents who answered the *terminal* lymph cancer questions first. Since the effect of the order of presentation was small, in this paper we focus on the responses for *all* respondents.

<sup>17</sup> See, for example, Slovic (1987) for a discussion of dread.

**Table 1** Lymph Cancer (LC)–Automobile Death (AD) Risk Equivalents

A) Curable Lymph Cancer (CLC)						B) Terminal Lymph Cancer (TLC)					
CLC/AD Risk Trade-off Rate <sup>a</sup>						TLC/AD Risk Trade-off Rate <sup>c</sup>					
<i>N</i>	Median	Mean	Std. Error of Mean	Min (#)	Max (#)	<i>N</i>	Median	Mean	Std. Error of Mean	Min (#)	Max (#)
719	1.600	2.775	0.214	0.04 (70)	40 (11)	724	1.000	1.523	0.129	0.03 (127)	30 (8)
Initial Question <sup>b</sup> Risk (per million people)						Initial Question <sup>d</sup> Risk (per million people)					
Disease		Area A	Area B			Disease		Area A	Area B		
Curable lymph cancer		140	100			Terminal lymph cancer		130	100		
Auto death		150	170			Auto death		150	170		

C) Within-Subject Risk Trade-off Rate for Two Types of Lymph Cancer: TLC/CLC

TLC/CLC Risk Trade-off Rate <sup>e</sup>					
<i>N</i>	Median	Mean	Std. Error of Mean	Min (#)	Max (#)
716	0.750	0.990	0.089	0.00075 (1)	37.5 (2)

<sup>a</sup> The ratio CLC/AD measures the rate at which subjects are willing to trade off units of curable lymph cancer risk for a unit of automobile death risk. From Equation (6) in the text, the *inverse* of the CLC/AD trade-off risk rate equals

$$\left(1 - \frac{[zU(\text{TLC}) + (1 - z)U(\text{LR})]}{U(H)}\right).$$

<sup>b</sup> The first question in the sequence of questions about curable lymph cancer asked subjects to choose between Areas A and B which differed on the two risk dimensions given in the table.

<sup>c</sup> The ratio of TLC/AD measures the rate at which subjects are willing to trade off units of terminal lymph cancer risk for a unit of automobile death risk. From equation (4) in the text, the *inverse* of the TLC/AD trade-off rate equals

$$\left(1 - \frac{U(\text{TLC})}{U(H)}\right).$$

<sup>d</sup> The first question in the sequence of questions about terminal lymph cancer asked subjects to choose between Areas A and B which differed on the two risk dimensions given in the table.

<sup>e</sup> The ratio TLC/CLC measures the rate at which subjects are willing to trade off units of terminal lymph cancer risk for a unit of curable lymph cancer risk.

explain their reasoning behind their responses, making it impossible to sort out the relative importance of these competing hypotheses.

The terminal lymph cancer results show the median respondent to be indifferent between death from lymph cancer and death from an automobile accident, i.e., the trade-off rate for this respondent is equal to one. Thus, Eq. (4) takes on the form

$$1 - \frac{U(\text{TLC})}{U(H)} = 1.000, \quad \text{or} \quad U(\text{TLC}) = 0.$$

This result implies that the utility of contracting terminal lymph cancer,  $U(\text{TLC})$ , equals the utility of death in an automobile accident,  $U(D)$ , which we have normalized to equal zero, or a death risk equivalent of 1.000. Stated another way, the median respondent expects to

**Table 2** Nerve Disease (ND)–Auto Death (AD) Risk Trade-off Rates<sup>a</sup>

Group Number <sup>c</sup>	Initial Question				<i>N</i>	ND/AD Risk Trade-off Rates <sup>b</sup>				
	Area <i>A</i> Risks		Area <i>B</i> Risks			Median	Mean	Std. Error of Mean	Min (#)	Max (#)
	ND	AD	ND	AD						
1	175	150	100	170	128	2.50	4.917	1.096	0.075 (15)	75.000 (3)
2	175	150	100	170	50	3.20	3.999	1.467	0.075 (8)	75.000 (1)

<sup>a</sup> Nerve disease risks and auto death rates are both measured in units of 1/1,000,00 per year.

<sup>b</sup> From Equation (3) in the text, the inverse of the ND/AD risk trade-off rate equals  $(1 - U(N)/U(H))$ .

<sup>c</sup> Group two subjects received the same questions as those in group one with the exception that group two subjects were told there were *two* studies both estimating an identical 175/1,000,000 risk of nerve disease in Area A.

lose 100 percent of the utility of good health by contracting terminal lymphoma.<sup>18</sup>

Because terminal lymph cancer differs from curable lymph cancer only in the likelihood of dying (100 percent versus 10 percent), it is to be expected that the median and mean trade-off rates in Parts A and B of Table 1 reflect a higher relative value placed on terminal lymph cancer than curable lymph cancer. To test this relationship further, we also calculated each respondent's ratio of his terminal lymph cancer trade-off rate to his curable lymph cancer trade-off rate. The median ratio is 0.75, indicating that respondents were more averse to terminal than curable lymph cancer. This ratio was less than one for 79 percent of the respondents. At the median a terminal lymph cancer risk is 1.33 worse than the risk of curable lymph cancer, a result which is broadly consistent with the median trade-off rates reported in Parts A and B.

Equation (7) allows us to combine the risk-risk trade-off rates for terminal and curable lymphoma to indirectly measure the utility loss associated with the *morbidity* component of lymphoma, that is, the fraction of the utility of good health which would be lost by contracting a nonfatal form of lymphoma. The preferences of the median respondent imply that for her Eq. (7) takes the form

$$1 - \frac{U(LR)}{U(H)} = 0.583,$$

or a death risk equivalent of 0.583. Thus, she would expect to incur a 58.3 percent loss in utility by contracting lymphoma and suffering the morbidity consequences without any risk of dying. Another way to interpret these results is that out of the 100 percent loss in utility that the median respondent would suffer from contracting terminal lymphoma, 58.3 percent of the loss would be due to the morbidity consequences and 41.7 percent of the loss would be due to death some time in the future.

Upon rearranging terms in the above equation, one has

$$U(LR) = 0.417U(H).$$

That is, for the median respondent, nonfatal lymphoma is equivalent to a lottery involving a 0.417 probability of being healthy and a 0.583 probability of death, which we have normalized by setting  $U(D)$  equal to zero.

The results in Table 2 for the nerve disease–automobile death trade-off rates indicate that respondents also consider nerve disease to be a serious disease, but not as undesirable as either form of lymph cancer. The majority of our respondents asked to choose between locations that differed in nerve disease and automobile death rates were given a *single* estimate of the nerve disease risks in each of the two locations (Group One). Fifty respondents were placed in a separate group (Group Two) to explore the effect on trade-off rates of

<sup>18</sup> An analysis of the distribution of trade-off rates showed that 41 percent of respondents found the lymph cancer death worse and 48 percent found an automobile death worse, with 11 percent indifferent.

**Table 3** Summary of Valuation Findings for Median Subjects

Health Outcome	Value on Lottery Scale	Value on Utility Scale: $U(H) = 1, U(D) = 0$	Death Risk Equivalent
Good Health	$U(H)$	1.000	0.000
Nerve Disease	$0.600 U(H) + 0.400 U(D)$	0.600	0.400
Morbidity Component of			
Curable Lymph Cancer	$0.417 U(H) + 0.583 U(D)$	0.417	0.583
Curable Lymph Cancer	$0.375 U(H) + 0.625 U(D)$	0.375	0.625
Terminal Lymph Cancer	$0.000 U(H) + 1.000 U(D)$	0.000	1.000
Death	$U(D)$	0	1.000

the number of studies used to estimate the nerve disease risks. Group Two respondents were told that *two* separate studies had shown the same nerve disease risk, while Group One respondents were given the results of only a single study. The Group Two median is somewhat higher than the Group One median, but its mean is lower, indicating that this manipulation had little effect.

The median respondent in Group One found a 2.50/1,000,000 reduction in the risk of nerve disease to be equivalent to a 1/1,000,000 reduction in the risk of an automobile death. This implies that a reduction in the risk of contracting nerve disease is worth 0.4 times an equivalent reduction of the risk of an automobile death. Thus, from Eq. (3) the median respondent expected to suffer a 40 percent reduction in utility by contracting nerve disease, that is

$$1 - \frac{U(N)}{U(H)} = 0.400, \text{ or } U(N) = 0.600U(H).$$

For the median respondent, the utility derived from nerve disease is equivalent to a lottery offering a 0.6 probability of good health and a 0.4 probability of death, whose utility has been normalized to equal zero.

Summarizing the utility information for the sample medians, the utility of sudden automobile death equals the utility of *terminal* lymph cancer. The utility of nerve disease  $U(N)$  is equivalent to the lottery between good health and death (0.6,  $U(H)$ ; 0.4,  $U(D)$ ), and the utility of *nonfatal* lymphoma is equivalent to the lottery (0.417,  $U(H)$ ; 0.583,  $U(D)$ ). This value reflects the utility derived from the certainty of experi-

encing the morbidity consequences of lymphoma. An individual who contracts *curable* lymphoma has a probability  $z$  of a fatality and a probability  $(1 - z)$  of survival to experience  $U(LR)$ , where the value of  $z$  is 0.1 for our study. The value of contracting curable lymphoma with  $z = 0.10$  is equivalent to the lottery (0.625,  $U(H)$ ; 0.375,  $U(D)$ ).

Although we have focused our discussion of Tables 1 and 2 on the median values, the mean values indicate the same relative values of the risks of terminal lymph cancer, curable lymph cancer, and nerve disease. In addition, the standard errors of the means of the trade-off rates are all small enough to make the differences in means easily significant at high confidence levels. Thus, although there are good reasons to expect some variability in trade-off rates across individuals, this variability is small enough to allow strong generalizations about the relative trade-off rates for the entire population.

The empirical results can be summarized in two different ways, as is shown in Table 3. The first column of this table indicates the health outcome in question. These outcomes have been ranked in the order of decreasing attractiveness, with good health being the most attractive and death being the least attractive. The second column of the table gives the value of these outcomes in terms of the lottery on the good health state with a payoff  $U(H)$ , and the adverse outcome death, which offers a reward of  $U(D)$ . With no loss of generality, we can define the utility of good health as equal to one and the utility of death equal to zero. This rescaling of utility values enables us to establish the utility metric given in the third column of Table 3. Once again, these values pertain to utility scales that must be used

within the context of lotteries rather than being treated as additive components. The final column provides death risk equivalents.

For benefit-cost studies it is useful to translate these results about disease risk-automobile death risk trade-off rates into dollar values. While the literature on the value of a statistical life gives a fairly wide range of estimates, a survey of the literature in Viscusi (1992) suggests that a figure in the range of \$4 million is consistent with the general range in the literature.<sup>19</sup> Using this number for purposes of illustration, our median results suggest a value of avoiding a case of nerve disease of \$1.6 million, a value of preventing a case of curable lymph cancer of \$2.5 million, and a value of avoiding a case of terminal lymph cancer of \$4.0 million.<sup>20</sup>

#### 4.2. Relative Aversion Scores: Corroborating the Survey Approach

Part of the introductory section in the questionnaires about both nerve disease and lymph cancer described the disease characteristics and then asked respondents to specify how important they felt it was to avoid each aspect of the disease. Eight of the main consequences of contracting lymph cancer were identified, as well as ten of the main consequences of nerve disease. These ratings were made on a 9-point scale with "least important to avoid," "somewhat important to avoid," and "most important to avoid" providing the verbal anchors for scores 1, 5, and 9, respectively. Thus, larger numbers indicate greater aversion to the consequences of the diseases.

These relative aversion scores are useful despite limited measurement properties. They are similar to a whole class of self-explicated models (Huber 1974, Srinivasan 1988). These procedures ask respondents to

**Table 4** Relative Aversion Scores<sup>a</sup> (9-point scale: 9 most averse, 1 least averse)

A) Lymph Cancer Consequences				
Rank	Consequence	Mean Aversion Score	Standard Deviation of Score	Standard Deviation of Mean
1	Bleeding	8.02	1.65	0.06
2	Infections	7.95	1.65	0.06
3	Depression	7.77	1.92	0.07
4	Loss of Energy	7.47	1.92	0.07
5	Swelling	7.31	2.20	0.08
6	Fever	6.99	2.20	0.08
7	Weight Loss	6.71	2.47	0.09
8	Sweating	6.70	2.47	0.09
B) Nerve Disease Consequences				
1	Loss of Strength	8.19	1.65	0.06
2	Inability to move easily	7.97	1.92	0.07
3	Constant pain	7.91	1.92	0.07
4	No cure	7.88	2.20	0.08
5	Weak muscles	7.79	1.92	0.07
6	Depression	7.75	1.92	0.07
7	Must quit work	7.39	2.47	0.09
8	Must restrict recreational activity	7.22	2.20	0.08
9	Medications required	6.61	2.47	0.09
10	Must restrict exercise	6.17	2.75	0.10

<sup>a</sup> *N* = 755.

evaluate their relative preference for attributes on a scale that is only assumed to be meaningful up to a linear transformation. Such measures are useful in two ways. First, if the scores are assumed to have interval properties, then their differences have ratio properties, thereby permitting one to assess the aspects of a disease that are most important to mitigate. Second, summing the aversion to all the consequences of a disease provides a measure of the overall aversion to the disease. The meaningfulness of these overall aversion scores requires that all consequences are equally likely given the disease and that different respondents use the 9-point scale the same way. To test these assumptions, we form these summed scales and compare them with the more precisely determined trade-off judgments.

Table 4 presents the means and standard deviations of the means of this relative aversion score for the main

<sup>19</sup> Most studies cluster in the \$3 million–\$7 million range, in 1990 prices. The study with the most extensive controls for nonpecuniary characteristics suggests a value of life of just under \$4 million.

<sup>20</sup> While not the main focus of our research, we did explore several models for explaining the variation in the risk-risk trade-off values across respondents. None of our cross-section regression results found strong results, but a priori we have little theory to guide our expectations for these results. Because the trade-off rates are defined in terms of reductions in the automobile death rate, rather than money, any income effects should net out so we would not expect a significant income coefficient.

**Table 5** Regression Analyses of Relative Aversion Scores and Auto Death (AD) Risk Trade-off Rates<sup>a</sup>

Equation Number	Dependent Variable (AD Risk Tradeoff Rates)	Independent Variable (Relative Aversion Scores)	Coefficient (Std. Error)	Prob. Value
1	AD/ND	ND_AVE	0.298 (0.093)	0.002
2	AD/CLC	LC_AVE	0.693 (0.170)	0.0001
3	AD/TLC	LC_AVE	1.715 (0.280)	0.0001

<sup>a</sup> All regression equations also included a constant term.

consequences of contracting the two diseases (with the one exception of the probability that the disease will be fatal, which is the only characteristic that differs across the two forms of lymph cancer, curable and terminal). The order of these mean relative aversion scores accords relatively well with the relative severity of the outcomes.<sup>21</sup>

If the risk-risk trade-off values described in the above section and the relative aversion scores for a disease's consequences both indicate the strength of an individual's preferences to reduce the risk of a disease such as nerve disease or lymph cancer, they should be closely correlated. By regressing the trade-off rates against the mean aversion scores averaged over all of a disease's consequences, we can test the hypothesis that the two variables *both* measure the same characteristic. The absence of a correlation would indicate that either one or

the other, or both variables do not measure the preferences for risk reduction. Given that there are different numbers of consequences for the two diseases and these consequences appear to be more or less independent, we use the *mean* aversion scores *averaged* across all of the disease's consequences as a measure of the strength of preference shown by the responses to the aversion rating responses.<sup>22</sup>

Equations 1 through 3 in Table 5 display the results of these simple regressions. The automobile death equivalent values for nerve disease and the two forms of lymph cancer are all closely correlated with the average of the mean aversion scores. All of the coefficients in Eqs. 1, 2, and 3 are positive, as expected, and significant at more than a 99 percent confidence level.<sup>23</sup> These results suggest that both measures, the risk-risk trade-off values and the average of the mean aversion scores, measure the same characteristic.<sup>24</sup>

<sup>21</sup> For example, lymph cancer respondents were most averse to "mild bleeding problems with skin and joints," which had an aversion score of 8.02 on a 9-point scale. It is likely that the lack of familiarity attached to bleeding of the joints increases the fear associated with this consequence; one knows how to deal with sweating (6.70) or weight loss (6.71), but not bleeding of the joints. This result is consistent with those of other researchers who have found that aversion to unfamiliar events such as an explosion in a nuclear power plant tends to be greater than their factual characteristics might justify. The next most averse consequences of lymph cancer were infections (7.95) and depression (7.77), both of which imply a vulnerability to the environment for which relatively few defenses exist. By contrast, the less averse consequences—swelling (7.31), fever (6.99), weight loss (6.1), and sweating (6.70)—may be uncomfortable, but are those kinds of misfortunes for which most people have well-developed coping mechanisms.

<sup>22</sup> If we knew the relative probabilities of each of these consequences occurring, we would use these probabilities to form a weighted average instead of an unweighted average.

<sup>23</sup> While it is the sign and statistical significance of the coefficients which are most relevant as a validity check, the *magnitudes* of the coefficients are also informative. For example, the coefficient in equation three indicates that a one unit increase in a respondent's relative aversion score (scaled 1–9) is associated with a 1.715 unit increase in the automobile death risk rate the respondent would trade off for a one unit reduction in his or her terminal lymph cancer risk rate.

<sup>24</sup> An alternative test of relationship between the risk-risk trade-off rates and the relative aversion scores could be constructed by regress-

## 5. Conclusions

This paper developed a death risk lottery metric approach to estimate the values that people place on reducing their risks from contracting chronic diseases. We focused on two diseases with long-term effects, a nerve disease (peripheral neuropathy) and two forms of lymphoma (cancer of the lymph system), one that is fatal and another with a 90 percent chance of survival. In previous work (Viscusi, Magat and Huber 1991) we developed a computer-based methodology to elicit values for avoiding short-term health risks; this paper extends that approach to the valuation of reducing the risks of contracting diseases with long-term health effects, including possible death and the other aspects of cancer.

Our approach elicited values for reducing the risks of nerve disease and lymph cancer using the metric of another familiar risk, specifically, the risk of dying in an automobile accident. We showed that these risk-risk trade-off rates measure the percentage reductions in the utility of good health caused by contracting the diseases. The relative values of the estimates of the automobile-death-risk-denominated values suggest that our approach is accurately measuring preferences for risk avoidance. The median respondent found that reducing the risk of contracting the least serious illness, nerve disease, to be 0.4 times as valuable as reducing the risk of an automobile death. In contrast, the median value of reducing the risk of contracting potentially curable lymphoma was 0.625 times the value of avoiding the risk of an automobile death, and the median respondent was indifferent between reducing the risk of

terminal lymphoma and reducing his or her automobile death risk. Further, the median respondent found reducing the risk of a non-fatal form of lymphoma to be worth to 0.583 times the value of an equivalent reduction in the risk of an automobile death. Both the magnitudes of these risk-risk trade-off values and their relative values are consistent with an objective evaluation of the consequences of contracting the three diseases.

As a test of the extent to which these risk-risk values measure respondents' true values of reducing the risk of contracting the diseases, we correlated them with an independent measure of their aversion to the major consequences of contracting each of the diseases. These relative aversion scores for each respondent were found to be positively and significantly related to their risk-risk values, adding additional support to the confidence that we can place in the risk-risk values.

Like most approaches to valuation, our approach assumes that people have reasonably well defined preferences for reductions in their risks of adverse health effects. Recent work by Payne, Bettman and Johnson (1992), Gregory (1993), and others argues that preferences are constructed, not pre-existing, especially for unfamiliar goods. If they are correct, then a critical question to address in comparing our approach with other ones is which *process* for eliciting values is most reasonable. While a full answer to this question is far beyond the objectives of this paper, arguably any desirable process for constructing preferences should satisfy the requirements that decision makers are well informed about the goods in question and that their values are derived from, and thus consistent with, choices they actually make.

Our approach, based on reference lotteries for good health and death, scores well on these two criteria. Respondents are forced to think carefully about each of the major consequences of the diseases and how averse they are to these consequences, and their preferences are elicited through carefully controlled choices over location decisions that, albeit highly simplified, are similar to those that most people face periodically in their lives. Indeed, from the point of view of the constructed preferences, our approach offers one way of constructing, or sharpening, preferences much like that which would be followed by an informed patient discussing his or her disease with a physician.

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ing the *ratio* of nerve disease trade-off rate to the lymphoma trade-off rate against the *ratio* of the relative aversion scores of the two diseases. Because of problems with the high variance of ratio measures and values near zero in the denominators, we performed similar regressions of the *difference* between AD/ND and AD/CLC and the *difference* between ND\_AVE and LC\_AVE, and of the (AD/ND – AD/CLC) against (ND\_AVE – LC\_AVE). The coefficients in these two equations take the expected positive signs, but are not statistically significant. The fact that the differences in the two measures for the two diseases are not as closely correlated as the absolute magnitudes of the two measures for each disease indicates that there is some noise in one or the other of the measures, but this differences test requires a greater degree of consistency across measures than simply comparing the two measures for each disease one disease at a time.

While we have applied our methodology to only one form of nerve disease and two forms of lymphoma, the results suggest that our approach can be broadly applied to other types of health risks involving important public policy decisions (although our specific results for nerve disease and lymphoma cannot be directly used for the valuation of other diseases). Increasingly, federal and state laws are requiring that regulations improving health be justified by rigorous analyses of the benefits of lower disease risks. The availability of an effective approach for valuing the reductions in various health risks is necessary because market-based values are generally not available and alternative benefit estimation techniques, such as hedonic pricing models and contingent valuation, all pose serious problems when applied to health risks, particularly chronic ones.<sup>25</sup>

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