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Paired Comparison and Contingent Valuation Approaches to Morbidity Risk Valuation[1]

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This research uses an experimental approach for eliciting consumer valuations of morbidity risk reductions associated with safter chemical products and introduces the paired comparison questions approach to non-market valuation. In four applications, the paired comparisons approach yields higher morbidity valuations than the more familiar contingent valuation approach. However, both methodologies produce large values of morbidity reduction benefits in comparison to estimates derived from wage hedonic studies. Explanations for the difference in the estimates and their magnitudes are suggested along with the public policy implications.

Environmental benefits are difficult to value because they are not traded explicitly in markets. Although many environmental attributes are traded implicitly in markets for housing, consumer products, and jobs, it is often difficult to assess the level of environmental attribute being traded and to disentangle the trade-off between the environmental attribute and money. As a result, there has been increased exploration of non-market approaches to assessing these values.

The most widely used of these techniques is the contingent valuation (CV) approach in which respondents are asked to give their willingness to pay for some outcome contingent on the assumed existence of a market in which it can be purchased.[3] This paper introduces another technique, that of paired comparison (PC) questions, and compares the consumer valuation responses using these two approaches. We extend previous studies by focusing on a class of health outcomes pertaining to individual morbidity.

The comparison of amenity values estimated using the CV method with values derived from other approaches is a central theme of much of the literature on contingent valuation. Our study resembles that of Desvousges *et al.* [5], who compare water quality estimates based on CV questions and the contingent ranking approach,[4] both of which are based on the survey methodology. Our study of paired comparisons differs from the contingent ranking approach in its structure, however. Most other CV comparisons have contrasted its estimates with those derived from

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[3]For examples, see the assessment of the literature by Cummings *et al.* [4], as well as [5, 7, 15, 17, 19, 20].

[4]The contingent ranking approach infers willingness-to-pay estimates from consumers' rankings of several alternatives.

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implicit market approaches, specifically the travel cost method [2, 5, 12, 20] and the hedonic price method [3, 4, 21].

We explore these approaches for one important class of consumer choice problems, that involving the value of risk reductions from making products safter. Our paired comparisons approach derives each consumer's willingness to pay for risk reduction from a set of comparisons of paired products that differ only in their purchase price and risk of injury. We select this approach because it has been successful in both the psychometric and the marketing literature.[5] Because of the ease that subjects have in making paired comparisons, as opposed to more precise responses required in a hypothetical market, this methodology may offer a greater opportunity for eliciting individual preferences in contingent contexts.

Our application of the CV methodology differs from most others in four ways. First, most of these analyses have addressed the valuation of public goods, such as air quality, water quality, and hazardous waste containment, or common property resources (see [4, 1]). In contrast, our study estimates consumer values for a private good—risk reductions accruing to a particular consumer or household from the use of safer chemical products.

Second, the commodity we analyzed—morbidity risk reductions—poses particular difficulties for individuals' cognitive processes. Most consumers are not accustomed to thinking about injuries from hazardous products in ways that require them to trade off money for reducing the probabilities that injuries will occur. To facilitate this comparison, we couch the morbidity valuation task in the context of a more familiar decision involving injury risk reductions, that of selecting among alternative products with different levels of safety. By tying the survey to a potential market context, we reduce the artificiality inherent in any contingent survey and make the subject's responses more meaningful. In effect, the study replicates the implicit market analyses for a hypothetical market.

Third, to simplify the decision-making task, most early applications of the CV method downplayed the uncertainty attached to the environmental amenities being valued.[6] Our analysis focuses on consumer responses to low probability events.

Finally, we report on the use of an interactive computer program for administering the questionnaire, reducing potential interviewer bias, and decreasing the length of the interview.[7]

Regulators need estimates of the benefits of protective regulations as well as their costs in order to make informed judgments about protection from the adverse health consequences caused by exposure to consumer and industrial products. Benefit estimation requires an assessment of the values consumers and workers place on reducing the incidence of these health consequences. Our study considers one common source of health benefits, those from morbidity reductions. We present several estimates of how much consumers value several types of morbidity benefits, but our main purpose is to determine the sensitivity of these values to the method of eliciting responses and to the context and structure of the choice environment.

After describing the structure of the questionnaire used to elicit morbidity valuations in the next section, we analyze two aspects of the valuation problem.

[5]See Huber and Holbrook [10] and David [6].

[6]There are some notable exceptions, such as the efforts to value risk reductions by Gallagher and Smith [7], Smith *et al.* [19], and Mitchell and Carson [16].

[7]See, for example, Waller and Covello [25], Kunreuther *et al.* [13], and Kahneman and Tversky [11].

Section 2 contrasts the values derived from PC questions with those derived from the CV technique, finding strong evidence that the method of preference elicitation affects the stated values. Section 3 analyzes the magnitudes of the implied values per statistical injury avoided and discusses why they are larger than those derived from nonsurvey approaches. We conclude by discussing the implications of our research findings.

1. STUDY DESIGN

A. Products, Hazards, and Procedures

We designed the questionnaire to elicit the values that consumers attach to reducing the probabilities of suffering several types of accidents, focusing on two hazards associated with each of two household chemical products—bleach and liquid drain opener. Each subject was given a bottle of one of the two products and asked a series of questions about the safety precautions he or she would take when using the product. Because these early questions are not directly relevant to the valuation issues, they will not be discussed further. For a more detailed discussion of the survey procedures and an analysis of the precaution-taking responses, see [23, 24].

The interviewer then explained to the subject that the remainder of the questions would be administered by a personal computer. For subjects receiving the household bleach, the computer program first described the health consequences of chloramine gas poisoning created by mixing bleach with another product containing ammonia and then asked questions designed to reveal the subject's willingness to pay to reduce the probability of chloramine gas poisonings. After describing the dangers from ingestion of bleach by a child, the second set of questions sought to determine the value that subjects attach to reducing the incidence of child poisonings. Subjects receiving the drain opener were asked similar questions about two of its major hazards, skin burns and child poisonings.

Both bleach and drain opener are widely used products that result in relatively large numbers of injuries in the United States, despite low accident rates per bottle used. Table I lists the two primary hazards associated with each of the two products. Although there are several other hazards identified with the unsafe use of these products, the Consumer Product Safety Commission data indicate that these hazards for each product cause a significant portion of the injuries associated with their usage.[8] The questionnaires carefully explained the adverse health consequences associated with the four hazards listed in Table I. For a description of these health effects, see Appendix A.

B. Subjects

A marketing research firm recruited the subjects for the study at a shopping center in Greensboro, North Carolina. Upon successfully answering screening

[8]These statements are based on a series of unpublished computer printouts generated for this study by the Food and Drug Administration and by the Consumer Product Safety Commission.

TABLE I

Hazards and Precautions Associated with Study Products

Products	Hazards	Precautions
Bleach	Chloramine gas	Do not mix
	Child poisoning	Store in safe place
Drain opener	Hand burns	Wear gloves
	Child poisoning	Store in safe place

questions to determine that they are current or potential users of one of the two household products, subjects were escorted into a quiet room in the mall where the interviews were conducted.

Of the 368 subjects participating in the mall interview, 200 were given the bleach questionnaire and 168 answered the drain opener questionnaire. Table II lists the characteristics of the overall sample. The characteristics of the subsamples of subjects receiving each of the two products (not shown) do not differ significantly from each other, and they correspond reasonably to general 1980 U.S. figures. The mall we selected for the interviews is frequented by a wide cross section of the city of Greensboro, which has a population broadly representative of the entire country.

TABLE II

Sample Characteristics

Variable	Sample mean	Standard deviation	U.S. Population mean
Family income[a] (1984 $/year)	30,828	17,932	28,557
Education[a] (years)	13.3	2.2	12.5
Age[a] (years)	33.3	12.8	30.0
Married[a] (1 = yes, 0 = no)	0.57	0.50	0.64
Male[a] (1 = yes, 0 = no)	0.32	0.43	0.47
Blacks[a] (1 = yes, 0 = no)	0.26	0.40	0.12
Number of children under 5 per family[a]	0.23	0.51	0.29
Bleach use per family[b] (bottles/year)	17.0	31.3	
Drain opener use per family[b] (bottles/year)	2.0	4.4	2.4

[a]Source of U.S. population statistics: Bureau of the Census, "Statistical Abstract of the United States," U.S. Department of Commerce (1985) (1983 data, with family income adjusted to 1984 $'s).

[b]Source of U.S. population statistics: Predicasts, Inc., "Predicasts Basebook," Cleveland, OH (1984).

CURRENT BLEACH	NEW BLEACH
Cost per year: \$10.00	Cost per year: ?
Injury level: 50 gas poisonings for every 2,000,000 homes	Injury level: 50% DECREASE in gas poisonings compared to the current product

How high would the price of the NEW BLEACH have to be before your would rather buy the CURRENT BLEACH?

\$__________/year

PRESS THE NUMBERS THAT SHOW HOW MANY DOLLARS AND CENTS YOU ARE WILL ING TO PAY.

FIG. 1. Sample contingent valuation question.

Elicitation Methods

We used two methods to elicit the subjects' morbidity valuations—the contingent valuation approach and an approach based on paired comparisons of products. The CV approach has been used extensively over the past decade to value environmental amenities (see [3, 4, 5, 15, 18, 19]). As defined by Randall *et al.* [17], "Contingent valuation devices involve asking individuals, in survey or experimental settings, to reveal their personal valuations of increments (or decrements) in unpriced goods by using contingent markets. These markets define the good or amenity of interest [in our case reductions in the incidence rates of each of the four injuries described above], the status quo level of provision and the offered increment or decrement therein, the institutional structure under which the good is provided, the method of payment, and (implicitly or explicitly) the decision rule which determines whether to implement the offered programs."

The CV method typically uses either a series of bids ending with the maximum willingness to pay for the environmental benefit or one direct question about the consumer's maximum willingness to pay. We chose the latter approach. Figure 1 illustrates one of our four CV questions that was used to value reductions in the chloramine gas poisoning rate from using bleach. The CV question shows the consumer two products (in the example, a current bleach and a new bleach) that differ by only two characteristics—their cost per year and the number of injuries for every two million homes (which subjects were told is the number of households in North Carolina).[9] For a given percentage reduction in the injury level associated with the new product, the CV question asks how high the cost of the new product

[9]Our pretests indicated that subjects were comfortable with the notion of an injury rate based on the population of households within their state. We suspect that using another less concrete base rate, such as one million households, would have made the injury rates less meaningful for many subjects.

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          CURRENT BLEACH                                NEW BLEACH
* * * * * * * * * * * * * * * * * * * * * * * * * *    * * * * * * * * * * * * * * * * * * *
*                                                 *    *
*          Cost per year:                         *    *        Cost per year:
*                  $10.00                         *    *               $15.00
*                                                 *    *
*          Injury level:                          *    *        Injury level:
*                                                 *    *          40% DECREASE in
*             50 gas                              *    *          gas poisonings
*             poisonings for                      *    *          compared to the
*             every 2,000,000                     *    *          current product
*             homes                               *
* * * * * * * * * * * * * * * * * * * * * * * * * *

                           Which bleach would you prefer?
Strongly                                                                   Strongly
Prefer                              Equal                                  Prefer
CURRENT                   ——— . ——— . ———                                  NEW
BLEACH                                       6              8              BLEACH
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PRESS A NUMBER INDICATING YOUR PREFERENCE AND THEN PRESS THE RETURN KEY.

FIG. 2. Sample paired comparison question.

must be before the subject would rather buy the current (i.e., riskier and less expensive) product. The implied value per injury avoided (in every two million households) is calculated by dividing the difference in annual costs for the two products by the number of injuries avoided.

In order to focus the subjects' responses on the trade-off between lower costs and lower risks to their own households, rather than societal risk reductions, we designed the choice environment around two private goods. In addition, the computer program (see Fig. 1) emphasized that "the NEW BLEACH is less likely to result in gas poisonings in your home than the CURRENT BLEACH. The amount you are willing to pay will affect only YOUR household's costs and not those of other bleach users."[10]

In contrast to this one-step CV elicitation procedure, the PC approach asks each subject to make a series of comparisons between products with differing characteristics. This approach is widely used in marketing research because it poses the issue in terms of the product choice context that simulates actual choices in the marketplace. As shown in Fig. 2, for each pair of products, the current product remains unchanged, but the cost and injury levels for the new product change. Subjects were asked to rate on a scale of one to nine which of the two products they preferred, with five representing indifference between them. From the five ratings of paired comparisons presented to each subject, we used two techniques to estimate the

[10]One reviewer raised the possibility that despite these explanations, some subjects may have thought that there was some relationship between their responses and the risks faced by other users of the product beyond their own households. We did examine how the CV responses varied with demographic characteristics, but found inconclusive results, most likely because of our relatively small sample sizes. Even if some subjects did think that their responses affected the risks to other households, this misunderstanding should not have been greater for either the CV or the PC questions, and thus would not have affected the *comparisons* approaches in the next section.

subjects' willingness to pay to avoid accidents: conjoint analysis of each individual's responses and regression analysis of the pooled responses for which the subjects were indifferent. The next section describes these techniques in more detail.

The CV and PC responses were elicited through questions asked on an IBM personal computer. The interviewer sat nearby to help if the subject did not understand any questions posed by the computer, but such assistance rarely was needed. Besides advantages in accurately storing and retrieving subjects' response data on the personal computer, this computer-based interview approach reduces the potential for interviewer bias because the program asks every subject the questions in exactly the same way. There also is less incentive for the respondent to misrepresent a response in an attempt to make a more favorable impression on an interviewer.

Perhaps the most innovative aspect of our paired comparisons technique is its interactive nature. Conceptually, the computer program uses the subject's responses to the first two paired comparison questions to design the trade-offs posed in the later questions. The criterion for this design is that the pairs be in the neighborhood of the subject's likely range of indifference between the two products.

Specifically, the algorithm first poses two paired comparison rating questions like the one in Fig. 2. Then it uses the values of the ratings (R), the changes in the yearly cost (ΔCOST), and the changes in the injury probabilities (ΔRISK) from the two questions to solve the equations below for the parameters α and β which measure the relative importance of money and injuries:

$$R_1 = \alpha \cdot \Delta\mathrm{COST}_1 + \beta \cdot \Delta\mathrm{RISK}_1$$

and

$$R_2 = \alpha \cdot \Delta\mathrm{COST}_2 + \beta \cdot \Delta\mathrm{RISK}_2.$$

Finally, the program designs the yearly cost levels for three more paired comparison questions, each with different percentage reductions in the injury rate, based on the rate of trade-off between money and injuries estimated from the first two questions. These three yearly cost levels are calculated to make the subject indifferent between the reduction in probability of injury and the increase in the cost of the product. For example, if the ratings for the first two questions implied a rate of trade-off ($-\beta/\alpha$) between injuries and costs of \$2 for every 10% decrease in the injury rate, then a new bleach with a 20% decrease in the injury level would be assigned a cost of \$4 more than the yearly cost of the current product.

This adaptive questioning reduces the number of paired comparisons that each subject must answer in order to produce stable estimates of the trade-off between money and injury reduction. It also greatly diminishes the possibility of bias from ceiling effects caused by subjects forced to use a "1" or a "9" rating for strongly one-sided choices.

2. DIFFERENCES IN MORBIDITY VALUE ESTIMATES DERIVED FROM THE CV AND PC APPROACHES

It is well known that the method of eliciting preferences can influence the values that consumers say they attach to a commodity or product attribute. For example,

TABLE III
Comparison of Injury Valuations
(Measured in $ per Injury Avoided in Every Two Million Households)[a]

Injury type	(1) Mean CV[b]	Paired comparison data (2) Mean conjoint	(3) Mean from indifferent pairs data	(4) Regression of indifferent pairs—restricted sample[c]	(5) Mean Δ$/injury due to CV approach
Bleach					
Gassings	0.15	0.69	0.72	0.77	−0.29[d]
	(0.02)	(0.11)	(0.09)	(0.09)	(0.15)
Child poisoning	0.21	0.25	0.35	0.29	−0.06
	(0.03)	(0.03)	(0.04)	(0.03)	(0.15)
Drain opener					
Hand burns	0.06	0.62	0.55	0.55	−0.25[d]
	(0.01)	(0.08)	(0.06)	(0.06)	(0.15)
Child poisoning	0.18	0.41	0.55	0.50	−0.16
	(0.02)	(0.10)	(0.06)	(0.05)	(0.15)

[a]Standard errors are listed in parentheses.
[b]The highest five and lowest five injury valuations were truncated before calculating the means and standard errors of the means.
[c]See the text for an explanation of comparisons deleted from the sample.
[d]Significantly different from zero at a 95% confidence level.

Hershey *et al.* [9] demonstrate what they call a "response mode bias" from estimating the shape of utility functions using both the certainty equivalent and the probability equivalent approaches. Not surprisingly, we find that the contingent valuation method yields morbidity value estimates different from those derived from the responses to the paired comparison questions. The more interesting question, however, is which approach induces the higher estimates and the magnitude of these differences.

A. The Contingent Valuation Approach

Table III displays estimates of the valuations of the four injuries from both the contingent valuation responses and the paired comparison responses. Although about half of the subjects answered a CV question first followed by the PC questions and the other half answered the PC questions first followed by the CV question, for comparison purposes only the means for the first set of responses made by a subject are shown in columns (1)–(3).[11]

The answers to the CV questions indicate how much more a subject is willing to pay for a new, safer product. These willingness-to-pay statistics represent the value to the consumer of reducing the probability of the injury by the designated

[11]By comparing means calculated from only the first set of responses by each subject, we avoid any biases created by the influence of the first set of questions using one approach on the answers to the second set of questions using another approach.

percentage (e.g., 50% for the example in Fig. 1). Given the annual number of injuries per two million homes associated with the current product, we calculated the number of injuries avoided and divided the indicated cost increase by the number to derive a measure of the subject's implied value per injury avoided (in every two million households).

Because the tails of each of the distributions of CV valuations contained some extreme outliers, in calculating the means in column (1) we truncated the top five observations and the bottom five observations in each distribution.[12] Although this truncation procedure makes the means somewhat arbitrary, we believe that the truncated means provide a more useful summary statistic for the distribution of values for each of the four valuation groups than non-truncated means.[13] Column (1) of Table III lists the truncated mean values of these morbidity values derived from the CV responses for those subjects who answered the CV questions *before* the paired comparison questions. Below we will address the properties of the responses to the CV questions that were asked *after* the paired comparison questions. These responses will be used to design a second test to compare the values from the CV and PC approaches, one which does not truncate the CV response distribution and thus provides a check on the sensitivity to the specific truncation procedure of the comparison of truncated means.

B. Paired Comparisons Approach

Conjoint analysis is one of the two techniques we used to derive morbidity values from the paired comparison responses. It has been used extensively in the marketing literature (see [8]) to estimate the structure of a consumer's relative preferences for different product attributes from ratings of paired comparisons. We used this approach to recover the relative preferences for money and risks possessed by *each* subject. The technique involves regressing the rating observations (RATING) for each of the five product pairs rated by a subject against both the change in cost levels (ΔCOST) for each pair and the change in injury levels (ΔRISK) for each pair. The results provide a set of regression estimates (coefficients α and β) of the relative importance of money to injuries for that consumer, or

$$\text{RATING} = \alpha \cdot \Delta\text{COST} + \beta \cdot \Delta\text{RISK}. \tag{1}$$

The ratio of the two coefficients $(-\beta/\alpha)$ measures the consumer's marginal rate of substitution of lower product cost for higher product risk. To understand the

[12] In some CV studies the authors have probed the motivation behind protest bids that occur when subjects claim that they would pay nothing for a product or public program. Protest bids occur because subjects are unfamiliar with the types of questions being asked or find them difficult to answer. In our study very few subjects refused to answer all the valuation questions posed by the computer. Given the structure of our study, we suspect that any protest bids were more likely to take the form of refusing to answer the question than refusing to pay a premium for a safer product. While some subjects said that they would pay the same price for the new product as for the current product, this is a legitimate response and we did not further probe their reasons for giving this response.

[13] Other truncation rules yield the same conclusions about the relative sizes of the CV and PC risk valuations. Note that because of the limited scale in the permitted responses, no truncation is necessary for the values derived from the conjoint analysis of the PC questions. As described below, each subject's conjoint value is derived from the coefficients in a regression equation. These coefficients represent central tendencies and thereby limit the noise associated with individual responses.

economic implications of this result, consider a utility function which has the attributes of the product as arguments and which is separable in product cost, product risk, and all other attributes[14]:

$$U = U_1(\mathrm{COST}) + U_2(\mathrm{RISK}) + U_3(\mathrm{OTHER}). \tag{2}$$

Then the utility difference between the new product (n) and the current product (c), which differ only in cost and risk, equals

$$(U^{n} - U^{c}) = (U_1(\mathrm{COST}^{n}) - U_1(\mathrm{COST}^{c})) + (U_2(\mathrm{RISK}^{n}) - U_2(\mathrm{RISK}^{c})). \tag{3}$$

Taking a first-order approximation to the two utility differences gives the linear function on the right-hand side of (1), where $\alpha = U_2'$ and $\beta = U_2'$. We use a linear rating scale to approximate the utility difference on the left-hand side.[15] Taking the total differential of (1) gives

$$\left.\frac{\Delta\mathrm{COST}}{\Delta\mathrm{RISK}}\right|_{U^{n}=U^{c}} = -\frac{\beta}{\alpha}$$

showing that the ratio of the two coefficients $(-\beta/\alpha)$ measures each subject's willingness to pay to reduce the accident rate by one accident per two million households.[16] This technique provides the consumer's marginal rate of substitution averaged over the risk range considered. Thus, the economic interpretation of the conjoint results is the same as for contingent valuation. Column (2) of Table II displays the mean responses across all subjects for the morbidity valuations derived from the conjoint approach.

As a check on the accuracy of the conjoint approach to evaluating the PC responses, columns (3) and (4) of Table III report alternative estimates of the injury valuations that avoid the need for a rating scale. Specifically, we restrict attention to only those pairs of products for which a subject was indifferent. Column (3) gives the mean value (for all subjects' indifferent pairs) of the ratio of the cost difference to the risk difference (ΔCOST/ΔRISK) for each pair of products. Column (4) presents the coefficient γ of the variable, the difference in risk (ΔRISK), in the following regression[17]:

$$\Delta\mathrm{COST} = \gamma \cdot \Delta\mathrm{RISK}$$

Note the close fit between the injury valuation in columns (3) and (4) of Table II with those derived from the conjoint approach in column (2). This congruence supports the validity of the conjoint methodology for measuring the injury valuations implied by responses to PC questions.

[14]This third term also includes other products, or their attributes.

[15]See Appendix B for a discussion and test of the linearity of the rating scale.

[16]As long as the subjects find the new and current products to be near indifference (i.e., a rating of then the linearity assumption for the rating scale (i.e., the difference in utility levels on the left-hand si of (3)) is not an issue. It is for this reason that we designed the computer program to select product pa that consumers would find to be indifferent.

[17]In this regression we further restrict the sample to those indifferent pairs for which the risk of t new product was non-zero (i.e., less than a 100% reduction in the number of injuries), but lower than t risk of the current product (i.e., eliminating that one question in the set of paired comparisons tl presents a new product which is *more* risky than the current one). In Viscusi and Magat [23] we anal the deleted pairs to determine if consumers are willing to pay a certainty premium to complet eliminate the risks from the products and if they respond differently to avoiding risk increases tl achieving risk decreases.

C. Comparison of the Two Approaches

The statistics in Table III show that the direct CV approach to eliciting injury valuations yields substantially *lower* values than the use of PC responses. The subsample of indifferent pairs produces estimates close to those derived using conjoint analysis on the full sample of paired comparison responses, and all of the estimates from the PC approach exceed the CV estimate for each of the four injuries. The average CV injury valuation is 58% lower than the average conjoint valuation (compare columns (1) and (2) of Table III).

Another method of comparing the CV and PC responses involved asking some subjects the CV question *after* they completed all the PC questions. By including the sixth CV response (and an indifference rating of "5") with the five PC responses, we were able to use the dummy variable CV (taking the value of one only for the CV response) to test whether the CV approach per se elicited a different valuation for risk compared with the PC approach. Column (5) of Table III lists the mean values for all subjects of the coefficient δ of the cross-product term, $\mathrm{CV} \cdot \Delta\mathrm{RISK}$, which was added to the right side of Eq. (1); i.e.,

$$\mathrm{RATING} = \alpha \cdot \Delta\mathrm{COST} + \beta \cdot \Delta\mathrm{RISK} + \delta \cdot \mathrm{CV} \cdot \Delta\mathrm{RISK} \tag{6}$$

The mean δ coefficients range from -0.06 to -0.29, with the bleach gassings coefficient and the hand burns from drain opener coefficient showing statistical significance at the usual levels. These coefficients translate into percentage reductions in the mean conjoint valuations in column (2) of 21 to 52% due to the CV formulation.

In this test the CV responses are affected by the fact that the CV question *followed* the several paired comparison questions, thus attenuating the expected differences across methods. Because of this attenuation, the significant differences found strongly corroborate the earlier conclusions based on cross-subject comparisons. Thus, both across-subject and within-subject comparisons of CV and paired comparison values indicate that the CV values are lower.

The result that direct CV questions yield lower responses than PC questions is consistent with two other findings in the literature. First, Desvousges *et al.* [5] found the mean water user values derived from direct CV questions to be in the range of three to four times less than the values estimated using contingent ranking. We would expect a similar ordering of CV and paired comparison values because the contingent ranking questions pose a similar, albeit more difficult, choice task than the paired comparisons.[18] Second, Schulze *et al.* [18] and Randall *et al.* [17] concluded that in two out of three studies they reviewed the starting CV bids were less than the final values obtained from a bidding, auction-like process. Although these comparisons and similar comparisons of direct and iterative CV responses reported in Desvousges *et al.* [5] cannot be considered strong evidence, they do at least suggest that direct, one-step CV questions may induce consumers to reval less than their reservation values.

We hypothesize that the reasons we found lower values of injury reduction from the CV approach than from the PC approach are the same two suggested by Schulze

[18] The contingent ranking questions require the consumer to compare simultaneously several alternative commodities rather than the series of pair-wise comparisons in our study.

et al. [18] for their finding of lower starting CV bids than final values derived fr an iterative bidding process. First, despite being given a practice question a answering several valuation questions, subjects may have believed that there v some chance that they would be offered an opportunity to revise their responses. making actual purchase decisions they are more accustomed to bargaining purchase a given product for a lower price, or searching across several stores fo lower price, than being required to formulate and reveal their reservation prices products. Given these patterns of customary behavior, they may have had trou completely ignoring their usual purchasing objective of maximizing the differe between what they pay for a product and their reservation price. Second, cognitive search process that many consumers use for determining their reservat prices probably starts by finding an acceptable price for the product and tl approaching the maximum willingness to pay from below.

In contrast to these reasons to suspect that CV responses are lower tl reservation prices, the paired comparisons approach produces no incentives subjects either to understate or to overstate their true valuations because of gam considerations or the search process they use to determine their valuations. these reasons, we would expect to find, as we did, that the paired comparis approach yields higher risk valuations than the contingent valuation approach.

3. MORBIDITY VALUATIONS

The analysis thus far has concentrated on the *differences* in the responses to two survey techniques, but it is also of interest to examine the *levels* of the valuations. We focus on the PC responses because they appear to be more accu measures of the willingness to pay than the CV responses.

The conjoint values in column (2) of Table III describe the subjects' m willingness to pay for one injury reduction for every two million households, ra than the value of a certain injury. Deriving the technical value of avoiding "statistical injury" requires multiplying the figures in column (2) by two millio The resulting mean values per injury avoided are $1.38 million for a bleach gass $0.50 million for a bleach child poisoning, $1.24 million for hand burns from d opener, and $0.82 million for child poisonings from drain opener.[20]

These values are high relative to several natural benchmarks. They exceed ave income by more than an order of magnitude. Further, they are far above

[19] Because we do not know for each injury the distribution of risks across the subjects in our sa we used the injury risks provided to them. This procedure assumes that the perceived risks which sul used to respond to a valuation question are distributed around the given risk value in a way that sat the following requirement—multiplying the mean values in column (2) by the given risk gives the value per injury avoided as would be obtained by calculating each individual's value per injury and taking the mean of these values.

[20] The two child poisoning injury questions were always asked *after* questions about another i (either bleach gassing or drain opener hand burns). This introduces imprecision into the PC poisoning responses and could explain why they led to lower injury values than for the other two inj despite the greater severity that most people probably attach to the child poisoning injuries. imprecision in the child poisoning injury valuations due to the order effect is further illustrat comparing columns (1) and (2) in Table III. The CV child poisoning estimates exceeded the valu avoiding the first injury posed to each subject (either bleach gassings or drain opener hand bu whereas the mean child poisoning estimates from the PC approach were less than the values for th injuries included in the questionnaires.

morbidity valuations that result from hedonic wage studies where the implicit value of a job injury ranges from \$20,000 to \$30,000.[21] Finally, the levels of the bleach and drain opener risk valuations are more in line with the estimated implicit values of life, which are on the order of \$650,000 for workers in high risk jobs and \$3.5 million for workers in average risk jobs.

How can these large morbidity valuations be reconciled with the above comparisons? And are they relevant for benefit analysis? The answer to the first question requires that the valuation responses be placed in the context of one important characteristic of the choices that subjects were asked to make, namely, the extremely low probabilities of the underlying risks—on the order of one injury per forty thousand households which use the products every year. The answer to the second question requires that the potential uses of the benefit estimates be carefully examined.

In considering alternative explanations for the observed behavior, we will distinguish between what consumers' expressed preferences are and what these expressed preferences would be if they were fully rational. We believe that our experiment provides an accurate reflection of how individuals respond to very low probability events that are called to their attention. We do not, however, believe that these preferences accurately reflect the preferences that they would express if they fully understood low probabilities and could act upon this information rationally. Thus, our results are intended to provide a predictive guide for how consumers react to risk. They do *not* provide a good normative guide to the appropriate level of risk–dollar trade-off for benefit assessment purposes.

Several researchers have shown that decisions involving low probability events differ from the decisions made with higher probability events by amounts that are not consistent with the differences in probabilities. Theoretical and empirical arguments have been generated to support two opposite reactions to decisions involving low probabilities—toward overweighting low probability events as well as toward underweighting them.[22]

One possible explanation for these two different responses to low probability events may be the difficulty of individuals to mentally account for both an aversion to a loss and the probability that a loss will occur. By focusing on either the loss itself or the low probability of its occurrence, and ignoring the second characteristic, they would tend to either overreact to the risky event or ignore it. If people have difficulty internalizing low probabilities but are *forced* by some mechanism, such as a survey, to consider them in making decisions, then they may respond by mentally augmenting the probability to a level that is familiar to them. In contrast, if decision makers are allowed to ignore low probability events as in Kunreuther's [13] example of making actual flood insurance decisions, then they may do so in order to simplify the processing costs of making those decisions.

Although other explanations are possible for the large increases in price that consumers said they would pay to reduce their households' risks from injury, this theory about how consumers respond to low probability events suggests one hypothesis that we find particularly plausible. In our study consumers could not avoid considering low risk injuries due to their prominence in the task. However,

[21] See Viscusi [22] for a survey of these studies.

[22] See Kahneman and Tversky [11] and Lichtenstein *et al.* [14] on the former reaction and Kunreuther *et al.* [13] on the latter.

they may have focused their attention much more on the numerical or percentage reduction in injuries between the two products in any pair, without closely internalizing the base number of households subject to risk (i.e., two million). Had a base of two hundred thousand or twenty thousand households resulted in roughly the same responses to the CV and PC questions, then the implied total values of injury reductions would have been ten or a hundred times less.[23] If this lack of attention paid to the base number of households is true, it could be explained by a decision process simplification strategy that uses primarily one piece of data (the percentage reduction in injuries) because of the difficulty of consumers to comprehend rates composed with such large denominators.[24]

An alternative possibility is that the morbidity valuations are high because they reflect both private and altruistic components. As was indicated in the last section, some steps were taken in the design of the questionnaire to reduce the possible influence of altruism. To the extent that altruism continued to play a role, it is unlikely that it is of sufficient magnitude to account for the extent of the difference between the implied morbidity avoidance values and results from wage hedonic studies. We have undertaken a subsequent survey to address this issue in more detail.

Our finding that subjects' valuations of morbidity reductions were higher than those derived from hedonic wage studies, and probably higher than their choice behavior would indicate in an actual purchase situation *in which they fully comprehended the levels of risk involved*, suggests an important implication for benefits measurements in situations involving low level risks. That is, consumers must fully comprehend the levels of risk involved if analysts are to use their responses in calculating benefit measures that can, in turn, be compared against other benefit estimates derived from choice situations involving either no uncertainty or higher levels of risk. This finding does not imply that experimental methods are incapable of supplying valuable benefit information for products or programs involving low probabilities. Either mechanisms have to be developed for conveying the low risks accurately and in ways that consumers can readily understand,[25] or else the valuations given by consumers must be limited to use in measuring the *relative* benefits of different consequences, each with the same base probability level.

4. DISCUSSION

Consumer willingness-to-pay values for the morbidity benefits resulting from safer products are difficult to estimate, but they are critical to evaluating the desirability of regulating product safety and environmental quality. Many regu-

[23]Although we did not test the hypothesis that our subjects arrived at their valuation responses through a mental process which used a lower base population number, or alternatively, a higher risk, a recent study by Smith *et al.* [19] provides evidence supporting it.

[24]One reviewer suggested that the subjects' responses may have been influenced by the levels of the yearly costs for the two products ($10 for bleach and $7 for drain opener). In order to make the choice situation as realistic as possible, we used product costs close to the production averages. It may well be true that using artificially low product costs would have lowered the valuations; however, we did not test this hypothesis.

[25]As examples of research along these lines, Kunreuther *et al.* [13] used mortality tables to convey risks, Smith *et al.* [19] represented risk by pie charts, and Mitchell and Carson [16] relied upon a risk ladder to communicate risks.

latory programs produce risk reductions rather than total elimination of morbidity risks, creating a particularly difficult valuation problem. This paper's main contribution is to present an experimental approach for valuing risk reductions based on linking the risk reductions to familiar product purchase decisions that would be affected by the regulatory program. We focused on two methods of eliciting monetary preferences for injury reductions, contingent valuation and paired product comparisons, using conjoint analysis and regression analyses of the indifferent pairs to analyze the latter responses.

Another contribution of this paper is to introduce the PC approach to the environmental economics literature. Based on several tests, the PC format is shown to yield consistently higher estimates than the CV approach. We argued that the non-iterative CV approach may create incentives for respondents to state values which are somewhat below their true reservation prices for the commodities being valued, while the PC approach eliminates these incentives to understate preferences, and thus it seems to provide more accurate measures of willingness to pay.

The fact that both methods produced implied values of statistical injury reduction which are large relative to morbidity and mortality valuation estimates derived from other techniques, such as the wage hedonic approach, raises important questions about how consumers make decisions about choices involving low probabilities. It also poses serious limitations on the use of these morbidity values in public policy decision making. Research is necessary to find ways of accurately conveying risk information to consumers and then training them to use low probabilities in decision making in ways that are consistent with their uses of higher probabilities. However, unless ways are found to avoid what appears to be a strong influence of low probabilities on risk valuations, care must be exercised in using the values derived from experimental studies such as ours.

APPENDIX A

Adverse Health Consequences

Chloramine Gassing from Bleach

"When bleach is mixed with ammonia or acid-based products like toilet bowl cleaners, chlorine gas forms. Breathing this gas causes headaches and burning lungs, eyes, and nose. The victim may need to be hospitalized for several days, and recovers completely within a week."

Child Poisoning from Bleach

"Children under 5 years old sometimes drink bleach accidently. The child then has difficulty breathing, may vomit and may complain of stomach aches. The child should be forced to vomit and then eat or drink only milk for several days."

Hand Burns from Drain Opener

"If liquid drain opener splashes onto someone's hands, it causes painful burns or red, swollen blisters. The treatment is to see a doctor, who will carefully wash the injured hands. Complete healing occurs within a week."

Child Poisoning from Drain Opener

"Children under 5 years old sometimes drink liquid drain opener. The result can be severe painful burns to the mouth and throat. An operation may be needed to replace parts of the throat and hospital treatment may last up to 3 weeks."

APPENDIX B

Linearity of Rating Scale

To test the linearity of the response scale, a necessary condition in using ordinary least-squares regression for estimating the utility weights on costs and injury reductions, we used Forrest Young's ALSCAL algorithm [26] to find the monotone transformation of the rating scale that maximizes its fit with the linear specification of the attribute weighting function (i.e., the right side of Eq. (1)). Figure 3 graphs the optimally transformed scale against the original scale. The transformed scale, while not perfectly linear, does not appear to fit any clear pattern with respect to the deviations from linearity. Furthermore, the coefficients from the optimal run correlate at 0.96 with the uncorrected values. Thus, we simply report the results from the linear formulation in Table III.

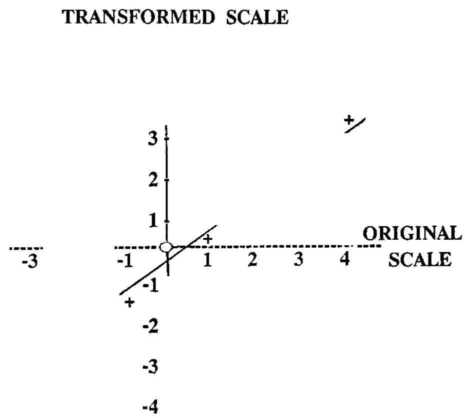

FIG. 3. Optimal transform of ratings scale using alternating least squares.

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