A Classification Tree for Predicting Consumer Preferences for Risk Reduction

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Economists have long been puzzled by differences in the implicit value of life that can be inferred from consumers' responses to different risks. Individuals appear to be willing to pay more to reduce the risks from pesticide residues on food, for example, than they are to reduce the risks from increased exposure to solar radiation resulting from depletion of the ozone layer. Attempts to explain these differences have often attributed them to psychological aspects of the risks, but so far most of the analysis has concentrated on defining the risk characteristics rather than on explaining preferences (Slovic, Fischhoff, and Lichtenstein). In this paper, we attempt to explain preferences for risk reductions using the attributes of the risky substances. How do attitudes depend on risk levels, costs of risk reductions, and other features of the risky situations?

The analysis is based on two surveys of members of local Parents-Teachers Associations (PTA) in which subjects were asked about their preferences for reducing the risks from a number of risky substances. We first characterize the substances by the numbers of deaths that might be prevented through a risk reduction program and test whether subjects prefer to maximize the number of deaths prevented given a fixed expenditure on risk reduction. If subjects do not prefer to maximize the number of deaths prevented, this suggests that they do indeed implicitly assign different values to risk reductions from different substances. Based on our survey results, we reject the hypothesis that subjects prefer to maximize the number of deaths prevented, given fixed expenditures.

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Several explanations are plausible. First, subjects may believe that they personally either are more at risk from the substance than the general population or are likely to bear more of the costs of regulation than the average person. They may also not entirely trust cost and risk information that differs from their own prior beliefs (see Viscusi). Alternatively, subjects may care much more about particular psychological or idiosyncratic features of the risks, such as how familiar people are with the hazards or whether the risk is voluntarily assumed. This behavior is more difficult to reconcile with a cost-benefit type of model of optimal risk regulation.

To explore these issues, subjects were asked to assess the extent to which they feel personally at risk from the given hazards, and how effective they feel government actions or their personal actions would be in reducing risks. Their responses were then used to predict preferences for reducing risk. We also included dummy variables for each of the individual substances to capture the effects of any idiosyncratic characteristics not explicitly considered. The survey results are analyzed with a nonparametric technique know as CART (Classification And Regression Trees) from Breiman et al. This provides a simple and useful picture of preferences for risk regulation.

Survey I

The first survey was administered in early May 1990 to members of a Parents-Teachers Association in the Washington, D.C., area. Using members of the PTA allows us to survey a relatively large group of subjects that is more representative of the U.S. population than most accessible groups (e.g., students, League of Women Voters) at a low cost.

Preferences for risk reduction were elicited through the following question:

A. Suppose the government had designed programs to reduce risks from four of these substances. The costs and benefits of these programs are listed below.

The costs include both costs that individuals would have to pay, and costs to the government. The benefits are given in terms of the number of deaths per year that could be prevented. Which substance do you think is most important to have the risk-reduction program for? Rank the substances from 1 to 4. Give a rank of 1 to the substance that you think it is most important to have the risk-reduction program for. Give a rank of 4 to the substance that you think it is least important to have the risk-reduction program for. Don't give the same rank to two different substances.

____**PCB in drinking water.** The proposed program would cost about $10 million per year and could prevent about 12 deaths per year.

____**Pesticide residues on foods.** The proposed program would cost about $10 million per year and could prevent about 5 deaths per year.

____**Radiation from the sun from use of CFC's.** The proposed program would cost about $10 million per year and could prevent about 8 deaths per year.

____**Automobile exhaust.** The proposed program would cost about $10 million per year and could prevent about 7 deaths per year.

There were five different versions of this question, each with the same four substances and the same four numbers of deaths prevented (5, 7, 8, 12) but with different pairings of substances and numbers of deaths. Each subject received one version only. The costs per death prevented in the version given above are $0.83 million, $2.00 million, $1.25 million, and $1.43 million, respectively. These costs reflect ballpark figures of the total economic cost of risk-reduction programs in general but not necessarily for specific risk-reduction programs for these four specific hazards.

The null hypothesis is that subjects prefer to maximize the number of deaths prevented, implying that the answer to this question for the version given above is the ranking: 1, 4, 2, 3.

Only nineteen out of ninety-four subjects chose the hypothesized ordering, and we reject the null hypothesis. (Details of the survey and the statistical results mentioned throughout the paper are available in Horowitz and Carson.) The finding that so few subjects preferred to maximize the number of deaths prevented is very striking, particularly because the tradeoff between deaths is so explicit in the set-up of the question. It suggests that idiosyncratic attributes of the risks themselves may play potentially large roles in consumer attitudes toward risk reduction.

To explore some of the possibilities, subjects were also asked to evaluate the following attributes for each risky substance: extent of exposure in the United States, potency, environmental effects, personal effectiveness in reducing risks from the substance, government effectiveness in reducing risks from the substance, number of current deaths attributable to the substance, number of future deaths attributable to the substance, and the extent to which the individual feels personally at risk from the substance. A total of eight substances was evaluated; see question B below for the list of substances.

The relationship between these attributes and the responses to question A was analyzed using a nonparametric technique known as CART. CART produces a classification or "decision tree" which uses a series of dichotomous splits of the data to predict the rank for each risky substance (see fig. 1). These dichotomous splits are based on the values of the explanatory variables. The explanatory variables in our analysis are the subject's evaluation of the eight attributes listed above (measured on a scale of 1 to 8) and the number of deaths prevented for the substance ("Deaths Prevented") as given in the subject's version of question A. The output of the classification tree is a set of predictions, such as "Pesticide residues on food will be ranked two," derived from a series of dichotomous splits of the form: "Is this one of the top two (out of eight) substances that caused the most deaths in the U.S. last year?" based on the individual's assessment of "Current Deaths."

CART is the most sophisticated of the general techniques available for ordinal (i.e., ranked) data with more than two levels of the dependent variable. It is particularly useful because it allows the response pattern between the dependent and independent variables to be different for different subsets of the data; for example, in tree A "Personal Risk" is an important attribute, roughly speaking, only if the "Future Deaths" rank is less than 3.5. It is flexible in allowing the researcher to incorporate different loss functions such as one in which underpredicting the rank assigned to a risk is considered worse than overpredicting the rank. Its primary disadvantage is that it does not exploit very efficiently the information from the subject's responses for one substance in predicting his responses for the other substances.

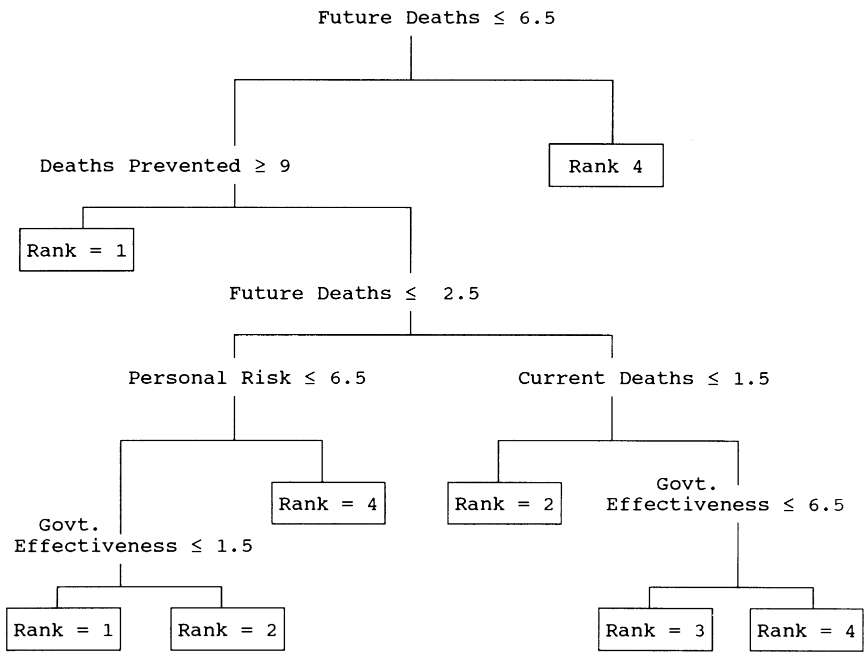
There are 92 complete responses. The 19 subjects who preferred to maximize the number of deaths prevented were not used in constructing the tree for the obvious reason that their responses can be predicted exactly on the basis of the number of deaths prevented. The tree generated from the remaining responses (tree A) is given in figure 1. Each observation consists of the rank assigned to one of the four substances by a subject (the dependent variable) along with his evaluations of the explanatory variables. There are evaluations of the four substances by 73 subjects, yielding a total of 292 observations.

Tree A first splits the observations according to the ranking on "Future Deaths": If the subject ranked a substance's "Future Deaths" between 1 and 6, go left; if it is ranked 7 or 8, go right. If the right branch is selected, the substance's rank in question A is predicted to be 4 and no further splits are made. But if future deaths were high and the left branch is selected, subsequent splits are made on the basis of the substance's "Deaths Prevented," then on the basis of "Future Deaths" again, and so on. The tree has eight terminal nodes. Notice that the splits at all of the decision nodes are in the expected direction; for example, if the personal risks from the substance are considered high (ranked closer to 1), the predicted rank in question A is also closer to 1.

To examine other potentially important substance-specific risk attributes, such as newness, dread, or voluntariness, a second classification tree (not pictured) was constructed that included dummy variables for each of the substances in the set of available explanatory variables. A prominent role for the dummies would indicate that characteristics other than those considered so far may be important components of risk attitudes, although it would not point out which specific omitted characteristics were most influential. However, there was no significant increase in the tree's predictive ability, and none of the decision nodes in this second tree was based on the substance dummies. This suggests that the more important features of the risks have already been identified and included in the analysis, at least for this particular set of substances.

Survey II

Further evidence on individual preferences for risk reduction comes from a second question that



A case goes left if the condition is true. All variables except Deaths Prevented are measured on a scale of 1 to 8 with 1 indicating more deaths, higher risk, or more effective government or personal actions.

Figure 1. Tree A

does not include explicit information about the number of deaths prevented. This is question B:

B. Suppose the government were going to spend $50 million per year to reduce risks caused by one of these substances. Rank order the substances from your first choice (give a rank of 1) to your last choice (give a rank of 8) for applying this money to.

____Radon
____Automobile exhaust
____Foodborne organisms
____Leaking Superfund sites
____Pesticide residues on foods
____Increased radiation from the sun from use of CFC's
____Shipping of chlorine
____Mercury from incinerators

Question B was administered to a second PTA group in September 1990. The responses are sets of ranks from 1 to 8 for 105 subjects. The mean ranks were 4.99, 2.78, 4.54, 4.07, 3.76, 4.13, 6.13, and 5.61, respectively. The strongest preference on average was for reducing risks from auto exhaust, followed by pesticide residues on food, leaking Superfund sites, increased radiation from the sun, foodborne organisms, radon, mercury from incinerators, and chlorine.

A tree for responses to question B, tree B1, is shown in figure 2. The potential right-hand-side variables (decision criteria in the tree) do not include the number of deaths prevented this time since none are provided in question B.

Trees A and B1 are remarkably similar despite the different formats and different subject groups. In both trees, attributes that measure the magnitude of the risks ("Future Deaths," "Personal Risk") are particularly prominent. Horowitz and Carson report that "Current Deaths" also appears as a predictive split in some of the classification trees they estimate. These results suggest that people may want the government to work to reduce the largest risks, possibly regardless of the actual reduction in risk that might be obtained.

The strong role played by the subject's perceived personal risk, "Personal Risk," likely occurs because not all subjects feel equally threatened by all substances, and they may prefer to reduce their own risks rather than to maximize the number of deaths prevented in society as a whole. The reason for "Future Deaths" importance may be similar; because the subjects were members of a PTA, most of them will have young children and can be presumed to see the items causing a lot of future deaths as a threat to their own households. Note that these assessments of personal risk levels and current and future deaths are entirely subjective and may not correspond

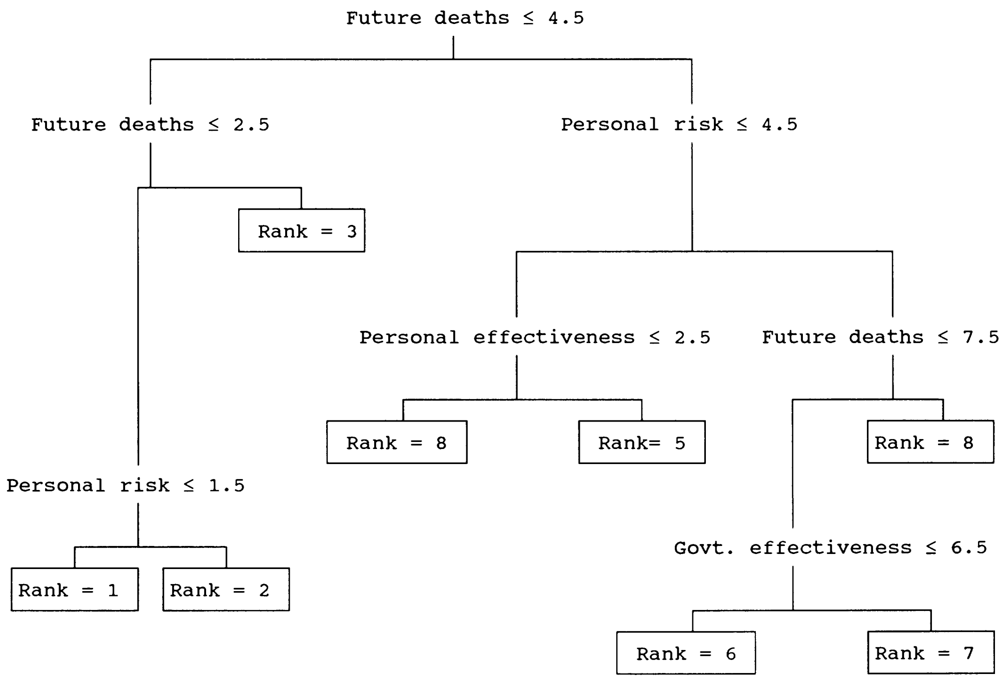


Figure 2. Tree B1

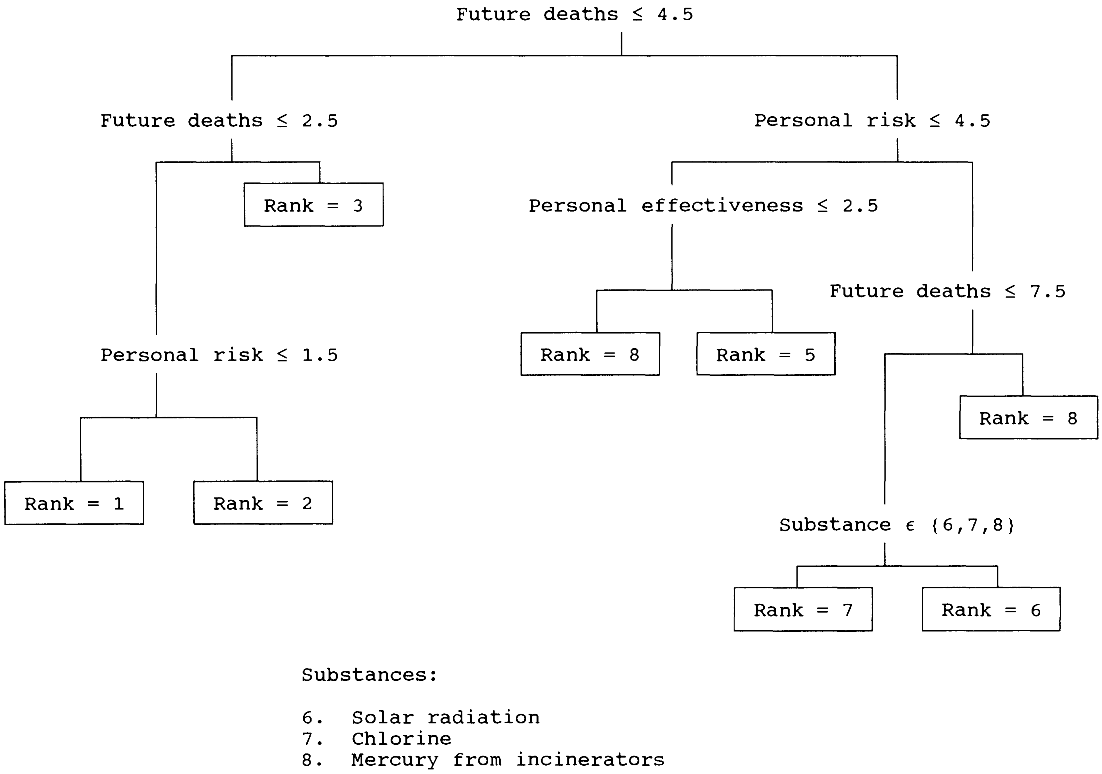


Figure 3. Tree B2 (includes substance dummy variables)

to the risk levels that scientists would calculate. Such perceptions may also be influenced by various attributes of the risks (e.g., Fischhoff et al.).

The other prominent variables in trees A and B1 are "Government Effectiveness," "Deaths Prevented" (in tree A), and "Personal Effectiveness" (in tree B1). Such findings make sense because subjects should prefer government actions to be directed where the number of deaths prevented is greatest or the government is most effective; this should be true even for those subjects who did not prefer to maximize the number of deaths prevented in all cases. People should also prefer projects where they cannot personally reduce risks very effectively.

The addition of substance dummies to the set of possible explanatory variables for question B yields tree B2 (fig. 3). Three substances (solar radiation, chlorine, and mercury from incinerators) are split from the other substances in the lowest branch of the tree. The tree is otherwise unchanged, and predicted mean rankings are not substantially altered from those of tree B1. An important question for future research is to determine what makes these three substances different from the others. It is interesting that the dummies show up as decision criteria only in the case where explicit risk information is not provided (question B) but not when such information is available (question A).

Concluding Remarks

Consumer attitudes toward health risks often appear difficult to explain. Our study suggests that risk preferences can be predicted using only a small number of attributes, including the number of deaths prevented, the perceived personal risk to subjects, the numbers of deaths attributable to the substance, and the effectiveness of government or personal action. Subjects appear to prefer to reduce those risks that threaten them most personally and for which government action is believed to be relatively effective. Subjects also appear to want to reduce risks that are expected to cause a lot of deaths in the future. Most subjects do not appear to prefer to maximize the number of deaths prevented in society as a whole, but this likely occurs because they believe that they are not affected by the risk or the regulations to the same degree as the general population.

In subsequent work we hope to explore these issues further by including both a wider set of risk attributes and a wider set of risky substances.

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