Staff Paper 190 August 1990

RELATING QUALITATIVE AND QUANTITATIVE EVALUATIONS OF COLLECTIVE RISKS: THE CASE OF DRINKING WATER CONTAMINATION

Donald J. Epp
Professor of Agricultural Economics

Brian Roach
Graduate Research Assistant

The research upon which this paper is based was partially supported by a Cooperative Agreement with the United States Environmental Protection Agency through the Environmental Resources Research Institute, The Pennsylvania State University

Presented at the American Agricultural and Economics Association meetings, Vancouver, British Columbia, Canada, August, 1990

Staff Papers are circulated without formal review by the Agricultural Economics and Rural Sociology Department. Content is the sole responsibility of the author(s).

Agricultural Economics and Rural Sociology Department
College of Agriculture
The Pennsylvania State University
University Park, Pennsylvania 16802

1990 Water Quality AAEA 1990.

Relating Qualitative and Quantitative Evaluations of Collective Risks: The Case of Drinking Water Contamination

ABSTRACT

A matrix of numerical risk statements and qualitative ratings was presented to respondents producing numerical equivalents for qualitative ratings of water contamination risk. There was general correspondence between risk magnitude and rated seriousness, but large variance in qualitative ratings of numerical risks renders some of the variables derived statistically insignificant.

#8473

Relating Qualitative and Quantitative Evaluations of Collective Risks: The Case of Drinking Water Contamination

An increasingly important aspect of public policy is to control the level of collective risks to which people are exposed. Collective risks are those risks to which all people in a specified group are exposed in about equal extent. Examples of collective risks range from the risks associated with the additives in foods to the risks from highway design or the extent of contamination removed from a Superfund site. In each case large numbers of people are exposed to the same level of hazard although they may differ in the extent to which harmful consequences will result. Collective risks are often very difficult or very expensive for individuals to avoid or mitigate; we increasingly rely on collective policy action, usually governmental, to protect us by establishing and enforcing a "safe" or acceptable level of risk. Thus, officials of governmental agencies that range from the Food and Drug Administration to the Environmental Protection Agency to state and local health boards are required to set specific levels or concentrations of substances that will pose an acceptably low level of risk to the public.

As these governmental decisions are made there is increasing concern and public discussion about the appropriateness of specific decisions. Those who must bear the costs of reducing the levels of risk argue that the standard should be set marginally higher while those who are particularly concerned about the risk argue that the standard does not provide enough safety. The debate is frequently compounded by the differing amount of information available about the costs of reducing the risks and the value of the benefits to be obtained by such reductions. Removing contaminants from drinking water, for example, involves the use of materials and labor that are exchanged in markets. Therefore, the difference in cost due to altering the amount of contaminant removed is easily calculated. Some of the benefits of reduced contaminant levels are also measured in market values. Health care costs and the value of production lost due to illness or reduced work capacity caused by the contaminant are fairly straightforward, if not easy, to calculate. But the controversy which surrounds many of the decisions about safe levels of substances in drinking water suggests that people have other values, not measured in market prices, that are important in these decisions.

These decisions also present a difficulty because of the specialized technical knowledge required. Most environmental health or food risk decisions involve information about the ways people become exposed to a specific substance, the way the human body reacts to the substance, how the substance is metabolized and what is known about these processes based on laboratory tests and epidemiologic studies. From whatever is known, knowledgeable people estimate the likely effects of various levels of contaminant. This judgement is frequently expressed as the number of additional occurrences of a particular affliction in a population of a certain size that is exposed to the contaminant for a given period of time. For example, it might be stated that the risk of consuming water contaminated with a given concentration of TCE for 70 years would be "X" additional cancer cases per million people. Many of the safety decisions by regulatory authorities are based on this type of information.

A problem arises when people affected by the decisions do not know the same facts as the decision makers or do not have the specialized knowledge to understand the information if it is presented to them. This difference in knowledge of the facts would not be serious if it were agreed by all that those with specialized knowledge will make the decisions and the rest of the public will accept the decision. A significant complication arises from the fact that different people evaluate a given risk differently. That is, one person may feel that the cost of reducing the incidence of cancer by one case in a million people is too great, another person may believe that the benefit is well worth the cost. Thus, public decision makers need not only the health facts about various levels of substances, but also need information about how people value the benefits of various reductions in the level of risk.

Economists have developed a number of methods to measure values not exchanged in markets. The contingent valuation and averting behavior methods are commonly used to value changes which affect individuals' health (Dickie and Gerking, 1987). When applied to questions about the value of changes in a collective risk, most of these methods require some information about the respondents' understanding of the risks involved. This paper reports an attempt to provide information about how risk perceptions may be determined when measuring the value of changes in the risk of cancer from contamination of drinking water.

BACKGROUND

Previous studies have attempted to determine respondents' perceptions of the risk involved either by a direct question, or more commonly, using a risk ladder. The risk ladder approach presents the subject with a linear, usually vertical, scale upon which they are asked to mark what they believe to be the risk under consideration. Frequently the scale will be anchored by marking the level of other know risks. For example, a questionnaire about cancer risk from air pollution might be anchored with indications of the cancer risk of smoking one cigarette per day and also from smoking one pack of cigarettes per day.

The idea of the anchors is to provide reference points for the respondent's answer. The responses to the risk ladder are usually converted to numerical equivalents, such as one in a million or six per one hundred thousand.

In some studies it has been found that people have trouble responding to the risk ladder because the ladder does not include a wide enough range of options to include what they think is the true risk or the respondents become confused by the examples provided as anchors. The confusion may arise because the anchor example is not related to the risk under consideration. For instance, people find it hard to relate the risk of lung cancer from air pollution to the risk of dying in an automobile accident. Another cause of confusion is that respondents may not have previously known about the risk given in the anchor. In these cases the responses to the risk ladder approach may not give realistic answers nor be very useful in understanding the values people place on avoiding particular risks.

Some studies of people's responses to risks have used a qualitative evaluation of the risk level. Abdalla (1989) asked respondents to describe their judgement of the risk of cancer from a water contamination incident by choosing from five descriptors--very serious risk, serious risk, moderate risk, not a serious risk, and insignificant risk. He found that the variable based on responses to this question was highly significant in a regression analysis of the expenditures people made to avoid the contaminated water. The results showed what logic would indicate--people who think the risk is serious are likely to place a higher value on avoiding the risk than are those who think the risk is insignificant. These results show that people are concerned about the contamination of water with a potential carcinogen and value highly the reduction of the risk, but there is not a clear connection between the respondents' qualitative judgement of the risk and a policy standard expressed as a concentration level. The policy maker needs a way to translate the highly significant qualitative variable into a quantitative expression of the risk.

METHOD USED

In order to bring these two ways of judging risks together, we developed a matrix with qualitative ratings of risks on one axis and numerical risk statements on the other. The qualitative ratings used were Insignificant Risk, Not a Serious Risk, Moderate Risk, Serious Risk, and Very Serious Risk. The nine numerically stated risks started with 1 in a billion and increased by steps of one order of magnitude to 1 in 10.

For this study respondents were asked to consider the risk of getting cancer from pollutants in the environment. This example was used to focus their thinking on the specific type of risk of interest in the study without asking them to rate a specific risk incident. They were asked to rate each of the numerical risks presented along the left hand side of a matrix using the five point rating scale presented across the top of the matrix.

This method was thought to provide several significant improvements over previous methods. First, this matrix presents a broader range of numerical risks than is presented in most instruments using a risk ladder. This feature was intended to reduce the frustration expressed by respondents to a risk ladder instrument (Figure 1) used in an earlier study of a similar contamination incident. In that study 93 individuals, or 16.4% of the respondents, wanted to place the risk in question either higher or lower than the range of risks included in the ladder. The range in the present survey instrument, from one in a billion to one in ten, covers almost all actual collective risks to health. Asking the respondent to consider increases in cancer risks is specific enough to focus attention on involuntary, long-term and possibly fatal health risks without confusing the respondent with excessive details or the need to anchor the ladder with examples of different types of risks.

Second, the matrix table allows individuals to rate several risk levels, rather than the single specific risk level used in conventional approaches. This feature is in keeping with the intention to determine the respondents' perceptions of the seriousness of various risks rather than test their knowledge of facts and was intended to reduce anxiety in the respondent over possibly giving the "wrong" number for the specific risk. Third, the respondents' answers can be checked for logical consistency. For example, if a respondent rates a risk of 1 in a million as more serious than a risk of 1 in 100, the inconsistent ratings probably indicate that the question was not understood and that observation can be deleted from the analysis. Additionally, an excessive number of inconsistent ratings would indicate that the procedure is not understood by the respondents and would suggest the need for revising the question. Finally, this technique can be used to obtain information about the valuation of non-marginal risk changes as well as marginal ones, since such a broad range of risk levels is presented.

APPLICATION

The study for which the risk evaluation matrix was developed examined the value of protecting drinking water supplies from contamination. The study obtained information about expenditures made by respondents to avoid consuming the TCE contaminated water supplied by the public water supply authority until the authority was able to remove the contaminant. Respondents that knew about the TCE contamination were asked to rate qualitatively their estimate of the risk of getting cancer by drinking the water from their water supply system. Most of the respondents rated the risk between "not a serious risk" and "serious risk" with fewer than 10% of the respondents failing to provide a rating (Table 1). The average rating of the risk on the scale used in Table 1 was 2.9, just less than a moderate risk.

From the responses of each individual who was aware of the contamination we calculated a numerical statement of risk that they had previously associated with the qualitative rating that they gave to drinking the water. For example, if a respondent who judged the risk posed by the contaminated water as serious had previously given a serious rating to risks of 1 in 10 and 1 in 100, the average of these risks, 1 in 55, was used as the numerical expression of the risk posed by the contaminated water. The variables describing people's evaluation of the risk were included in regression analyses of the expenditures they made in response to the contamination. The results of those analyses give insights into the potential usefulness of the matrix approach and into the problems facing regulatory authorities when risk is involved.

The qualitative evaluation of the risk (insignificant to very serious) was found to be very significantly related to the changes made in expenditures to avoid consuming the water or to provide home treatment to remove the contaminant (Roach). This was similar to the results of an earlier study (Abdalla). The variables derived from the matrix which provided numerical statements of the risk, however, were not significant in any of several alternative specifications of the equations.

Conceptually the qualitative and quantitative evaluations of a given risk are related. People who think a risk is serious would be expected to judge that a higher chance of harmful effect is more serious than lesser chance of harm. The results of this study showed that to be true. Most of the matrices filled out by the respondents were logically consistent and greater numerical risks were judged more serious than were lesser numerical risks. The combined responses of all participants in the study are shown in Table 2. While the majority of responses are consistent with expectations, problems arose from the fact the evaluations of a given numerical risk vary widely among repondents. For example, one person may have judged a risk of 1 in 100,000 as very serious while another person judged it as not a serious risk. For the second person the risk might have had to increase to 1 in 1000 before it was judged as very serious.

The distribution of average numerical risks associated with each qualitative rating of the risk from consuming the water by the group of participants who were aware of the TCE contamination is given in Table 3. It is clear that those who used the term very significant to describe the risk of drinking the water considered the term to represent very high numerical risks. The averaging procedure was such that the 19 individuals who judged the risk of drinking the water as very serious had previously assigned that evaluation to risks of 1 in 100 and 1 in 10 on the matrix; thus the average numerical rating of 1 in 55. It is also clear that, in general, people rated the higher numerical risks (top of the table) as more serious and the lower numerical risks (bottom of the table) as less serious.

The reason for the lack of significance of the numerical versions of the risk variable in the explanation of avoidance expenditure could be the large variance in the evaluations of specific numerical risks. While numerical risks of less than 1 in a million had a few people evaluate them as insignificant, all of the risks from 1 in one hundred million up to 1 in 100 had at least one person rate it as not a serious risk, moderate risk, or serious risk. This lack of concurrence as to whether a particular risk is serious or not causes the variables representing numerical statements of risk to have variances so large as to render them statistically insignificant, even though the qualitative evaluations of risk are highly significant.

CONCLUSION

The wide variation in how people judge specific numerical risks is a problem for researchers and policy makers alike. If the results of this study are typical of the population, we might conclude that it is futile to attempt to relate numerical statements of risk to people's actions or preferences for avoiding risk at this time. Further education about risk and greater familiarity with risk decisions as public policy debates continue may be expected to produce greater consistency of evaluation in the future. Alternatively, it might be concluded that people are presently knowledgeable enough to evaluate given risk expressions and that what was found here is an inherent difference in people's preferences. More precise information about the actual numerical risk associated with exposure to a certain hazard may not change people's judgement as to the seriousness of the risk. In that case the economic analyst interested in providing information that leads to socially efficient risk standards may be best advised to determine a willingness to pay for specific changes in certain risks and recognize that people vary greatly in what that amount will be and that part of that variation in willingness to pay is a variation in the evaluation of the seriousness of the risk.

REFERENCES

Abdalla, Charles W. Measuring the Costs of Groundwater Contamination: An Empirical Application Using Averting Behaviors. Staff Paper #161, Department of Agricultural Economics and Rural Sociology, Pennsylvania Sate University, April 1989.

Dickie, Mark and Shelby Gerking. "Benefits of Reduced Morbidity from Air Pollution Control: A Survey." in Hendrik Folmer, ed. Migration and Labor Market Efficiency. Martinus Nijhoff, 1988.

Roach, Brian. Using Averting Behavior Costs to Measure the Value of Changes in Drinking Water Quality. M.S. thesis, The Pennsylvania State University, 1990.

Table 1. Qualitative Rating of Cancer Risk Associated With the TCE Contamination of the Water Supply

Risk Category	Frequency	Percentage
1. Insignificant Risk	23	7.6
2. Not a Serious Risk	84	27.6
3. Moderate Risk	92	30.3
4. Serious Risk	57	18.8
5. Very Serious Risk	23	7.6
Missing Values	25	8.2
Total	304	100.0

Table 2. Responses to the Risk Rating Matrix.

Numerical Risk	Risk Rating				
	Insignificant	Not Serious	Moderate	Serious	Very Serious
1 in					
10	1	2	12	12	484
100	1	9	13	39	449
1000	2	13	33	126	336
10,000	6	25	99	175	203
100,000	11	65	173	143	114
1,000,000	51	162	150	86	59
10,000,000	118	192	110	47	41
100,000,000	241	147	61	23	38
1,000,000,000	332	86	38	18	36

Table 3. Distribution of average numerical risk associated with qualitative risk ratings.

Average Numerical Risk	Risk Rating				
	Insignificant	Not Serious	Moderate	Serious	Very Serious
1 in					
55	0	1	1	0	19
100	0	0	1	1	0
550	0	2	0	1	0
1000	0	0	1	7	0
5500	0	0	0	4	0
10,000	0	0	2	4	0
55,000	0	4	9	6	0
100,000	0	6	8	4	0
550,000	0	10	6	4	0
1,000,000	0	10	12	4	0
5,500,000	6	16	6	2	0
10,000,000	0	4	9	1	0
55,000,000	3	5	3	1	0
100,000,000	3	8	3	1	0
1,000,000,000	2	2	2	0	0

Figure 1. Risk Ladder Used to Assess Risk Perception in a Community with PCE Contamination of the Public Water Supply.

The Chart below shows the additional risk of getting cancer during a person's lifetime if they undertake certain activities for one year. Numbers on the left side represent the number of additional cancer deaths over a lifetime. Activities on the right side have been found to be associated with cancer at the levels indicated. For example, eating 4 tablespoons of peanut butter a day for a year will cause 50 extra cancer deaths per million people who undertake this activity.

In terms of the information available to you, how would you rate the health risks associated with the levels of PCE in your water from July 1987 to December 1987? Please indicate your choice, marking the chart below with a horizontal line.