The Interplay of Science and Values in Assessing and Regulating Environmental Risks
Author(s): Frances M. Lynn
Source: *Science, Technology, & Human Values*, Vol. 11, No. 2 (Spring, 1986), pp. 40-50
Published by: Sage Publications, Inc.
Stable URL: http://www.jstor.org/stable/689231
Accessed: 26-09-2016 09:00 UTC

REFERENCES
Linked references are available on JSTOR for this article:
http://www.jstor.org/stable/689231?seq=1&cid=pdf-reference#references_tab_contents
You may need to log in to JSTOR to access the linked references.

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at
http://about.jstor.org/terms

Sage Publications, Inc. is collaborating with JSTOR to digitize, preserve and extend access to *Science, Technology, & Human Values*

This content downloaded from 147.251.232.138 on Mon, 26 Sep 2016 09:00:08 UTC
All use subject to http://about.jstor.org/terms

The Interplay of Science and Values in Assessing and Regulating Environmental Risks

Frances M. Lynn

In the late 1970s, the U.S. Occupational Safety and Health Administration (OSHA) proposed a standard for identifying, classifying, and regulating carcinogens.[1] The hearings for the standard attracted the largest number of participants in OSHA's rulemaking history and lasted for two months (May and June 1978). Although a standard was never implemented, OSHA's efforts stimulated a debate over the assumptions and decisionmaking process for assessing and regulating cancer risks which continues today. This debate about the methods for identifying and estimating occupational cancer risks appears at first to be predominantly scientific, but an analysis of the responses to OSHA's proposal led me to hypothesize that regulatory values and other social and political values influenced the selection among scientific assumptions and, furthermore, that these regulatory values seemed linked to place of employment.

To test these hypotheses, I designed an empirical study that explored the impact of regulatory values, institutional affiliation, and other social and political attributes on occupational health scientists' selection among assumptions used in the OSHA standard. I conducted 136 interviews with occupational physicians and industrial hygienists working for industry, academia, and government.

This article describes some of the results of that study and focuses on the role of science and scientists in the decisionmaking process for determining whether a product or technology is acceptably safe. It addresses the question of how to incorporate expertise into the formation of regulatory policy, while at the same time protecting democratic control of the final decision. The article is divided into three sections: A detailed look at the policy context surrounding discussions of risk, analysis of the interview findings, and a discussion of the study's conclusions and policy implications. In an appendix, I describe, in more detail, the choice, construction, and evaluation of the research instrument, the sampling process and data analysis techniques.

Frances Lynn is Research Assistant Professor, Institute for Environmental Studies, The University of North Carolina at Chapel Hill, Chapel Hill, NC 27514.

Policy Context

In the last ten years, a quiet but persistent effort has developed to incorporate different types of formal analytic methods such as cost-benefit analysis and risk analysis into environmental decisionmaking. Supporters of these techniques view them as a means to make environmental decisionmaking more rational and less highly charged. Critics challenge their use both on the grounds of methodological flaws and also because they believe that embedded within the techniques are value-laden assumptions often missed in the false precision suggested by the use of numbers and statistics.

Risk analysis, particularly as applied to the risk of contracting cancer from exposure to chemicals, is currently receiving widespread attention. Following OSHA's efforts to adopt its carcinogens standard, other governmental bodies and private groups—including the U.S. Environmental Pro-

© 1986 by the Massachusetts Institute of Technology and the President and Fellows of Harvard College. Published by John Wiley & Sons
Science, Technology, & Human Values, Volume 11, Issue 2, pp. 40–50 (Spring 1986) CCC /0162-2439/86/020040-11$04.00

This content downloaded from 147.251.232.138 on Mon, 26 Sep 2016 09:00:08 UTC
All use subject to http://about.jstor.org/terms

tection Agency (1985), the White House Office of Science and Technology Policy (1985), the State of California (1982), the National Academy of Sciences (1983), and the U.S. Department of Health and Human Services (1985)—have issued documents with the hope of affecting the way cancer risks are assessed and regulated.

Most of these reports have adopted William Lowrance's division of the field of risk into two phases: risk assessment and risk management.[2] Lowrance characterized the first phase, risk assessment, where one estimates the health effects that varying doses of a substance pose, as an objective pursuit with decisions and recommendations most appropriately made by scientists. Lowrance viewed the second phase, risk management, as being more value-laden, involving tradeoffs between health risks and ethical, economic and other social considerations. In risk management, Lowrance saw a role for participation in decisionmaking by the non-expert.

In 1981, the National Academy of Sciences (NAS), in response to a directive from the Congress, sponsored another study of risk, convening the Committee on the Institutional Means for the Assessment of Risk to Public Health. This Committee had three primary objectives: to assess the merits of separating the analytic functions of developing risk assessments from the regulatory functions of making policy decisions; to consider the feasibility of designating a single organization to do risk assessments for all regulatory agencies; and to consider the feasibility of developing uniform risk assessment guidelines for use by all regulatory agencies.[3]

Project Director Lawrence McCray, in his working paper for the NAS Committee, labeled as "naive" the underlying premise that "matters of science" could be segregated from "matters of value" and "left to an organization primarily responsive to scientific authority."[4] In fact, the Committee's final report suggested that there were multiple places in risk assessments where risk to human health could only be inferred. In those situations, the NAS Committee commented "how difficult it is to disentangle the mixture of fact, experience (often called intuition), and personal values,"[5] and it concluded that throughout the process of risk assessment it was possible to make choices among assumptions which would increase the likelihood that a substance would be judged to be a significant risk to human health.[6] The Committee recommended establishing a board of risk assessment which would make explicit "underlying assumption and policy ramifications" of the different choices which face scientists who perform a risk assessment.[7]

The research on which this paper is based, while conceived and executed before the National Academy of Sciences' report on risk assessment, is an empirical complement. The research considers non-scientific influences on scientists' selection of assumptions that form the basis for quantitative risk assessment and risk–benefit analysis.

Empirical Findings

The study confirmed the initial hypotheses that there were links between political values, place of employment, and scientific beliefs. Even after controlling for the influence of such standard demographic variables as age, sex, region, religion, and family background, scientists employed by industry tended to be politically and socially more conservative than government and university scientists. They chose scientific assumptions that decreased the likelihood that a substance would be deemed a risk to human health and increased the likelihood that a higher level of exposure would be accepted as safe. Government scientists were the most liberal politically and most protective in choosing among scientific assumptions. University scientists fell in between their governmental and industrial colleagues.

Perceptions of the Risks Society Faces

The respondents were asked questions that attempted to tap their general perceptions about the risks of technology as well as what they considered to be appropriate degrees of regulation. One such question was adopted from a Louis Harris poll "Risk in a Complex Society."[8] The question asked whether the respondents felt that the "risks associated with advanced technology have been exaggerated by events such as Three Mile Island and Love Canal."

Figure 1 shows how occupational health scientists interviewed for the study responded to that question. The proportion of industry scientists who supported this statement (82%) is almost identical to that of the sample of corporate executives interviewed by Harris. In the Harris survey,

This content downloaded from 147.251.232.138 on Mon, 26 Sep 2016 09:00:08 UTC
All use subject to http://about.jstor.org/terms

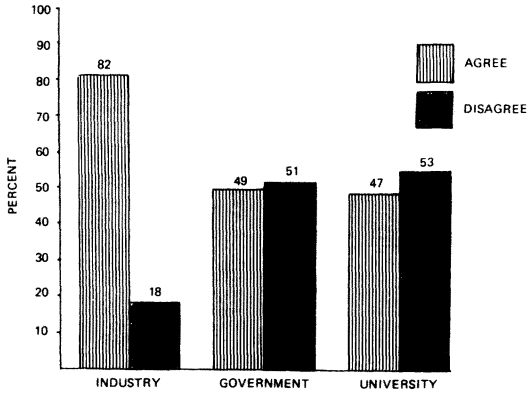

Figure 1. Percent who believed that the risks were exaggerated by TMI.

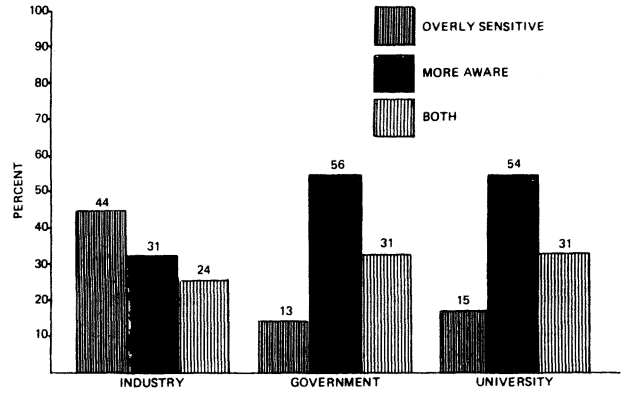

Figure 2. Feelings about American society's attitudes toward risks.

88% of the corporate executives agreed with the statement. Government and university occupational health scientists were more evenly divided in their response—echoing what Harris found when he asked the question of members of Congress, regulators, and the general public.

In another question taken from the Harris poll, respondents were asked whether

> American society is becoming overly sensitive to risk, and that we now expect to be sheltered from almost all dangers . . . [or] . . . simply becoming more aware of risks and starting to take realistic precautions.

In the Harris poll, corporate leaders were four times more likely than either the public or regulators, and three times more likely than members of Congress, to characterize American society as "overly sensitive to risk and wanting to be protected from nearly all dangers." In this study of industrial hygienists and physicians, those working for industry were three times more likely than government and university scientists to believe that Americans are overly sensitive to risk and want to be protected from nearly all dangers (Figure 2).

Respondents were also asked to agree or disagree with the statement "society has only perceived the tip of the iceberg with regard to the risk associated with modern technology." Sixty-eight percent of the government and university occupational health scientists agreed with this statement, compared to thirty-two percent who worked in industry.

No Anti-Regulation

Although they disagreed about the extent of risk facing society, those interviewed for this study, including those working for industry, were not necessarily anti-regulatory. Although the majority of industry scientists were Republicans (*see* Figure 3), had voted for President Reagan (74%), and were self-identified as conservative (56%), they expressed surprise at the Reagan Administration's vehement attacks on environmental regulation. When read a list of different types of environmental regulations (e.g., air, water, consumer products) and asked whether the regulations should be made "more strict," "less strict," or "kept the same," very few industry respondents wanted the regulations weakened.

On the other hand, very few wanted them strengthened. For example, when asked about reg-

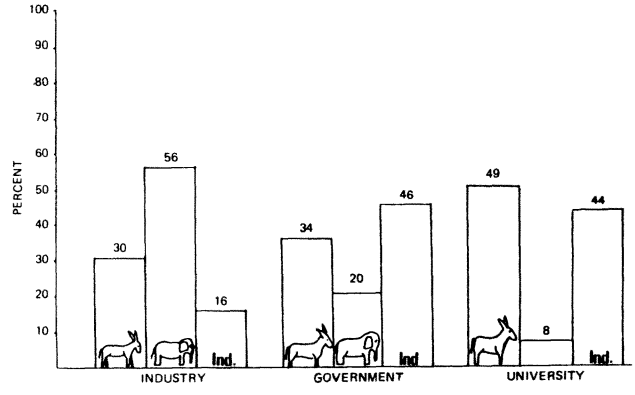

Figure 3. Party identification of respondents (Democrat, Republican, or Independent).

This content downloaded from 147.251.232.138 on Mon, 26 Sep 2016 09:00:08 UTC
All use subject to http://about.jstor.org/terms

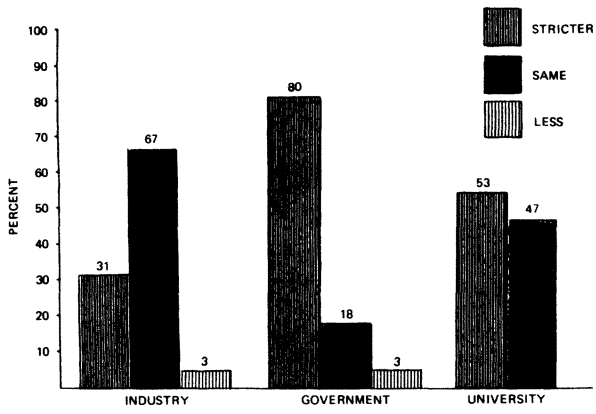

Figure 4. Percent who believed that regulations to protect employees from health risks like cancer should be stricter, be more lenient, or remain the same.

ulations to protect employees from working conditions that cause health risks like cancer, the majority of industry scientists (67%) wanted the regulations kept the same. This finding contrasts with the responses of government scientists, 80% of whom wanted the regulations made stricter. Academic opinion was evenly divided between wanting the regulations made more strict or keeping them as is (Figure 4).

The dominant sentiment across all institutional settings, however, was that a minimum level of safety had to be maintained. Majorities in all three subsamples (Figure 5) disagreed with the question taken from the Harris poll, which asked whether "a consumer should be allowed to choose between a very safe product at a higher price and the same product at a lower price without safety equipment." By inference, respondents seemed to disagree with a 1983 suggestion made by James Miller III, chairman of the Federal Trade Commission and now head of the Office of Management and Budget that "imperfect products should be available because consumers have different preferences for defect avoidance."[9]

Attitudes Toward Cost–Benefit Analysis

Cost–benefit analysis, a major proposal for regulatory reform, was most strongly supported by industry scientists (Figure 6). Proponents view cost–benefit analysis and its cousin, risk–benefit analysis, as means by which to make environmental decisionmaking more systematic.[10] Critics challenge the use of cost–benefit analysis, suggesting that the technique has major methodological flaws and has imbedded within it philosophically conservative assumptions about issues of distribution, equity, and individual rights.[11]

The response of the sample to questions that probed the basis of cost–benefit analysis suggest the technique is not well understood. For, although 71% of the industry sample supported the use of cost–benefit analysis (Figure 6), only 52% agreed with the statement that "society must attempt to place an economic value on human life in order to allocate scarce resources."

When presented with the dominant methods currently used to value life in cost–benefit analysis (human capital, willingness-to-pay, and wage differentials), almost half of the sample was dissatisfied with all three options (Table 1). In fact, only 5% of the total sample, including 5% of industry scientists, supported the method currently

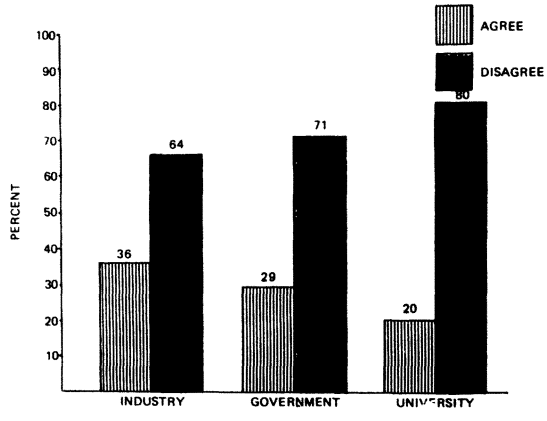

Figure 5. Attitudes toward consumer choices between price and safety.

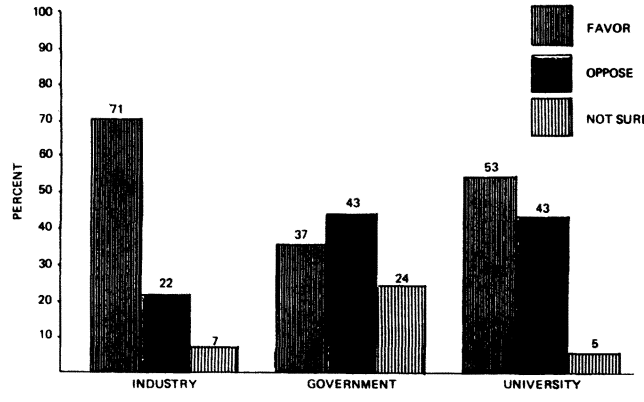

Figure 6. Attitudes toward the government's use of cost-benefit analysis.

This content downloaded from 147.251.232.138 on Mon, 26 Sep 2016 09:00:08 UTC
All use subject to http://about.jstor.org/terms

Table 1. Attitudes toward dominant methods used by economists to value life. Respondents were asked the following question: "A number of economists think that ultimately one must place a value on human life, that is, decide how much money society is prepared to invest in order to prevent one additional death or save one additional life year. Three methods are currently being used by economists. If you had to choose a technique for valuing life, which would you select? (**A**) Compute the amount of earnings that would be lost in the case of premature death or disability and equate this with the value of life/disability (HUMAN CAPITAL APPROACH); (**B**) Ask individuals how much they would be willing to pay to reduce the probability of death or disability (WILLINGNESS-TO-PAY APPROACH); or (**C**) Analyze wage differentials in occupations involving varying risk of death or injury and use wage rate differentials as reflections of societal willingness-to-pay for decreases in risk (WAGE DIFFERENTIALS)."

	Human Capital	Willingness to pay	Wage Differentials	None
Industry N = 42	38%	17%	5%	40%
Government N = 41	32%	17%	5%	46%
University N = 34	9%	26%	6%	59%
TOTAL N = 117	27% (32)	20% (23)	5% (6)	47% (56)

popular among economists, using wage differentials (i.e., hazard pay) as proxies for the value that people place on measures to reduce risks of injury or death.[12] The wage differential method uses regression analysis to measure job earnings against a measure of the risk level of each job, holding constant other variables that also influence variations in observed earnings. Studies using this technique have yielded estimates of life values ranging from $300,000 to $35 million.

This research attempted to involve the scientists in a willingness-to-pay exercise. The willingness-to-pay approach is another technique currently popular with economists as a means to value life. Respondents were asked to select an acceptable level of risk, stated in an annual probability of death. They were next asked what salary increase would make them accept a job with a higher probability of death. Many refused to participate because they found such an exercise odious. Some wanted a list of common risks and their probabilities of death in order to make comparisons. But many others said that given their existing income, they would never have to make such choices and would not now.

Critics of the willingness-to-pay approach question the technique's assumption that workers possess accurate knowledge of risks and can readily move to jobs posing lower risks.[13] Critics also claim that the technique ignores existing income distributions. The rich will pay more (or earn less) to reduce the risk of their death.[14]

Even those in the sample who generally favored the use of cost–benefit analysis did not advocate it as the deciding factor in standard setting. Ninety-eight percent of the entire sample viewed cost–benefit analysis as a "decision tool," not a "decision rule." Moreover, majorities in all employment categories in the sample (including 89% of industry scientists) supported the "public policy goal of decreasing cancer risks" even if it "caused the average price of goods and services to increase" (Figure 7). Similarly, majorities "supported the public policy goal of decreasing cancer risks . . . [even if it] . . . caused some factories to close down and increased unemployment."

Given the lack of support for the dominant techniques used to value life and a willingness to accept price rises for prevention of disease, why did respondents tend to support cost–benefit analysis? For some, support may be symbolic of the desire to lessen regulatory burdens on business. But for others, support may be a part of a hope that a technique can be found to make environmental decisionmaking easier. In this sense, cost–benefit analysis and risk assessment share a common attribute. Both are expected to provide

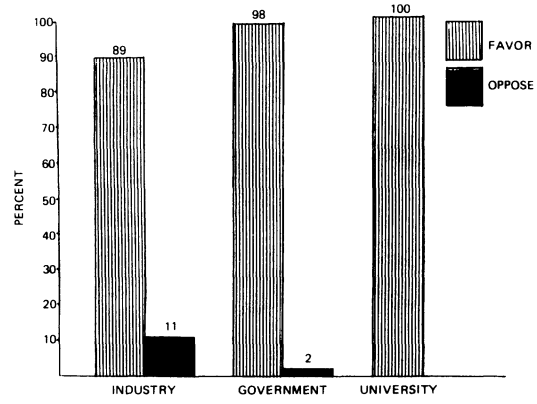

Figure 7. Attitudes toward preventing cancer at the risk of rise in prices.

This content downloaded from 147.251.232.138 on Mon, 26 Sep 2016 09:00:08 UTC
All use subject to http://about.jstor.org/terms

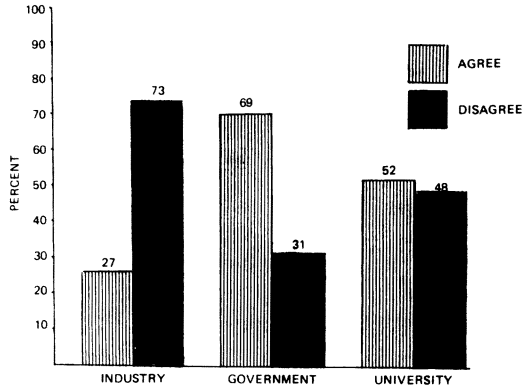

Figure 8. Attitudes toward using animal data to identify risks to people.

objective answers to uncertain and value-laden processes.

Quantitative Risk Assessment

The National Academy of Sciences in its 1983 report, *Risk Assessment in the Federal Government,* characterized risk assessment as the use of a "factual basis to define the health effects of exposure to individuals and populations to hazardous materials and situations.[15] The NAS viewed risk assessment as both "quantitative and qualitative" and involving "the interplay of science and policy." The NAS identified close to fifty areas in a risk assessment where a scientist or risk assessor must make choices among "several scientifically plausible options" in which "policy considerations inevitably affect and perhaps determine, some of the choices."[16]

Figure 8 shows this sample's response to one of those inference points: using animal data to predict risks for humans. Respondents were asked whether they agreed or disagreed that "a substance which is shown conclusively to cause tumors in experimental animals should be considered a carcinogen, thereby posing a risk to humans." The majority of government (69%) and university scientists (52%) agreed with this statement, while only 27% of the industry sample agreed. The National Academy of Sciences feels that

> the inference that results from animal tests are applicable to humans is fundamental to toxicological research; this premise underlies much of experimental biology and is logically extended to the experimental observation of carcinogenic effects.[17]

A similar question is whether or not threshold levels exist for carcinogens below which there are no negative effects. A threshold model for carcinogenesis assumes that there is a dose below which cellular or tissue damage does not occur. Under this model, one assumes that the body has mechanisms that withstand toxic events at low doses. A linear model suggests, especially in the case of carcinogens, that a single interaction with a single cell can trigger a toxic reaction. The National Academy of Sciences Committee on Risk Assessment concluded that there was no conclusive biological evidence to support either type of model.[18] The regulatory policy implications of support for the existence of thresholds is viewed as less protective of public health. The State of California,[19] as well as the Office of Science and Technology Policy,[20] rejected the concept of thresholds for carcinogens in their guidelines.

As in the choice of using animal data to identify cancer risks for humans, the occupational health scientists working in industry held views about thresholds that differed substantially from those of government scientists. Eighty percent of the industry scientists interviewed agreed that thresholds exist for carcinogens, compared to 37% of government employees (Figure 9). Noteworthy are the responses of academics, the majority of whom supported the existence of thresholds. Among academics, age made a difference in attitudes; older academics were more likely to believe in thresholds than younger ones. A likely explanation for this difference is that when older academics entered the field of

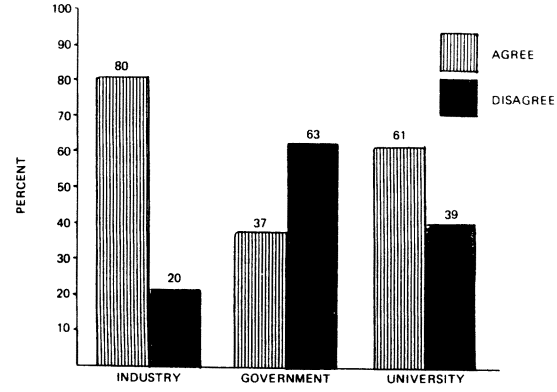

Figure 9. Attitudes toward the existence of thresholds for carcinogens.

This content downloaded from 147.251.232.138 on Mon, 26 Sep 2016 09:00:08 UTC
All use subject to http://about.jstor.org/terms

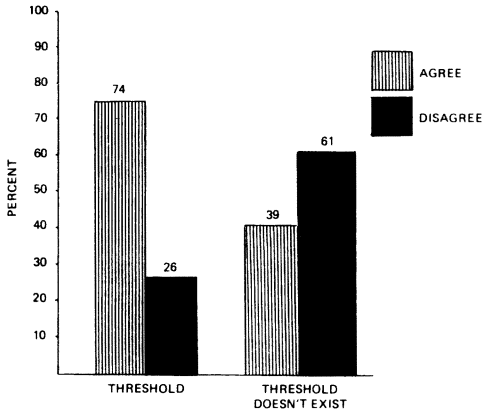

Figure 10. The relationship between belief in a threshold to attitudes about whether TMI exaggerated the risks.

occupational and environmental health in the late 1930s and 1940s, levels of exposure were high and scientific recommendations seemed clear. The older academics may have believed that government policy of the 1970s was becoming overprotective.

Figures 10 and 11 and Tables 2 and 3 show that the samples' beliefs toward the existence of thresholds correlate positively with social and political attitudes reported earlier in this article. The key finding of these data is that support for the existence of thresholds is associated with conservative political attitudes and with perceptions that suggest that American society is overly sensitive and overreacting to environmental risks. Similarly, those who question the use of animal data to predict carcinogenesis in humans are more likely to hold conservative political attitudes and believe that Americans are too risk adverse.

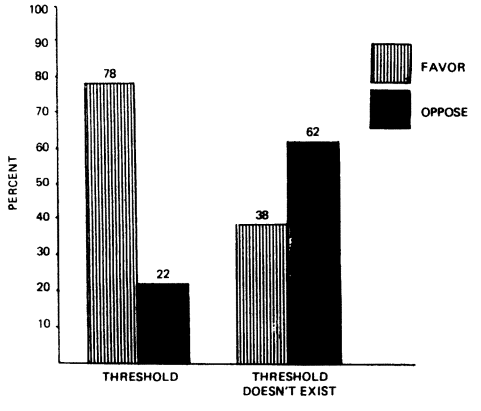

Figure 11. Attitudes toward the existence of a threshold and the government's use of cost-benefit analysis.

Table 2. The relationship between attitudes toward the existence of thresholds and the respondent's vote in the 1980 Presidential election ($p < 0.02$; $N = 75$).

Attitudes about Thresholds	Vote in 1980 Presidential Election		
	Carter	Reagan	Total
Thresholds exist	36% (18)	63% (31)	99% (49)
Thresholds don't exist	69% (18)	30% (8)	99% (26)
Total			

For instance, 74% of those who believe in thresholds also believe that the reactions to TMI have exaggerated the risks associated with advanced technology. By contrast, only 39% of those who question the existence of thresholds believe that the risks of advanced technology have been exaggerated by Three Mile Island (Figure 10).

A similar pattern held on the issue of risk sensitivity. Fifty-seven percent of those who believe in thresholds also believe that "Americans are overly sensitive to risk and [want] to be protected from all dangers." Only 16% of those who question the existence of thresholds for carcinogens believe that Americans are overly sensitive to risk.

Belief in the existence of thresholds correlates with voting in the 1980 Presidential election (Table 2) and self-identification as conservative and Republican. Support for the existence of thresholds for carcinogens is also linked to support for the use of cost-benefit analysis (Figure 11) as well as to a decreased willingness to strengthen environmental regulations (Table 3). In sum, in areas of science where there is no data to distinguish choices of models or assumptions, scientific choices correlate highly with personal political

Table 3. The relationship between attitudes toward the existence of thresholds and the regulations to protect employees from cancer should be made more strict or kept the same ($p < 00$; $N = 86$).

Attitudes about Thresholds	Regulations to Protect Employees		
	More Strict	Kept Same	Totals
Thresholds exist	43%	56%	99% (53)
Thresholds don't exist	75%	25%	100% (33)

This content downloaded from 147.251.232.138 on Mon, 26 Sep 2016 09:00:08 UTC
All use subject to http://about.jstor.org/terms

beliefs. The policy implications of these findings are treated in the final section of this article.

Policy Implications

The idea for this study grew from the debates over OSHA's attempt to adopt a generic method to identify and classify carcinogens. OSHA's was the first in a series of continuing efforts by both public and private bodies to promulgate guidelines for identifying and assessing cancer risks. In recent years, the debate over the use of a linear dose–response model and the role for animal data has been joined by issues such as the incorporation of pharmokinetic data, differentiation among genotoxic and non-genotoxic data, the role given to different routes of exposure or to tumor sites in animals not found in humans, and whether to use "best estimates" or "worse case" characterizations of data.

A reading of the record in the OSHA hearings as well as of contemporaneous articles in scientific journals suggests a lack of consensus on the methods and models in the rapidly emerging field of carcinogenic risk assessment. The issues seemed to fall into the category of "trans-science," a term that Alvin Weinberg used in a 1972 article in the journal *Minerva*.[21] Weinberg cited the determination of the biological effect of low-level radiation insults as an example of a trans-scientific issue. He suggested that the argument about low-level radiation insults would have been far more sensible had it been "admitted at the onset that this was a question which went beyond science. The matter could have been dealt with initially on moral or aesthetic grounds."

Weinberg's observations in the early 1970s seemed to go unnoticed in much of the debate surrounding the OSHA standard and ensuing discussions of assessing the risks of cancer. As late as 1983, EPA Administrator William Ruckelshaus was reiterating the distinction between risk assessment and risk management, saying in a speech before the National Academy of Sciences that

> Nothing will erode public confidence faster than the suspicion that policy considerations have been allowed to influence the assessment of risk.[22]

A year later, however, in a February 1984 speech at Princeton University, Ruckelshaus qualified his position by saying that he had found that separating the assessment of risk from its

> management is rather more difficult to accomplish in practice . . . values, which are supposed to be safely sequestered in risk management, also appear as important influences on the outcome of risk assessments.[23]

Nonetheless, Ruckelshaus's qualification seemed to fall on deaf ears, for on 4 January 1985 the White House issued Executive Order 12498 which stated that risk assessments are to be "scientifically objective."

The results of the study on which this article is based call into question the characterization of risk assessment as "objective." The results suggest that under conditions of scientific uncertainty, regulatory policy implications either consciously or unconsciously influence the models, assumptions and theories that scientists' choose.

U.S. District Court Judge David L. Bazelon in a 1979 speech, "Risk and Responsibility," warned that

> in reaction to the public's often emotional response to risk, scientists are tempted to disguise controversial values decisions in the cloak of scientific objectivity, obscuring those decisions from political accountability.[24]

Currently, American industry is seeking to create and lodge increasing decisionmaking responsibility in science advisory panels. The most public of these efforts was a 1983 proposal by the American Industrial Health Council (AIHC), an association of over 90 different companies and trade associations formed in reaction to OSHA's cancer proposal, to establish a Central Board of Scientific Risk Analysis under the National Academy of Sciences to review regulatory agencies' risk assessments. A bill to accomplish this was introduced by Representative James Martin (R–North Carolina) and was viewed by the AIHC as a means of getting "statutory recognition of good science" and part of the AIHC's plan to "spearhead efforts to ensure distinction between risk assessment and risk management."[25]

Representative Martin withdrew his bill in the spring of 1984. It had been criticized not only by environmental groups but also by professional organizations such as the American Chemical Society and by prominent scientists. Epidemiologist Alice Whitmore, in an article in the *Journal of the Society for Risk Analysis*, argued that

This content downloaded from 147.251.232.138 on Mon, 26 Sep 2016 09:00:08 UTC
All use subject to http://about.jstor.org/terms

> attempts to view toxicant risk analysis as involving two stages (risk assessment and risk management) with risk assessment relying on scientific activity and scientific judgment . . . [was] . . . an erroneous description of reality and an unattainable goal for the regulatory process.[26]

Her research suggested that values unavoidably enter virtually every aspect of risk analysis. Whitmore contended that

> creating a central authoritative panel of distinguised scientists who will resolve on a case-by-case basis, complex or difficult issues for regulatory agencies . . . would move the scientists from the frying pan into the fire . . . [and] . . . would ensure that a scientist's values would drive the decision.[27]

The potential danger of these boards and panels, especially in areas with pervasive uncertainties such as quantitative risk assessment, is that scientists alone will make decisions with important political and ethical implications for the protection of human health. The question is whether scientists are the only ones that should be involved.

One could argue that the most appropriate role for the scientists in this situation would be to self-consciously provide decisionmakers and the public with as much information as possible about the uncertainties in his or her work. Social scientists and ethicists could be involved in analyzing which, if any, social, ethical and political implications flow from selecting one assumption, model or theory instead of another.

This will mean that a new type of debate will be occurring in policy discussions, one which is more conscious of those places in the scientific process where non-scientific values play a role and hard political choices must be made. This will be to the benefit of science for it may avoid the spectacle of the dueling scientist and place the very difficult decision of degrees of protection and the acceptability of a risk into the political arena, where, in a democracy, it belongs.

Appendix

This appendix focuses on the choice, construction, and evaluation of the research instrument. It also describes the sampling process and data analysis techniques.

The research instrument used was an interview pre-tested and conducted in person by the author. The decision to conduct interviews as opposed to a mailed questionnaire, and hence a larger sample, was made primarily because of the sensitivity and relative newness of the subject matter under investigation, and because of a desire to have an explanatory richness difficult to obtain through the questionnaire process. Sensitive questions included probing institutional constraints and ethical dilemmas which arise in the process of an occupational health professional's job. In the case of issues which involved scientific uncertainty and/or controversy such as the existence of thresholds and the use of cost-benefit analysis, the interview format offered the potential for probing explanations and possibly a better understanding of the basis for attitudes.

Over half of the interview items came from other studies of risk. The main source of these questions was from a study, "Risk in a Complex Society," conducted by the Louis Harris survey organization for Marsh and McLennan, Inc., the world's largest insurance broker. The survey, the most expensive ever conducted by the Harris organization, was administered in 1980. A second source of questions came from a study, "Public and Worker Attitudes Toward Carcinogens and Cancer Risk," prepared for Shell Oil by Cambridge Reports.

One hundred thirty-six randomly-selected, in-person interviews were conducted in the New York and Cincinnati metropolitan areas and the Research Triangle and Triad of North Carolina. All geographic areas contain a sufficient number of academic, government and industrial institutions to provide an adequate sampling frame.

An effort was made to make the selection process replicable. Names were selected from the main professional organizations. For industrial hygienists, these groups included the American Industrial Hygiene Association (AIHA), the American Conference on Governmental and Industrial Hygienists (ACGIH), and the American Academy of Industrial Hygiene (AAIH). Within occupational medicine there is no one or even two organizations to which all physicians, regardless of employment, belong. Physicians working for industry, but not for academia or the government, belong to the American Occupational Medicine Association (AOMA). The industry sample, therefore, was drawn from the membership rosters of AOMA. The department heads of univer-

This content downloaded from 147.251.232.138 on Mon, 26 Sep 2016 09:00:08 UTC
All use subject to http://about.jstor.org/terms

sity-based occupational health programs supplied the names of academic physicians. Heads of government agencies likewise advised on government physicians.

The sampling frame was defined by zip codes, stratified by institutional setting and profession (industrial hygiene or occupational medicine), and then randomly selected. In all but two categories (industrial and academic physicians), the response from the initial postcard request ranged from 75% to 85%. Follow-up calls to physicians in industry and academia were successful in filling quotas. These are unusually high response rates and can probably be attributed to the salience of the topic and the specialized nature of the sample. Several respondents said that they were intrigued by the topic and felt that they could learn something from the interview. The sample was predominantly white (98%), male (88%) and Protestant (56%).

The data analyzed was categorical (e.g., information measured on nominal or ordinal scales or grouped continuous data). Statistics used to analyze the data included frequencies, chi-squares and weighted least-squares, an application of the general linear model to categorical data. In the weighted least-squares technique, one looks at variations in cell probabilities and models hypothetical regression lines for associations or interactions among variables. One uses the goodness-of-fit chi-square statistic to compare expected and observed frequencies, asking the question whether "the departures between observed and expected values . . . [can] . . . reasonably be attributed to chance or . . . [whether] . . . they are so large that the model itself seems wrong?"[28]

Initial contingency tables showed extremely strong statistical significance between institutional affiliation and a wide variety of dependent variables. Methodologist Hubert Blalock feels that we may be saying "quite a bit when we can establish significance with small samples" because small samples require a "much more striking relationship in order to obtain significance."[29]

In addition to institutional affiliation, controls were run for the following variables: age, region, religion and father's education. Age was the only variable which appeared to make a substantive difference on the effect of institutional affiliation. Age did not prove to be statistically significant in altering the effect of employment setting.

An unanticipated result of doing personal interviews was the opportunity, on a limited basis, to experiment with a more interactive questioning mode. In the last set of interviews, respondents were given the option of filling out the fixed choice questions themselves. This technique permitted more time for open-ended questions and probes. In at least six interviews involving research scientists, the interviewees were asked to reflect on the process by which he or she made a hazard determination and to identify those points in the process where professional and/or personal judgment, as opposed to scientific certainty, were involved. The interviewees seemed to welcome the opportunity to reflect on the research process. The role of the interviewer was to keep the respondent on as straight a path as possible and to question constantly the basis for decisions. This is a fruitful method to be used in research of this type.

Notes

1. U.S. Department of Labor Occupational Safety and Health Administration, Identification, Classification and Regulation of Potential Carcinogins Federal Register, Volume 45, No. 15 Book 2, 1980.
2. William W. Lowrance, *Of Acceptable Risk: Science and the Determination of Safety* (Los Altos, CA: William Kaufman, 1976).
3. National Academy of Sciences, *Risk Assessment in the Federal Government* (Washington, DC: National Academy Press, 1983).
4. Lawrence McCray, *An Anatomy of Risk Assessment: Scientific and Extra-Scientific Components in the Assessment of Scientific Data on Cancer Risks*, Working Paper for the National Academy of Sciences Committee on the Institutional Means for Assessment of Risks to Public Health (Washington, DC: National Academy Press, 1983), p. 13.
5. National Academy of Sciences, *op. cit.*, p. 36.
6. *Ibid.*, p. 34.
7. *Ibid.*, p. 171.
8. Louis Harris and Associates, *Risk in a Complex Society* (New York: Marsh and McLennan Companies, 1980).
9. Mark Green, "The Gang that Can't Regulate," *The New Republic*, Volume 188, (1984): 14–17.
10. C. Starr, *Science*, Volume 165, Number 3899 (1969); Ezra J. Mishan, *Cost–Benefit Analysis* (New York: Praeger, 1976); Edith Stokey and Richard Zeckhauser, *A Primer for Policy Analysis* (New York: W.W. Norton and Co., 1978); Richard Zeckhauser, "Procedures for Valuing Lives," *Public Policy*, Number 23, (1975): 419–462.
11. Lawrence H. Tribe, "Policy Science: Analysis or

This content downloaded from 147.251.232.138 on Mon, 26 Sep 2016 09:00:08 UTC
All use subject to http://about.jstor.org/terms

Ideology?" *Philosophy and Public Affairs,* Volume 2, (1972): 66–110; Baruch Fischhoff, "Cost–Benefit Analysis and the Art of Motorcycle Maintenance," *Policy Sciences,* Volume 8, (1977): 188–202; Nicholas Ashford, "The Usefulness of Cost–Benefit Analysis in Decisions Concerning Health, Safety, and the Environment," *Annals of the New York Academy of Sciences,* Volume 363, 1980; Michael S. Baram, "Cost–Benefit Analysis: An Inadequate Basis for Health Safety and Environmental Regulatory Decision Making," *Ecology Law Quarterly,* Volume 8, (1980): 474–531; Marguerite Connerton and Mark MacCarthy, *Cost–Benefit Analysis and Regulation* (Washington, DC: National Policy Exchange, 1982).

12. Robert Smith, *The Occupational Safety and Health Act* (Washington, DC: American Enterprise Institute, 1976); Richard Thaler, and Sherwin Rosen, "The Value of Saving a Life: Evidence from the Labor Market," in Nestor Terleckyi, ed., *Household Production and Consumption* (New York: Pergamon Press, 1976); Kip Viscusi, "Labor Market Valuations of Life and Limb: Empirical Evidence and Policy Implication," *Public Policy* (Summer, 1978): 369–372.
13. David Zimmerman, "Coercive Wage Offers," *Philosophy and Public Affairs,* Volume 10, (1981): 121–145.
14. Thomas C. Schelling, "The Life You Save May Be Your Own," in S.B. Chase, ed., *Problems in Public Expenditure Analysis* (Washington, DC: Brookings Institute, 1968).
15. National Academy of Sciences, *op. cit.,* p. 3.
16. *Ibid.,* p. 28 and p. 33.
17. *Ibid.,* p. 22.
18. *Ibid.,* p. 25.
19. State of California, Department of Health Services, Health and Welfare Agency, *Carcinogen Identification Policy: A Statement of Science as a Basis of Policy* (1982): 19.
20. Office of Science and Technology Policy, Executive Office of the President, *Chemical Carcinogens: A Review of the Science and Its Associated Principles,* Federal Register, Volume 50, Number 50 (1985).
21. Alvin Weinberg, "Science and Trans-Science," *Minerva,* Volume 10, (1972): 209–222.
22. William Ruckelshaus, "Science, Risk and Public Policy," *Science,* Volume 221, (1982): 1026–1028.
23. William Ruckelshaus, "Risk in a Free Society," speech given at Princeton University, 18 February 1984, mimeo.
24. David Bazelon, "Risk and Responsibility," *Science* Volume 205, (1979): 277–280.
25. American Industrial Health Council, *Report to the Membership,* Scarsdale, NY, 1983.
26. Alice Whitmore, "Facts and Values in Risk Analysis for Environmental Toxicants," *Risk Analysis,* Volume 3, (1983): 23–33.
27. *Ibid.,* p. 32.
28. H.T. Reynolds, *Analysis of Nominal Data* (Beverly Hills, CA: Sage Publications, 1977), p. 58.
29. Hubert L. Blalock, *Social Statistics* (New York: McGraw-Hill Book Co., 1960), p. 227.

This content downloaded from 147.251.232.138 on Mon, 26 Sep 2016 09:00:08 UTC
All use subject to http://about.jstor.org/terms