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Valuing Changes in Hazardous Waste Risks: A Contingent Valuation Analysis

Volume I

Draft Interim Report

EPA Cooperative Agreement No. CR-811075
The Benefits of Hazardous Waste Management Regulations Using Contingent Valuation

Prepared for

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PREFACE

The objective of this report is to provide a summary of the research completed during the first phase of U.S. Environmental Protection Agency (EPA) Cooperative Agreement No. CR-811075-01, "The Benefits of Hazardous Waste Management Regulations Using Contingent Valuation."

When this Cooperative Agreement was initiated August 8, 1983, several activities related to the research were already underway with other EPA funding. Chief among these was a project to use and evaluate focus groups in developing contingent valuation survey questionnaires for valuing reductions in the risk of exposure to hazardous wastes. With the initiation of complementary research under the Cooperative Agreement, the scope of the focus group analysis was expanded to meet the specific needs of the research under the Cooperative Agreement. Thus, the report submitted in December 1984, The Role of Focus Groups in Designing a Contingent Valuation Survey to Measure the Benefits of Hazardous Waste Management Regulations, was a joint product reflecting activities undertaken both under EPA Contract No. 68-01-6596 (Subcontract 700-C, Work Assignment No. C-011) and under the Cooperative Agreement. A detailed summary of the focus group activities was also prepared for more limited distribution under these two agreements.

This volume is the draft interim report for the Cooperative Agreement. It summarizes the research activities during and the findings from Phase I of the Agreement. Volume II is the appendix material to the report. In addition, we have also provided a third volume to supplement this report. Volume III contains the 11 working papers prepared by various authors over the course of the research with the support of the Cooperative Agreement. Some of these articles will soon appear in print, but we have collected them here to ensure easier access. While the findings of most of these working papers have been integrated into this report, the papers sometimes provide more detailed treatments or more extensive reviews of particular issues. However, due to budget limitations, we have been able to prepare only a few copies of Volume III for our EPA Project Officer. The reader who desires access to Volume III is asked to contact him.

In preparing this draft report which involved the complex interaction of several authors and participants, it was often difficult to give all contributors the opportunity to review the entire report. Consequently, to limit the liability of specific individuals, we have prepared Table I, which describes the writing responsibilities for each chapter in this report. As the ones responsible for the overall research, we are of course the most culpable. Table I lists three categories of contribution--primary responsibility, contributor, and assistance. Primary responsibility implies the individual responsible for completing the first draft of the chapter, for assembling comments or proposed

TABLE I. RESPONSIBILITIES FOR CHAPTERS OF DRAFT INTERIM REPORT

Chapter	Primary responsibility	Contributor	Assistance
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5	V. Kerry Smith		
6	A. Myrick Freeman III	V. Kerry Smith	
7	William H. Desvousges	V. Kerry Smith	
8	William H. Desvousges	Hall B. Ashmore, Diane H. Brown, V. Kerry Smith	
9	William H. Desvousges	V. Kerry Smith, Bruce Jones	
10	Hall B. Ashmore	William H. Desvousges, V. Kerry Smith	Lu Lohr
11	William H. Desvousges	V. Kerry Smith	
12	William H. Desvousges		V. Kerry Smith
13	V. Kerry Smith		William H. Desvousges
14	V. Kerry Smith	William H. Desvousges, Matthew McGivney	
15	V. Kerry Smith		William H. Desvousges, Lu Lohr
16	V. Kerry Smith		

changes from other contributors, and for developing the draft provided in this report. Contributor designates coauthor status achieved either through design of the research or through involvement in key specific research activities. Assistance implies that an individual provided key information, editorial suggestions, and research assistance in the activities associated with a chapter.

With those chores behind us, we can now turn to our most important task--that is, extolling the many who contributed to our research effort. First, we would like to acknowledge the important role of our coauthor Rick Freeman. Although Rick was primarily responsible for the conceptual analysis of intrinsic benefits, he provided valuable comments throughout the research. He also attended our interviewer debriefing sessions to help us interpret the information gained in these sessions.

We would also like to point out the valuable roles of a number of EPA personnel in our research activities, including structuring the research objectives, commenting on the questionnaire design, reacting to the proposed design of the empirical analysis, and attending the interviewer debriefing sessions. George Provenzano, the EPA Project Officer, performed all of these tasks and put up with Kerry's grumblings over administrative details of the project. Ann Fisher also contributed substantively to the effort through her initiation and supervision of the focus group project and in commenting on all aspects of the research activities undertaken under the Cooperative Agreement. Along with our field interviewers, we especially appreciated Ann's participation in our training session. Also helpful were several members of the Office of Solid Waste. Dale Ruther provided important guidance at a crucial stage; Peggy Podolak, formerly of the Office, improved the questionnaire in several key areas; and Jim Craig has continued the liaison with the Office.

We were also fortunate to receive comments on the development of the questionnaire from a large number of individuals. Table II lists these brave individuals, to whom we are grateful. We would like to note the contributions of two individuals in particular: Robert Mitchell and Thomas Wallsten. Robert provided two thorough reviews on short notice and helped us avoid several potential problems. Tom helped in a number of ways. His thoughtful suggestions and insights on questionnaire development and on the psychological literature on individual behavior under uncertainty were especially important to the research design. In addition, he served as a member of the Research Advisory Committee for the project and provided many helpful ideas as part of that group as well.

The project was especially fortunate to have the guidance of an excellent Advisory Committee who assisted us at several key stages of the research design (and who, ultimately, will be our toughest and most helpful reviewers of this draft report). In alphabetical order, they are as follows:

Jerry Hausman, Massachusetts Institute of Technology
Robert Haveman, University of Wisconsin
Milton Weinstein, Harvard University
Thomas Wallsten, University of North Carolina at Chapel Hill

TABLE II. QUESTIONNAIRE REVIEWERS AND KEY CONCERNS

Name	Affiliation	Concerns	Version(s) reviewed
Tom Wallsten	University of North Carolina (Psychologist--Advisory Committee Member)	· Context of risk · Design issues · Risk ladder	Several
Bill Schulze	University of Wyoming (Economist)	· Direct question vs. bidding · Probability complexity · Payment vehicle	September 1983
Robert Mitchell	Resources for the Future (Sociologist)	· Context · Probability complexity	September 1983
		· Equity · Probability design · Risk ladder	November 1983 and February 1984
Milt Weinstein	Harvard University (Economist--Advisory Committee Member)	· Analytical design · Certainty case · Context	September 1983
Alan Randall and John Hoehn	University of Kentucky (Economists)	· Bidding · Context · Analytical design	November 1983
George Tolley et al.	University of Chicago (Economists)	· Length · Complexity · Bidding	September 1983
Bob Haveman	University of Wisconsin (Economist Advisory Committee Member)	· Analytical design · Length	September 1983
Nancy Bockstael	University of Maryland (Economist)	· Context · Analytical design	September 1983
Dick Kulka	Research Triangle Institute (Psychologist)	· Length · Context	Several
Garrie Kingsbury	RTI (Chemical Engineer)	· Health effects--technical issues	February 1984
David Harrison	Harvard University (Economist)	· Averting cost · Hypothetical vs. actual	September 1983
Ron Wyzga	Electric Power Research Institute (Economist)	· Length · Analytical design · Context	February 1984
Bob Raucher	Economic Analysis Division U.S. EPA (Economist)	· Risk ladder · Complexity	February 1984
Tom Lareau	Economic Analysis Division U.S. EPA (Economist)	· Risk ladder · Complexity	February 1984
Peggy Podolak	Office of Solid Waste U.S. EPA (Economist)	· Length · Technical content	Several
Dale Ruther	Office of Solid Waste U.S. EPA (Economist)	· Risk levels	February 1984
Nick Nichols	Economic Analysis Division U.S. EPA (Economist)	· Risk ladder · Complexity	February 1984
Alan Carlin	Economic Analysis Division U.S. EPA (Economist)	· Risk ladder · Complexity	February 1984
Allen Basala	Office of Air Quality Planning and Standards U.S. EPA (Economist)	· Air pathways · Payment vehicle	February 1984
Reed Johnson	Economic Analysis Division U.S. EPA (Economist)	· Length · Complexity	September 1983
Al McGartland	Economic Analysis Division U.S. EPA (Economist)	· Length · Complexity	September 1983

The Advisory Committee provided detailed reviews of our proposed questionnaire and critical evaluations of our analysis plan for empirical analysis of the survey data. Many of their comments sparked ideas that are discussed throughout the report.

We would also like to thank David Harrison for his contribution. David reviewed several drafts of the questionnaire and attended some of our focus group sessions in Boston. Along with James Stock, David also gave us background and data for his property value analysis that enabled us to do our comparative analysis in Chapter 15.

Several individuals at Vanderbilt played key support roles. It would not have been possible for Kerry to complete his work without the continuous assistance of John Mott and Wei-Wei Kao in helping him to learn and use a new IBM computer facility introduced at Vanderbilt in September 1984. Long weekends and late nights by John at crucial times assured the project would have the needed computer resources.

The day-to-day administration of the project, budget management, monthly and quarterly reports, drafts of chapters, comments and plans, and all of the correspondence from Vanderbilt would not have been possible without Sue Piontek. Because Sue handled all of these aspects of the project so well, Kerry was able to focus primarily on research administration. Steve Smartt of the Office of Sponsored Research at Vanderbilt also contributed in a significant way to ease these administrative burdens.

Several people at RTI assisted us in conducting our research. The quality of the contingent valuation data is due in large part to Kirk Pate, RTI Survey Specialist, who worked with us in every aspect of the focus group sessions and in developing the questionnaire. In addition, he conducted the videotaped interviews, coauthored the interviewer training manual, developed the overall survey plan, and conducted the interviewer training sessions. Kirk also supervised the activities of all the interviewers and the assembly of the questionnaires. Kirk was assisted in these tasks by Annette Born, who supervised the day-to-day activities in Boston along with helping in the pretest.

We are grateful to Matthew McGivney of RTI who constructed the SAS data set and helped perform the means and regression analysis reported in Chapters 11 and 12 and the contingent ranking analysis reported in Chapter 14. Matt also helped transfer the data for Harrison's hedonic model to SAS data sets. Glenn Jones of Vanderbilt University also helped in this second task. David Toy of RTI assisted in the results presented in Chapters 11 and 12, and Lu Lohr of RTI helped by constructing the Census data needed for the comparative analysis and by organizing the detailed background information on the survey area.

While the preface to the focus group report identifies the roles that various people played in those activities, we would like to add a few special commendations in this report because of the importance of these activities. As we noted earlier, Kirk Pate's efforts as our unflappable moderator were most valuable. He always knew at the end of the sessions that we still needed a

survey questionnaire. In addition, Diane Brown, formerly of RTI, now working for the Power Plant Siting Commission of the State of Maryland, almost singlehandedly summarized those sessions, helped organize them, and generally provided good counsel on many issues. Ann Dunson, who has left RTI to start her own business, helped organize most of our sessions. Finally, we would like to thank the participants of the sessions who helped us begin to understand how to deal with risk in a survey questionnaire.

We also appreciate both the continuous support and valued counsel of Tayler Bingham, Head of RTI's Environmental Economics Department. While Tayler often keeps himself in the background, his help is always highly valued.

Hall Ashmore, Publications Manager in RTI's Center for Economics Research, is primarily responsible for the level of communication, consistency, and overall form of this report--especially the visual aesthetics of our figures and tables. Hall has helped to make every chapter more readable and to ensure that all the chapters work together in the overall report. We would also like to thank Hall for his assistance in writing Chapters 8 and 10.

Last, but certainly not least, in our appreciation is Jan Shirley and her staff of word processing specialists. In working with us over the past 3½ years, they have consistently turned the impossible into the possible. Each time the scale and complexity of this effort increased, their response grew to meet it. They continue to be a most valuable part of our research team.

In a project involving multiple locations and almost 2 years of activities, we would have been scuttled without the help that these many individuals have given us. Not only these individuals but their families have contributed by their patience and support when faced with another long working weekend. In this regard, our wives, Pauline and Shelley, and our children, Timothy, Shelley, and Anne, have contributed dearly.

We can say without any reservations that we could not have reached this point in our research without each and every one of you. Had any of the links in this long and winding human chain failed, we would have been lost. Thank you.

V. Kerry Smith
Nashville, Tennessee

William H. Desvousges
Research Triangle Park, North Carolina

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CHAPTER 1

ON VALUING REDUCTIONS IN HAZARDOUS WASTE RISKS

1.1 INTRODUCTION

This chapter introduces our draft interim report on using the contingent valuation approach to measure the benefits of reducing hazardous waste risks. This approach involves using survey techniques to elicit people's expressed preferences, or intended behavior, to estimate the value of reducing these risks.

The research described in this report was conducted in response to our two main objectives:

- To develop a framework for using the contingent valuation approach to measure the benefits to individuals from reductions in hazardous waste risks.
- To design a framework for comparing a hedonic property value model* for benefit measurement with contingent valuation when a risk change is the source of the benefits.

To meet the first objective, our contingent valuation analysis explicitly recognizes the difficulties posed by investigating individual behavior under uncertainty. As a first step, we began our conceptual analysis. To complement this effort, and before conducting the contingent valuation interviews, our research activities focused on improving our understanding of the interview techniques and questions that communicate concepts involving risk. These activities involved using focus groups, a detailed pretest, and videotaped interviews and progressively revising the questionnaire and vehicles used to explain risk.†

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*In this approach, values are indirectly inferred from the residential location decisions of the household.

†Given the scope of this effort, a separate report of these activities was prepared with partial support from this cooperative agreement (see Desvousges et al. [1984a,b] for a more complete summary of these activities). Chapter 8 in this report summarizes the process used to develop the questionnaire, but should not be considered a complete description of these activities.

Based on these efforts, we conducted a contingent valuation survey in the Boston area during the Spring and early Summer of 1984. This report presents preliminary results from the empirical analysis of the valuation responses elicited in these interviews.

To meet the second main objective, we also formed a joint effort with David Harrison (then of Harvard University, now associated with Dun & Bradstreet) to acquire information consistent with a hedonic property value analysis involving hazardous-waste-related risks that he was completing with support from the U.S. Environmental Protection Agency (EPA) under Cooperative Agreement No. CR-809702-01. Harrison's independently developed hedonic model is the indirect method for measuring the marginal value of risk changes to which we compare our contingent valuation approach. Harrison's method also provides some of the necessary information for using part of the contingent valuation survey in comparing the two approaches. This report presents the preliminary results from this comparison.

In addition to our two overall objectives, the research has many specific objectives, which are identified and discussed in the chapters that follow. Among these specific objectives are measuring both use and intrinsic values for risk changes and examining the influence of the attributes of risk, risk endpoints, and risk outcomes on individuals' values for risk reductions. Additionally, our research examines the importance of assigning different property rights to risk levels. Finally, our research compares alternative question formats for eliciting individuals' values of reductions in hazardous waste risks.

The report provides substantial support for using contingent valuation to elicit values for reducing hazardous waste risks. The overall quality of fieldwork, the relatively low number of protest responses, the generally high levels of statistical significance of valuation response means, and the good performance of our "restrictive" models lend credence to this conclusion. However, the specific estimates must be regarded as very preliminary. Indeed, this report is best viewed as structuring an agenda for future research activities that either may yield more definitive estimates of the values for risk reductions or suggest reasons that general conclusions on the nature of these values cannot be drawn from the methods and information in our survey results.

To introduce the report, the following sections provide an economic perspective for viewing regulatory policies involving hazardous wastes. Specifically, Section 1.2 highlights the legislative mandates that suggest the importance for hazardous waste environmental policies. Section 1.3 discusses the role of benefit analysis for the regulatory policies resulting from that legislative mandate. Section 1.4 describes the outcomes of these regulatory policies as reductions in the risk of exposure to hazardous wastes for households and the ecosystem. Section 1.5 provides a general economic framework for viewing a household's decisions involving risk. Section 1.6 describes the more restrictive conceptual framework that underpins our contingent valuation analysis for measuring the benefits of reducing hazardous waste risks. Section 1.7 provides a brief overview of the contingent valuation approach, which is one of the primary focuses of our research activities. Section 1.8 presents an overview of our overall research design, including our research objectives and the activities completed. Finally, Section 1.9 presents a guide to the report.

1.2 THE IMPORTANCE OF HAZARDOUS WASTE REGULATORY POLICY

Hazardous waste regulations constitute one of the decade's most pressing environmental policymaking challenges. Local, State, regional, and several Federal agencies are already participating in a regulatory process that will ultimately encompass the generation, transportation, storage, and disposal of hazardous wastes. Despite this wide range of activity, however, our primary focus is on the most influential regulatory element--the hazardous waste regulatory actions of EPA.

Congress has mandated EPA's involvement by passing the Safe Drinking Water Act of 1974, the Resource Conservation and Recovery Act (RCRA) of 1976, and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980, also known as the "Superfund" Act. The Safe Drinking Water Act provides for general protection against a variety of organic and inorganic contaminants and also protects specific aquifers. RCRA contains a wide range of regulatory mandates involving all facets of the hazardous waste problem. The Superfund Act requires a comprehensive "cleanup" of unregulated, abandoned hazardous wastes dumps.

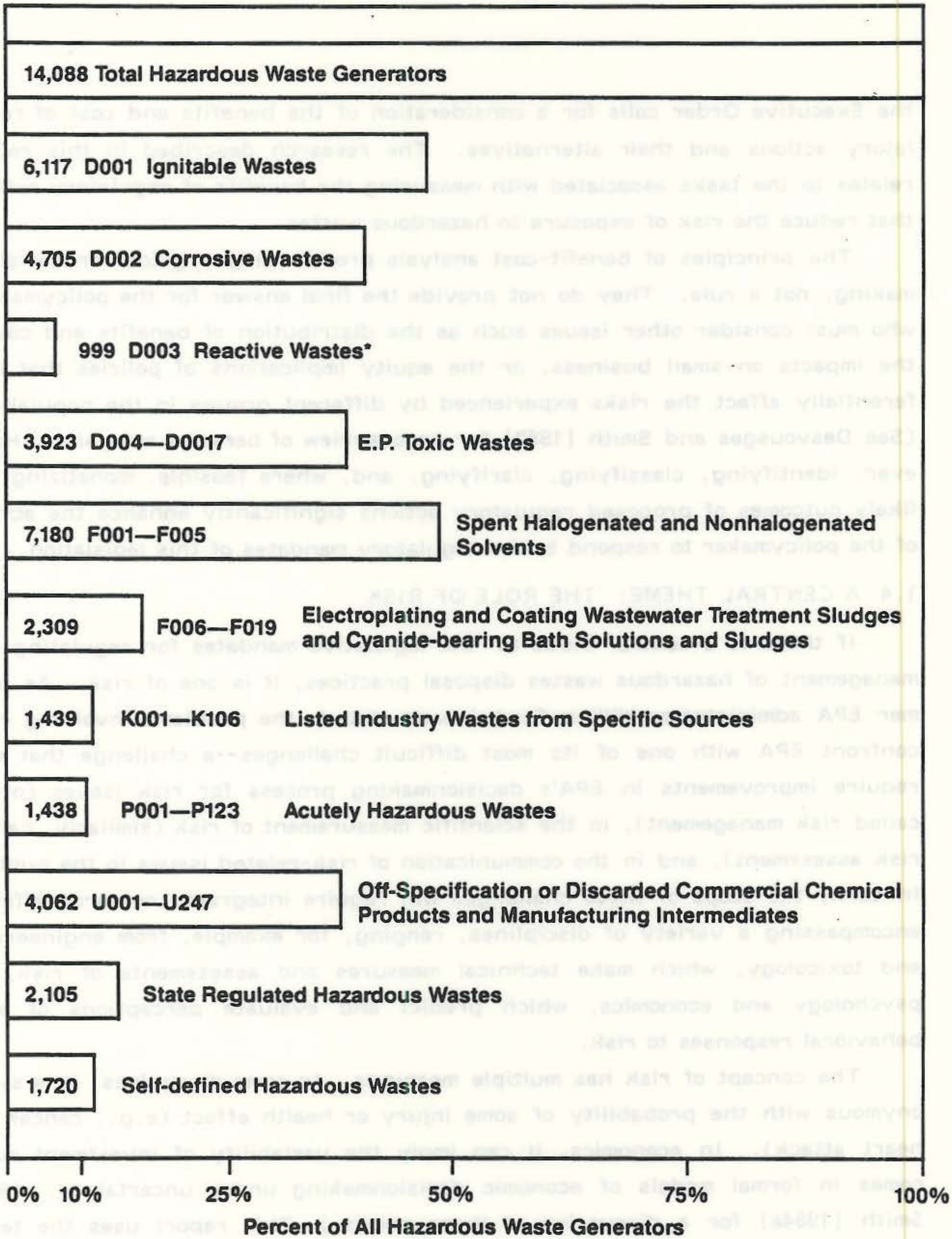
The importance of EPA's role in hazardous waste policy has been directly stated in the recent reauthorization of RCRA. In the Hazardous and Solid Waste Amendments of 1984, Congress has required EPA to take significant steps to reduce the likelihood of exposures to hazardous wastes. For example, the Congress has called for the prohibition of the land disposal of any hazardous wastes where such disposal cannot be shown to be protective of human health and the environment. If implemented according to its narrowest interpretation, this prohibition will impose costs on the society that could be in the billions of dollars annually. Clearly, these legislative actions imply that EPA can be expected to play a central role in future hazardous waste regulatory actions.

To identify substances whose transportation, treatment, storage, or disposal might increase mortality or serious illness or pose a hazard to human health or the environment, EPA has defined hazardous waste as any solid waste that is ignitable, corrosive, reactive, or toxic. This definition currently involves some 400 chemicals and 85 waste processes, but, as yet, the magnitude of the hazards is uncertain.

An important, and often confusing, aspect of this definition is the difference between a hazardous substance and a hazardous waste. The two terms are not synonymous even though they may involve the same substance, e.g., chromium. A hazardous substance becomes a hazardous waste only after it is discarded or, in economic terms, becomes a residual of some production process. Figure 1-1 shows the distribution of various types of wastes and the number of generators from each waste type. Present estimates are that 85 percent of these wastes are from the manufacturing sector, with the chemical and related processes, metal-related products, and electrical equipment industries accounting from the majority of the wastes generated (see Westat [1984]). Thus, hazardous waste legislation and the resulting regulatory policies ultimately affect sectors that are important components of the overall economy.

1.3 THE ROLE OF BENEFITS ANALYSIS FOR REGULATORY POLICY

In implementing some of the regulatory actions that stem from the Congressional mandates, EPA will be subject to the provisions of Executive Order 12291. This order requires that agencies conduct regulatory impact analyses of major regulations and of precedent-establishing regulations. Specifically,



*Confidence Interval exceeds ± 25% at the 95% Confidence Level.
Source: Westat [1984].

Figure 1-1. Number of establishments generating each major waste group.

the Executive Order calls for a consideration of the benefits and cost of regulatory actions and their alternatives. The research described in this report relates to the tasks associated with measuring the benefits of regulatory actions that reduce the risk of exposure to hazardous wastes.

The principles of benefit-cost analysis provide only a guide for decisionmaking, not a rule. They do not provide the final answer for the policymaker, who must consider other issues such as the distribution of benefits and costs, the impacts on small business, or the equity implications of policies that differentially affect the risks experienced by different groups in the population. (See Desvousges and Smith [1983] for an overview of benefits analysis.) However, identifying, classifying, clarifying, and, where feasible, monetizing the likely outcomes of proposed regulatory actions significantly enhance the ability of the policymaker to respond to the regulatory mandates of this legislation.

1.4 A CENTRAL THEME: THE ROLE OF RISK

If there is a central theme to the legislative mandates for regulating the management of hazardous wastes disposal practices, it is one of risk. As former EPA administrator William Ruckelshaus stated, the problems involving risk confront EPA with one of its most difficult challenges--a challenge that will require improvements in EPA's decisionmaking process for risk issues (often called risk management), in the scientific measurement of risk (similarly, called risk assessment), and in the communication of risk-related issues to the public. In turn, the scope of these challenges will require integrated research efforts encompassing a variety of disciplines, ranging, for example, from engineering and toxicology, which make technical measures and assessments of risk, to psychology and economics, which predict and evaluate perceptions of and behavioral responses to risk.

The concept of risk has multiple meanings. In some disciplines, it is synonymous with the probability of some injury or health effect (e.g., cancer or heart attack). In economics, it can imply the variability of investment outcomes in formal models of economic decisionmaking under uncertainty. (See Smith [1984a] for a discussion of these points.) This report uses the term risk to imply the chance that a detrimental event will happen. (Chapter 2 provides a comprehensive discussion of our definition of risk and compares it with other frequently used definitions.)

In this research, reductions in the risk of exposure to hazardous waste play a fundamental role. We view these risk reductions as the primary policy outcomes, or effects, of regulations on the management of hazardous wastes. Our framework considers these risks from hazardous wastes as consisting of two parts--an exposure risk and a conditional risk of dying if exposed to hazardous wastes. This distinction is fundamental to our research design. Moreover, we have assumed that regulations affect only the risks of exposure and not the conditional risk. Finally, our focus had been almost exclusively on mortality as the outcome and not morbidity.*

To illustrate the role of reductions in hazardous waste risks in our research, Figure 1-2 shows one example of linkages between a regulatory action, its effects, and a household's behavioral responses. In this example, the regulatory action changes the types of disposal practices that are allowed for a hazardous waste. Specifically, the action might eliminate land disposal as an alternative for liquid wastes containing cadmium. The action changes the risk of contamination by cadmium for the affected environmental media--e.g., groundwater and surface water. By lowering the risk of contamination for groundwater and surface water, the ecological habitats that are affected by these media--e.g., plants, fish, and wildlife that live in an ecosystem near a recharge zone for an aquifer--experience a lower risk of exposure to cadmium. Equally important, households are affected by a lowered risk of exposure through the drinking water or some other pathway. In evaluating the prospective welfare gains from such policies, the task of a benefits assessment is to measure the value that the household places on the risk changes as a result of the regulatory action.

The processes underlying these linkages are considerably more complex than we have described. The extent of this complexity is not fully known as there is an inadequate understanding of the technical, environmental, and behavioral processes that are at work. Nevertheless, such an outline does

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*We recognize that changes in morbidity risks also may be very important effects from hazardous waste regulations, but found it necessary to narrow the emphasis to mortality to make the scope of the research more manageable. If our approach proves to be useful for valuing changes in mortality risks, the morbidity component could be added in future research efforts.

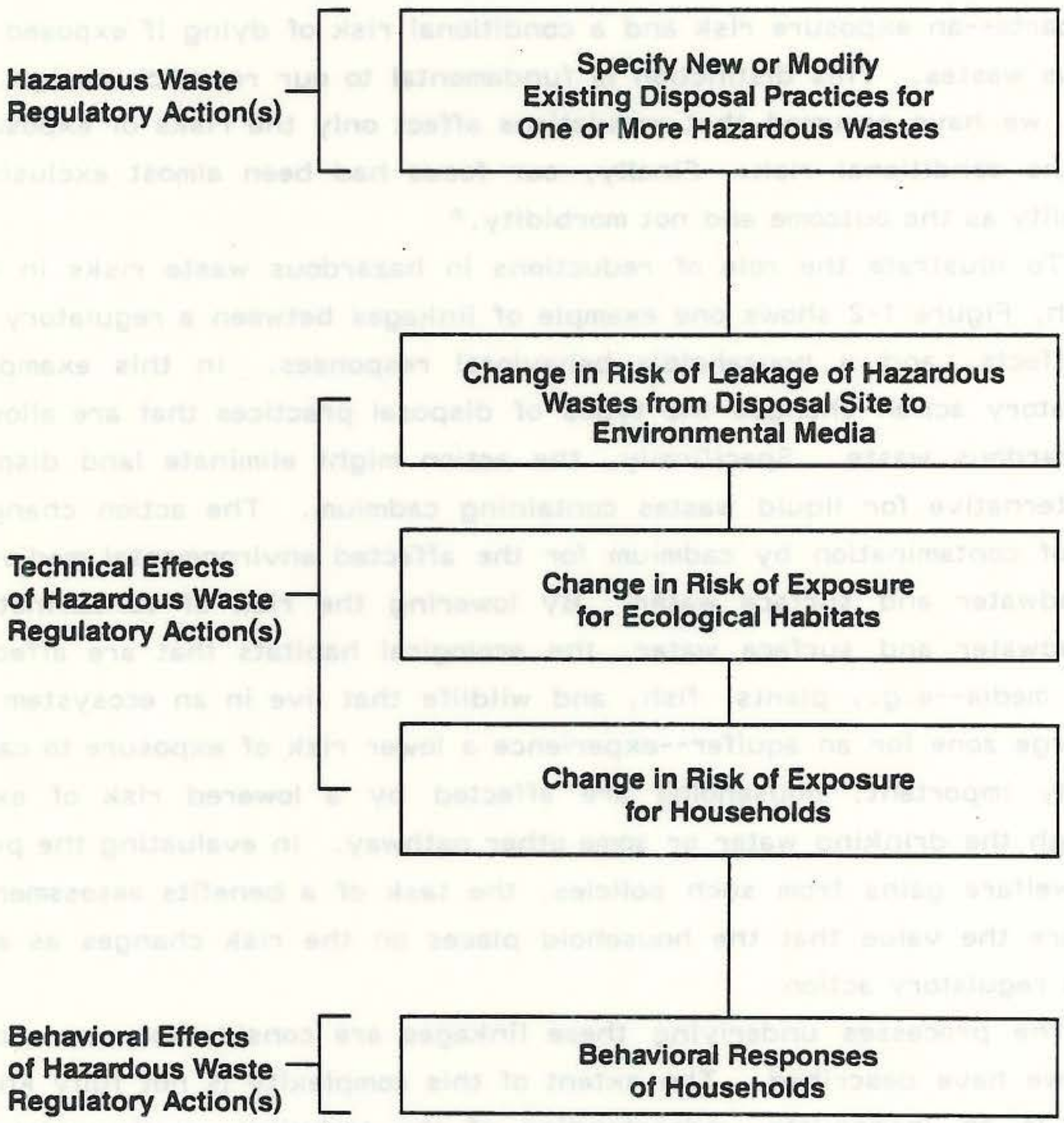

Figure 1-2. Effects and responses to a hazardous waste regulatory action.

enable us to develop a general basis for describing the effects of regulatory actions as changes in risks.

In contrast, much of the research in areas involving risk has concentrated on the outcomes--e.g., cancer cases avoided, reductions in restricted activity days. This focus on outcomes is essentially an ex post view of the benefits of reducing risks. As developed in Chapter 4, our conceptual analysis suggests that differences in these valuation perspectives--this ex post approach versus an ex ante perspective--can result in substantial differences in values placed on changes in risk.

1.5 RISKS AND HOUSEHOLD DECISIONS

Individuals make decisions involving risk every day. For example, these decisions may involve planning purchases for durable goods--such as an automobile--with limited knowledge of their future income and use patterns for the goods planned for purchase. In addition, the implicit value of the automobile can be affected by circumstances and actions that are within the household's control as well as those that are not. A dramatic increase in the price of oil, as occurred twice in the 1970s, can change the relative values of large versus small automobiles. Such changes are outside the household's control; thus, uncertainty over the price of gasoline affects household choices both in the purchase decision (as a yes/no choice) and in the type of vehicle selected. Other choices of the household--such as residential location--can also be important to the value of the sevices provided. Economic models of these decisions routinely assume that individuals acquire information and formulate plans based on that information.

A household's opportunities for adjusting to uncertainty affect its planned behavior. For example, paying a higher price for a fuel-efficient car is one way to provide for the present cost and the uncertain future costs of using the automobile (i.e., the price of gasoline). Maintenance contracts that protect against the car's failing are another. The first adjustment opportunity is an example in which a single payment--i.e., the premium in price for the vehicle--is paid regardless of the future price of gasoline. The second case is an example of differential payments. That is, the household purchases the maintenance contract at a price that constitutes the full cost if the automobile does not experience problems. However, with failures in performance covered in the contract, the costs of repair--and hence the actual cost of the contract--are subsidized. This latter adjustment is the basic nature of insurance. It is a claim to a level of wealth that is tied to a particular outcome that may or may not occur. Thus, the presence of a market for contingent claims, or insurance, provides one way for a household to adjust to the presence of uncertainty. Our conceptual analysis developed in Part I suggests that opportunities for adjusting to risk will affect the household's values for a risk reduction.

Clearly, modeling household decisions involving risk is a complex task. In this report we have not developed a comprehensive framework for modeling all such household decisions. Nonetheless, it is possible to describe the elements of a simplified view of how such a framework ultimately might be structured. Figure 1-3 is an example of how one might view the households' decisions regarding risk. At the center of the framework is the household, which is exogenously faced with some risk of dying in a given year by virtue of its genetic endowment. It also experiences risks through its occupational choices, the location of its residence, and its purchases and use of goods and services. Each of these boxes has two arrows indicating that these hazards can be voluntarily accepted, to the extent there is sufficient information to perceive them. In addition, there is another set of sources for risk that are imposed on the household by other factors--the actions of other individuals or firms, policies of any level of government, or nature itself. These are in some respects similar to genetic risks in that the household usually has no basis for direct control of them. We have designated these risks with single arrows to suggest that, for the most part, they are involuntary. This does not imply the household cannot take action to avoid them or mitigate their impacts; rather, it implies there are few (if any) perceived mechanisms for the household to change them directly.

The risk of exposure to hazardous wastes can be experienced as both a voluntary and an involuntary risk.* However, these risks are generally thought to be involuntary and experienced through the location of the household's residence, which includes its environmental conditions and drinking

*The information about the risk can also be a determinant of whether it is a voluntary or involuntary risk.

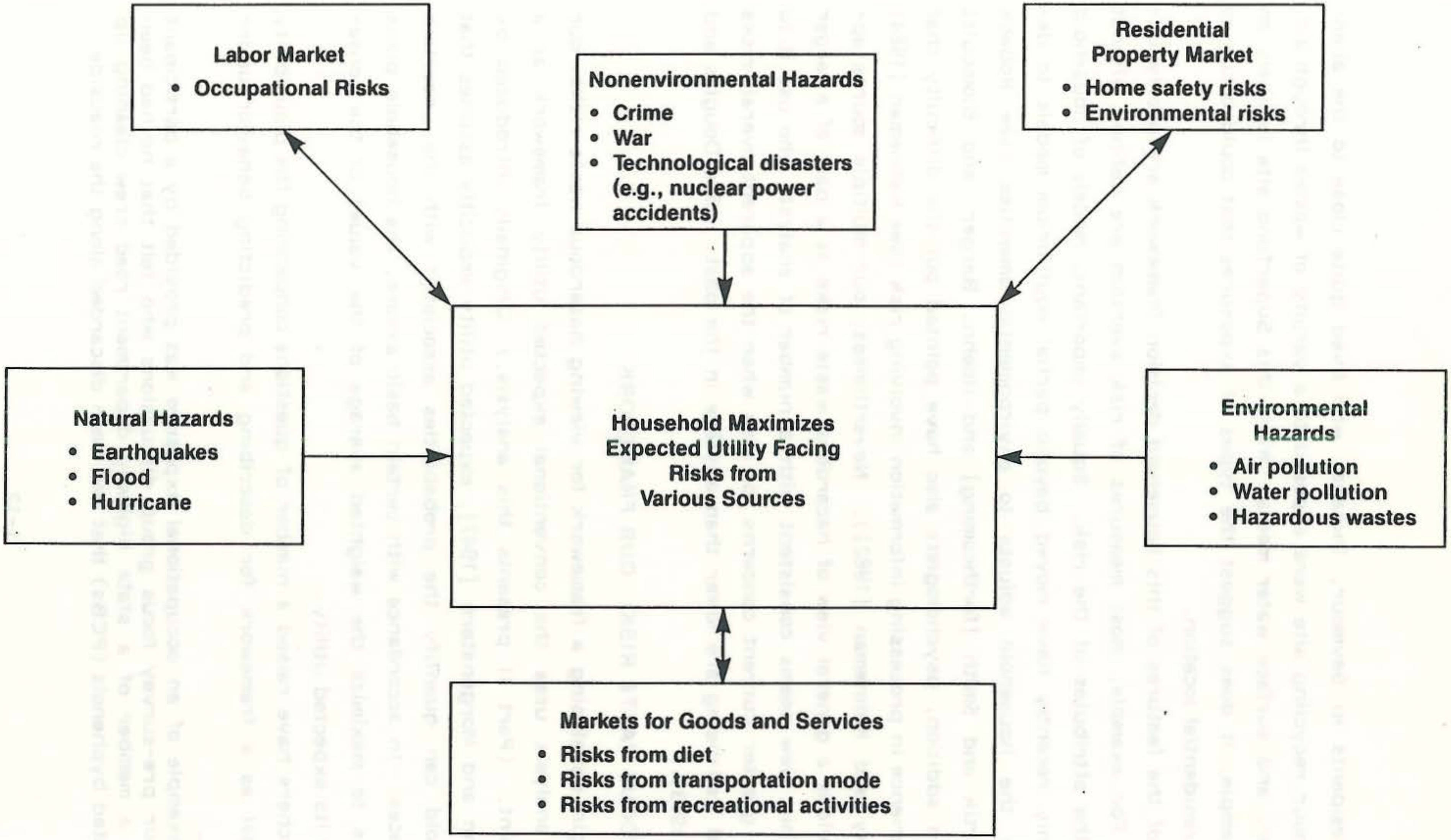

Figure 1-3. Multimarket framework.

water.* Residents in Seymour, Indiana, who lived quite close to the abandoned Seymour recycling site were exposed to a variety of wastes through air, groundwater, and surface water media. While this Superfund site is likely an extreme example, it does suggest the types of exposures that could occur as a result of residential location.

Many of the features of this household decision framework are poorly understood. For example, most measures of risk aversion are defined without regard to the attributes of the risk. Equally important, models of household behavior only recently have moved beyond partial equilibrium models to describe how the household adjusts to environmental amenities (see Roback [1982], Bartik and Smith [forthcoming] and Hoehn, Berger, and Blomquist [1984]). In addition, psychologists also have pointed out the difficulty that people experience in processing information involving risk (see Kahneman [1984] and Tversky and Kahneman [1982]). Nevertheless, our multiple source approach provides a general view of hazardous waste risks as a part of a larger picture. This view seems consistent with a number of analysts who use it to explain the greater current concerns for risk when the apparent overall risks to individual well-being are lower than anytime in the past. (See Douglas and Wildavsky [1983].)

1.6 HAZARDOUS WASTE RISK: OUR FRAMEWORK

To begin developing a framework for viewing hazardous waste risks, our conceptual analysis uses the conventional expected utility framework as a starting point. (Part II presents this analysis.) Originally introduced by Von Neumann and Morgenstern [1947], expected utility implicitly assumes that the household can quantify the probabilities associated with the uncertain events it faces. In accordance with certain basic axioms, the household plans its decisions to maximize the weighted average of the values of the consequences, or its expected utility.

Researchers have raised a number of questions concerning the plausibility of this model as a framework for describing and predicting behavior under

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*One example of an occupational exposure was provided by a participant in one of our pre-survey focus group discussions who felt that he had been exposed as a member of a state highway department road crew cleaning up polychlorinated byphenols (PCBs) that had been discarded along the roadside.

uncertainty (see Schoemaker [1982]). Our conceptual analysis suggests that amending the framework to allow the household's utility to depend on the state of the world that actually occurs may explain some of the inconsistencies that have been found in previous research.* For example, under this view, an individual's utility function will differ depending on whether or not exposure to hazardous wastes occurs.

An important implication of our conceptual analysis is that the appropriate basis for valuing reductions in the risks of exposure to hazardous wastes depends upon the opportunities available to the individual for adjusting to risk. Under certain circumstances, this measure of value will be the option price, or constant payment irrespective of the outcome at risk, for the specified change in the likelihood of the detrimental event.

Our research design also recognizes that not all risks are the same. The literature in psychology and, to a lesser extent, in economics has begun the process of distinguishing types of risks. With this identification of types comes a corresponding need to identify how they are different--in effect, to enumerate their attributes. Although our conceptual analysis does not explicitly include the attributes of risk in its description of household behavior, the design for our empirical analysis provides preliminary information on how some of these risk attributes might affect households' valuation responses.

1.7 CONTINGENT VALUATION: A BRIEF OVERVIEW

Contingent valuation is the use of survey methods to elicit individuals' values for improvements in environmental quality, such as reductions in hazardous waste risks. These values are elicited for specific hypothetical changes in environmental quality that are described in the survey questionnaire. The use of surveys to elicit behavioral information is widespread in psychology, sociology, and market research, and use of the contingent valuation approach to value improvements in environmental quality has generated a decade of experimental and field research. Even in this relatively short period, however, the approach has grown more sophisticated, improving how it defines

*The terms <u>household</u> and <u>individual</u> are used interchangeably throughout this report. It is possible to develop models demonstrating that households as collections of individuals behave as if guided by a single utility maximizing economic agent. See Becker [1981] for examples and further citations.

the objectives of the survey, how it structures, orders, and asks the questions to elicit respondent valuations, and how it chooses appropriate samples of respondents. Of course, the cornerstone of contingent valuation is the survey questionnaire, which must

- "Frame" the commodity--i.e., describe believable and understandable terms in the regulatory effects that the respondent must have.
- Establish a "market" context for the commodity that effectively describes the conditions under which it must be valued.
- Effectively elicit respondent values for the commodity.

The need for considering the contingent valuation approach for valuing hazardous waste risk changes stems from the lack of any organized market in which the changes would be valued. In the absence of markets, economists have used other approaches besides contingent valuation. Presently, we are unsure of their relevance for valuing hazardous waste risk changes. For example, the travel cost approach using the implicit price that people are willing to pay to visit a recreation site may not be appropriate because few recreation sites are likely to be affected by hazardous wastes. In addition, the early results with the property value studies seem to have too much noise to determine the effects of hazardous waste risks on property values. Thus, asking people directly in a survey may offer the only alternative.

The central question facing our research is "Can contingent valuation be used to value reductions in hazardous waste risks?" A long and formidable list of reasons has been given as to why contingent valuation cannot provide accurate estimates of values. From the psychologist, the reasons that contingent valuation cannot be used include the following:

- People's values for commodities like hazardous waste risks are labile or poorly formed (Slovic, Fischhoff, and Lichtenstein [1982])
- People's preferences will be very sensitive to how questions to elicit values are framed (Tversky and Kahneman [1981])
- People will be unable to process information regarding low probability events.

The economist's list includes the psychologist's concerns and adds the following:

- People will be unable to comprehend the commodity to be valued because it has no market equivalent (Cummings, Brookshire, and Schulze [1984])
- People will give unreliable answers because the questions are hypothetical (Bishop and Heberlein [1984])
- People will give a response based on attitudes and not behavior (Bishop and Heberlein [1984])
- People are not familiar with the range of their preferences that involve hazardous waste risks (Freeman [1984b])

These are important concerns. This report attempts to provide the information necessary to address a large number of them. However, in most cases, there is no unambiguous standard that can be used. Rather, the reader must weigh the information provided and decide whether or not contingent valuation can be used to measure the benefits of reducing hazardous waste risks.

We suggest that the economists and psychologists are basically saying the same things but are using a different vocabulary. The crux of the matter is effectively framing the commodity. In this regard, we have adapted several techniques from psychological and market research--e.g., focus groups, videotaped interviews, and extensive pretests--to evaluate the effects of different frames on respondents and to develop our final questionnaire. This detailed report is our way of letting the reader judge for himself about the overall success of our efforts.

In view of the number and types of issues concerning contingent valuation, some perspective on the approach may be helpful in trying to evaluate it. Important considerations include the following:

- Contingent valuation elicits responses directly from people--frequently a random sample chosen from some population. Contingent valuation allows the researcher--through the questionnaire--to elicit information both on values and on the reasons for the values provided.
- Contingent valuation offers the opportunity to tailor questions to the issue at hand. It also has the ability to structure an experimental design for testing specific concerns that may be relevant to a valuation estimate.

- Contingent valuation research can exert control over the sampling and survey procedures used to collect data and thereby provide information designed for the task at hand.

- Contingent valuation can yield insights into people's ability to perform tasks that implicitly are required of them by the indirect or market based approaches.

These attributes strongly suggest it may be useful in understanding people's preferences for changes in hazardous waste risks. And while the specific estimates in this report are preliminary for many reasons, we have concluded that the overall prospects for using contingent valuation to value risk changes is quite good--good not only in terms of the response rates, the rates of people rejecting the commodity, and the estimated mean valuations that are consistently significant, but also in terms of the performance of our more in-depth regression analysis using the restrictive models and the plausibility of the contingent ranking analysis. The reference operating conditions for the accuracy of contingent valuation developed in Cummings, Brookshire, and Schulze [1984] would have led us to expect a less optimistic prognosis. At this stage, a number of issues will require further investigation to understand their full implications. Nevertheless, in our judgment--and it is only that--contingent valuation can yield meaningful economic information. Ultimately, the reader will have to draw his own conclusion based on his interpretation of the information provided in this report.

1.8 RESEARCH OVERVIEW

Our primary objectives, which relate to the task of valuing risk changes, have provided the main guideposts for our research. Figure 1-4 presents an overview of our research to attain these objectives. Both our objectives and the subsequent activities follow directly from our assumption that risk changes are delivered by regulatory actions involving hazardous wastes.

As shown in Figure 1-4, the types of values to be measured are important to these research objectives. Our research considers two types of values:

- Use values, which accrue to households as a reduction in their risk of exposure and possible premature death from hazardous wastes

- Intrinsic values, which accrue to households from knowing that the risk of exposure to hazardous wastes has been reduced for plants, wildlife, and animals.

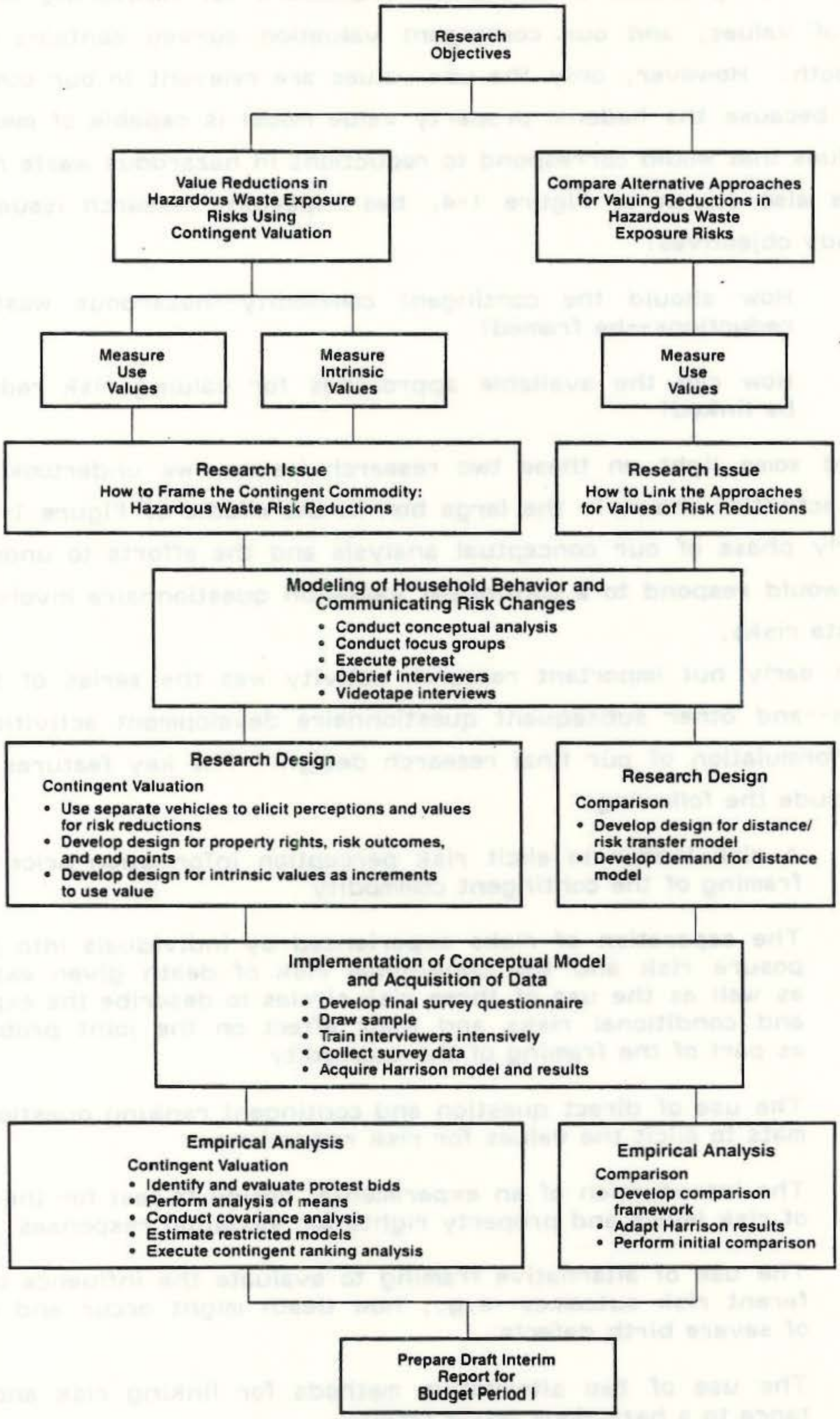

Figure 1-4. Study overview.

Our research provides a conceptual framework for measuring both of these types of values, and our contingent valuation survey contains questions to elicit both. However, only the use values are relevant to our comparison objective because the hedonic property value model is capable of measuring only use values that would correspond to reductions in hazardous waste risks.

As also shown in Figure 1-4, two important research issues stem from our study objectives:

- How should the contingent commodity--hazardous waste risk reductions--be framed?
- How can the available approaches for valuing risk reductions be linked?

To shed some light on these two research issues, we undertook several research activities shown in the large box in the middle of Figure 1-4, including the early phase of our conceptual analysis and the efforts to understand how people would respond to a contingent valuation questionnaire involving hazardous waste risks.

An early but important research activity was the series of focus group sessions--and other subsequent questionnaire development activities--that led to the formulation of our final research design. The key features of this design include the following:

- A risk ladder to elicit risk perception information prior to the framing of the contingent commodity
- The separation of risks experienced by individuals into an exposure risk and the conditional risk of death given exposure as well as the use of three risk circles to describe the exposure and conditional risks and their effect on the joint probability as part of the framing of the commodity
- The use of direct question and contingent ranking question formats to elicit the values for risk reductions
- The introduction of an experimental design to test for the effect of risk levels and property rights for valuation responses
- The use of alternative framing to evaluate the influence of different risk outcomes--e.g., how death might occur and a risk of severe birth defects
- The use of two alternative methods for linking risk and distance to a hazardous waste facility.

These activities led to a final survey questionnaire that was administered by a staff of interviewers to a stratified random sample of 953 households in suburban Boston that resulted in 609 completed interviews. Almost 87 percent of enumerated households completed the interviews. Only 3 interviews out of the 612 were broken off after initiation.

With these data, and the model and results acquired for the property value analysis, we have initiated the preliminary empirical analysis that is presented in Part III of this report. The activities included the following:

- Examination of protest responses
- An analysis of mean option price responses
- Multivariate analysis of the option price responses
- Estimation of contingent ranking models and a preliminary comparison with the direct question responses
- Development of a framework for comparing contingent valuation and hedonic models including an initial comparison.

These findings are all preliminary because of a substantial number of issues that are not included in this report due to time and resource constraints. Table 1-1 summarizes the type of issues that were considered in the empirical analysis and shows the location of each in the report.

1.9 GUIDE TO THE REPORT

For the reader's convenience, this draft interim report is divided into three parts. These three parts and the chapters they encompass are as follows:

- Part I -- A Conceptual Framework for Measuring the Benefits of Reducing Hazardous Waste Risks
    - Chapter 2 -- The Nature of Benefits Analysis in Hazardous Waste Management
    - Chapter 3 -- Modeling Behavior Under Uncertainty: A Heuristic Review
    - Chapter 4 -- The Role of the Ex Ante and Ex Post Perspectives in Measuring Welfare Changes Under Uncertainty
    - Chapter 5 -- A Conceptual Framework for Valuing Risk Reductions

TABLE 1-1. SUMMARY OF THE OBJECTIVES AND STRUCTURE OF THE RESEARCH

Objective	Type of risk	Concept of value	Direction of risk change	Measurement method	Experimental design	Results
Valuation of risk changes	Exposure to hazardous wastes	Ex ante value to individual	Decreases and increases.	Direct question for hypothetical situation. Contingent ranking for hypothetical cases	Exposure risk and conditional probability Exposure risk and payment ----	Chapter 11 Chapter 12 Chapter 13 Chapter 14
		Existence value	Decreases only	Direct question		
Influence of personal characteristics for risk valuation	Exposure to hazardous waste Job risk	Ex ante value	Decreases and increases	Report on actual conditions and attitudes	Representative sample of households in suburban Boston (with oversampling of Acton)	Chapter 11 Chapter 12 Chapter 13
Comparative evaluation of methods	Exposure to hazardous waste	Ex ante value	Decreases	Direct question for hypothetical question and hedonic property value.	----	Chapter 15
	Job risk	Ex ante value	Increases	Direct question for hypothetical question and hedonic wage model.	----	Not in Phase I report
Evaluation of attributes of risk	Fatal accident on the job	Ex ante value to individual	Increases only	Direct question for hypothetical cases.	----	Not in Phase I report
Information on wastes	Exposure to hazardous wastes	----	----	Direct question of individuals and review of newspapers	---	Chapter 10
Perception of risk	Fatality due to auto accident, heart disease, air pollution, hazardous waste	----	----	Direct question of perceptions.	Different types of risk	Chapter 10
	On-the-job risk of death					Not in Phase I report
Role of averting cost or alleviating activities on risk valuation	Exposure to hazardous waste	Ex ante value to individual		Report on household's actual activities.	Representative sample of households in suburban Boston (with oversampling of Acton)	Not in Phase I report

Chapter 6 -- Ecological and Intrinsic Values Under Uncertainty

- Part II -- Research Design, Questionnaire Development, and the Survey

  Chapter 7 -- Research Design: The Transition from Theory to Practice

  Chapter 8 -- Survey Questionnaire Development

  Chapter 9 -- Sampling Plan and Survey Procedures

  Chapter 10 -- Profile: The Survey Area and Its Population

- Part III -- Preliminary Empirical Analysis

  Chapter 11 -- Option Price Results: The Framing of the Commodity and an Analysis of Means

  Chapter 12 -- Option Price Results: Preliminary Regression Analyses Using Unrestricted Models

  Chapter 13 -- Valuation Estimates for Risk Reductions: Using Restricted Models

  Chapter 14 -- The Use of Contingent Ranking Models to Value Exposure Risk Reductions: Preliminary Results

  Chapter 15 -- A Comparison of Contingent Valuation and Hedonic Property Value Models for Risk Avoidance

  Chapter 16 -- Policy Implications and Research Agenda

Part I--Chapters 2 through 6--describes the conceptual framework we developed for assessing the benefits from regulations governing hazardous wastes. Part II--Chapters 7 through 10--explains how we implemented our conceptual framework by developing and administering a contingent valuation survey. Part III--Chapters 11 through 16--presents preliminary findings of our empirical analyses of the survey data. Also for the reader's convenience, each part is preceded by an introduction that explains the objectives and research activities associated with each and outlines the purpose, scope, and contents of each chapter. Chapter 17 contains references we have cited in the text.

PART I

A CONCEPTUAL FRAMEWORK FOR MEASURING THE BENEFITS OF REDUCING HAZARDOUS WASTE RISKS

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PART I

A CONCEPTUAL FRAMEWORK FOR MEASURING THE BENEFITS OF REDUCING HAZARDOUS WASTE RISKS

Part I of this draft interim report describes how we developed a conceptual framework for assessing the benefits expected to accompany regulations governing hazardous wastes. In particular, Part I consists of the following five chapters:

Chapter 2 - The Nature of Benefit Analysis in Hazardous Waste Management

Chapter 3 - Modeling Behavior Under Uncertainty: A Heuristic Review

Chapter 4 - The Role of the Ex Ante and Ex Post Perspectives in Measuring Welfare Changes Under Uncertainty

Chapter 5 - A Conceptual Framework for Valuing Risk Reductions

Chapter 6 - Ecological and Intrinsic Values Under Uncertainty

While our intention is not to evaluate the benefits arising from specific regulatory actions, the purpose of the framework is to provide a basis for describing how such analyses might be conducted. As briefly outlined in the following paragraphs, there are five important elements in the proposed framework.

First, the analysis assumes that regulations for hazardous wastes reduce the probability that an individual will experience some type of adverse effect from the unintended release of wastes to the environment. This assumption seems consistent with the U.S. Environmental Protection Agency (EPA) regulatory evaluation policies such as the RCRA Risk/Cost Model and the Liner Location Model. Because release of the wastes can lead to risks to human health and to ecological systems, individuals may place a positive value on policies that reduce these risks. A conceptual framework for describing this valuation process is a necessary first step before empirical analysis can be undertaken.

Second, the assumption that regulations change the risk of exposure experienced by individuals suggests the need to develop a conceptual basis for valuing these risk changes based on a model of individual behavior under uncertainty. This analysis assumes that the expected utility model can provide the starting point for describing individuals' responses to risk. Consequently, it enables us to define an individual's values for changes in risk. That is, the values for reducing hazardous waste risks will be based on the expected utility that the individual anticipates from a regulatory action. For example, more stringent containment of hazardous wastes in land-based disposal sites might be assumed to reduce exposure risks by some amount. This action, in turn, reduces the likelihood of detrimental events (e.g., exposure and some health effect) and thereby increases the expected utility to be experienced by the affected individuals. The monetary value of the risk change could be measured by following the Hicksian analogy for the case of certainty.

Third, once the expected utility framework is used as the basis for valuing risk changes, we have accepted an ex ante perspective for welfare analysis. That is, we are maintaining that the relevant benefit measure is based on how the individual's planned activities change with risk changes. As we develop later, the perspective for measurement is important for evaluating decisions made under uncertainty, especially if those decisions affect the nature of the uncertainty itself.

Fourth, to define how much the individual would be willing to pay for the risk change, we must define how these payments would be made and the opportunities available to the individual for adjustment to changes in risk. In effect, we must define the institutions that constrain how an individual can plan his expenditures given uncertainty as to future states of the world.

Finally, the last key element in our conceptual framework is the motivation for valuing the risk reduction. We noted earlier that a pattern of exposure implies a subsequent set of risks that may involve detrimental health effects for the individual or impacts on specific ecological systems. Each of these types of events will affect individuals differently. These different effects can lead to different types of values or benefits for policies that regulate the disposal of hazardous wastes.

Clearly, each of these elements involves complex problems. Moreover, in some cases the literature is not fully developed with respect to the specific issues associated with extending benefits analysis to deal with risk changes. It is therefore unrealistic to expect that we can provide a comprehensive analysis of all of the issues in a few chapters. Thus our objectives have a more limited scope:

- Review the elements involved in our proposed formulation of the problem
- Relate them to past efforts to define benefit concepts under uncertainty
- Describe the association between the behavioral relationships in our framework and the findings of psychologists and decision scientists involved in the study of individual behavior in the presence of risk
- Explain the statistical hypotheses and more informal empirical results that we expect should follow from our analysis of individual behavior.

Chapter 2 introduces our conceptual framework by discussing types of benefits in a conventional taxonomy and the valuation problem for risk changes. It uses a set of scenarios to describe how events involving hazardous wastes "fit into" our framework.

Chapter 3 reviews an economic approach for describing individual behavior under uncertainty using a state preference characterization of how individuals plan their actions when the future states of nature are uncertain. The key elements in the model for our description of the values of risk reduction are the specification of preferences, the description of the adjustments available to the individual for responding to risk, and the characterization of individual attitudes toward risk.

Chapter 4 compares the conventional approach to benefit analysis with the framework implied by an ex ante analysis of individuals' valuations of risk reductions. This comparison uses the planned expenditure function introduced in Chapter 3 as the basis for classifying different types of benefits.

Chapter 5 describes the specific implications of our model for an individual valuation of the risk reductions associated with regulations on the disposal of hazardous wastes and how we might expect these values to be affected by the type of risks experienced.

Chapter 6 completes the conceptual analysis by focusing on ecological and intrinsic values in the context of uncertainty, including a reconsideration of the conventional concepts of existence and option values. It extends the analysis of Chapters 3, 4, and 5 to the value of reductions in risk to environmental and ecological resources.

CHAPTER 2

THE NATURE OF BENEFIT ANALYSIS IN HAZARDOUS WASTE MANAGEMENT

2.1 INTRODUCTION

As the first component in Part I, this chapter addresses several of the important elements in our conceptual framework for assessing the benefits expected to accompany regulations governing the management of hazardous wastes. Given the likely generic effects of hazardous wastes in the environment, the following sections describe the types of benefits that might accrue from regulating the management of hazardous wastes and the types of economic agents to whom those benefits might accrue. In particular, Section 2.2 presents a conventional taxonomy of benefits that serves as a starting point for our analyses, Section 2.3 outlines our treatment of policy outcomes as changes in the risk of exposure to hazardous wastes and compares this approach to previous approaches for benefit analysis, and Section 2.4 introduces our notion of <u>risk</u> as synonymous with the probability of a well-defined detrimental event (e.g., death). Section 2.5 describes representative scenarios to suggest the generic sources of exposure risk and to provide examples of typical contamination incidents. Section 2.6 briefly summarizes the chapter's main points.

2.2 CONVENTIONAL BENEFIT TAXONOMIES

Analysts have used a variety of classification schemes to describe the components of the total benefits of a policy action. In the early literature on benefit-cost analysis, the most widely used taxonomy distinguished between the benefits associated with private market transactions and public allocations--i.e., the provision of goods and services which could be purchased in markets (e.g., hydroelectric power)--and the benefits associated with goods or services that did not exchange on such markets (e.g., recreation). The benefits associated with the second type of commodity were often assumed unquantifiable and were usually labeled as the intangible component of benefits. The history of methods development for benefits assessment of environmental resources has seen a progressive advance in our ability to measure these intangible benefits. Thus, taxonomies that distinguish between the benefits associated with market goods and intangibles have become less useful over time.

The recent literature on environmental benefit estimation has tended to follow a general classification scheme originally suggested by Krutilla [1967]. This framework separates user and nonuser sources of benefit from environmental resources. Mitchell and Carson [1981] refined this initial proposal for the case of water quality benefits in an effort to understand what would be measured by the various approaches to benefit analysis. Their taxonomy has provided the basis for several recent efforts to estimate and to distinguish the individual components of the benefits individuals realize from environmental resources.*

Figure 2-1 presents an example of this type of benefits taxonomy. It has been simplified from the form presented in Desvousges, Smith, and McGivney [1983] but contains many of the same elements. In this format, the mechanisms leading to the beneficial effects experienced by individuals are more specifically identified. Within the category of direct benefits, a distinction is drawn between use and nonuse benefits. However, several aspects of these terms require further discussion. Throughout this report, <u>use</u> and <u>user</u> benefits are considered synonyms. Since there can be subtle distinctions between the two, it is important to describe what they will mean here. Use benefits arise because of the active consumption of the services of a resource. As Figure 2-1 indicates, this can be through clean air's generating improved health or clean water's allowing game fishing. In all cases, use benefits require the active involvement of the individual as a user of the services of the resource.

If the definition of <u>user</u> is narrowly interpreted, we might be tempted to conclude that economic agents termed <u>users</u> are precluded from having nonuse benefits. However, this is not the case. To appreciate why users may also

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*Desvousges, Smith, and McGivney [1983] revised the Mitchell-Carson framework and used it in estimating the components of water quality benefits associated with a specific resource--the Monongahela River. More recently, Fisher and Raucher [1984] have used the framework to appraise the relative magnitude of nonuser (or intrinsic) benefits and user benefits based on recent empirical studies that have included both sources of individual values.

<table>
<tr><td rowspan="7">Potential Benefits of Hazardous Waste Management Regulations</td><td rowspan="3">Indirect Benefits from Effects on Markets or Production</td><td colspan="2">Improved Agricultural Production</td></tr>
<tr><td colspan="2">Improved Forestry Production</td></tr>
<tr><td colspan="2">Improved Fishery Production</td></tr>
<tr><td rowspan="4">Direct Benefits from Effects on Individuals' Utility</td><td rowspan="2">Use</td><td>Improved Human Health Conditions</td></tr>
<tr><td>Recreation and Other Uses of Environment</td></tr>
<tr><td rowspan="2">Intrinsic</td><td>Option Value:
Possible Future Use</td></tr>
<tr><td>Existence—No Use</td></tr>
</table>

Figure 2-1. The conventional benefits taxonomy adopted for hazardous waste management regulations.

have nonuse benefits, it is helpful to consider how the resource being valued contributes to the utility of an individual. When it requires some type of active experience involving the resource's services, the resulting increment to utility is a use benefit and the individual experiencing it is a user. However, this same individual may also derive an increment to utility with no action by simply knowing that a resource has been enhanced or increased in some way. This change in utility is a nonuse benefit because the individual does not actively acquire the services of the improved resource. Knowledge of the improvement itself was sufficient to enhance utility.

Figure 2-1 also can be used to show the major channels through which hazardous materials may enter the environment and affect human welfare. This figure distinguishes between the effects on production and market values that affect people's utility indirectly and the direct effects on individuals' utility. Production or market values arise when some attribute of the ecosystem is an argument in the production and cost functions for a marketed good. For example, if the presence of hazardous wastes in the environment results in a lower level of an ecosystem attribute, the economic productivity of the ecosystem would decrease, causing an increase in the cost of producing the marketed good. These changes in turn would result in changes in market quantities, product prices, factor prices, rents, and/or profits. Standard economic models can be used to obtain measures of the economic value of changes in the productivity of managed and commercially exploited ecosystems. (See Freeman [forthcoming a] for a review of these models.) In the case of production and market values, hazardous wastes in the environment affect individuals' utility only indirectly by changing the prices of goods they purchase with their incomes.

In addition to these indirect effects, however, the figure indicates that hazardous materials can affect individuals directly by altering the level of some argument in their utility function. For example, if utility depends in part on health status, exposure to a toxic material through environmental pathways can lead to lower health status and, therefore, lower utility. Also, if some attribute of the environment or an ecosystem (e.g., the number of different species) is an argument in individuals' utility functions, then hazardous materials can affect utility by altering the level of that attribute.

Another key distinction in the direct benefits lies between those associated with in situ use of the environment and those associated with nonuse or intrinsic values. As noted above, the in situ use of the environment is an activity that includes the scarce resources of the individual, including, but not limited to, time. For example, the individual may have to incur time and other costs to travel to the site of the ecosystem to engage in some activity. Nonuse or intrinsic values, on the other hand, are defined as those benefits or welfare gains to individuals that arise from ecosystem changes independently of any direct use of the ecosystem. The figure further divides intrinsic values into pure existence and option values related to some uncertainty concerning future demands or the availability of the system for possible use.

The concept of pure existence value was apparently first suggested by Krutilla [1967] and was further discussed in Krutilla and Fisher [1975, p. 124]. Weisbrod [1964] first introduced the term option value in the literature of benefit-cost analysis 21 years ago. Option value is said to arise either when an individual is uncertain whether he might demand a good in the future or if he is faced with uncertainty in the future supply or availability of that good. Weisbrod apparently viewed the existence of positive option value as intuitively obvious. But, as subsequent analysis has shown, option value, as conventionally defined, can be either positive or negative depending upon the particular circumstances [Schmalensee, 1972; Bishop, 1982; Freeman, 1984a].

However, there is a basic inconsistency in this and earlier taxonomies. They combine two distinct perspectives for welfare analysis--the ex ante and the ex post frameworks for defining values. The concept of option value connects the two frameworks. Rather than a separate component of benefits, option value is the result of these different perspectives for welfare concepts. Consequently, a more consistent taxonomy would identify the particular valuation perspective instead of mixing ex ante and ex post. We will return to this more general framework in Chapter 4. Therefore, we present the taxonomy in Figure 2-1 as a starting point for viewing benefits from risk changes. In particular, benefits analyses for policies that involve changes in risks will require a different orientation of the selected welfare measures. For example, consider how we have proposed to describe "the services" delivered by regulations governing the disposal of hazardous wastes as the reductions in the risk of exposure to hazardous wastes. Using this present taxonomy, these risk reductions yield a use benefit when the household's planned consumption choices of all commodities in all possible states of nature are changed. That is, any action that causes a change in these planned choices generates a positive or negative use value.

Use value accrues to the household, but it requires only a change in planned consumption or activities and not an active involvement. Moreover, use value involving risk changes can arise only in an ex ante valuation perspective. If an ex post perspective were employed, the benefit is no longer the use benefit from the risk change. In an ex post framework, the value would stem from the outcome and not the risk change. Thus, the presence of valuation under uncertainty reveals the need of a new taxonomy for benefits analysis that also distinguishes between the valuation perspective--ex ante versus ex post--and the nature of the commodity--certain or uncertain.

2.3 THE TREATMENT OF POLICY OUTPUTS AS RISK CHANGES

The conventional practice in environmental benefit analysis maintains that policy actions lead to changes in either the quantity or the quality of the services provided by an environmental resource. These changes were assumed to be known with certainty. Thus, benefit concepts were defined based on how the environmental resource was assumed to affect individual preferences. By contrast, our analysis of policies related to the disposal of hazardous wastes treats them as changing the likelihood an individual will be exposed to these wastes. It seems reasonable to inquire into the rationale for making this distinction.

Given our current state of knowledge, it seems reasonable that there is no aspect of environmental quality that we can assume is available with certainty. The observed level of air or water quality at each time and in each location has a significant stochastic element determining its value. This is true for a number of reasons. One of the simplest to explain concerns the environmental quality--weather interaction. Weather patterns affect the ambient concentrations of pollutants and these patterns are best treated as realizations of a stochastic process. Equally important, our current knowledge of the relationship between the activities under policy control--e.g., emissions of residuals into the atmosphere or water courses--is imperfect. The character of the air diffusion system governing the residuals--i.e., the ambient air quality associated with each location or the absorptive capacity of each river or lake--determines the relationship between measures of environmental quality that are relevant to individuals' behavior and the patterns of emissions of residuals. Since it is the latter that is affected by policy, this case also has a significant amount of uncertainty in the connection between what policy actions can do and what is "delivered" to the individual.

What is at issue is the degree of uncertainty. Current benefits assessment practices have implicitly maintained that the random influences and associated uncertainty are small enough that individual behavior can be described as if it were in response to certain changes in the environmental resources under study. Of course, this is an assumption--one that may well be inappropriate for some circumstances. However, what is important for our purposes (i.e., in defining the individual benefits associated with a policy action) is not the random components connecting residual emissions with ambient quality but, rather, the influence of these sources of uncertainty on individual behavior.*

In contrast to the assumptions underlying the policies in the Clean Air and Clean Water Acts directed at the conventional air and water pollutants, there are significant questions concerning whether any level of exposure to hazardous wastes can be said to be free of risk.† Moreover, it is not clear that there is a continuous relationship between the level of exposure and the impacts on the individual. Rather, a discrete framework has often been selected in describing the implications of hazardous wastes for individuals with any level of exposures potentially leading to detrimental outcomes. In the case

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*There is, of course, a separate issue as to how to treat estimation uncertainty in benefit-cost analysis. In this case, we assume that individuals can be described as making choices with certainty, but we as analysts observe these decisions and understand their motivations imperfectly.

†This is part of the motivation for the definition of hazardous air pollutants in the Clean Air Act.

of air and water pollution, the dose-effects relationships have generally been assumed to be continuous.*

Finally, it should also be acknowledged that our understanding of disposal technologies (and their effectiveness) and of the implications of a wide array of hazardous wastes for ecological systems in general and for human health in particular is quite limited. Consequently, a framework that recognizes these uncertainties explicitly and acknowledges that individuals will respond to them was judged to be necessary for this case.

2.4 WHAT IS RISK?

The term risk has been used in a number of different ways in policy analysis. A wide variety of definitions can be found in the literature on risk assessment and risk management. Equally important, in economics, risk is often associated with that portion of the uncertain outcomes facing an economic agent that cannot be diversified away (i.e., insured against using market opportunities). To this point and throughout this report, the term risk is used in a narrow definition. It is considered synonymous with the probability of a specific detrimental event.

The definition of a particular event at risk and the characterization of the decision problem provide the mechanisms for incorporating some of the factors discussed by a number of analysts as important to explaining individuals' responses to risk. For example, Crouch and Wilson [1982] define risk as a composite of the probability of an adverse event and the severity of the event. According to their framework, the risk facing an individual can be reduced either by reducing the probability of the event or by lessening the magnitude or severity of the event involved. Similarly, in discussing the problems associated with judging acceptable levels of risk, Fischhoff et al. [1981] defined risk as the probability of a more specific outcome--reduced human health and death. They also acknowledge that the cause of the risk can be important to its perceived severity to the individual. Both of these discussions of risk

*Of course, in implementing these models, distinctions are drawn between chronic and acute health effects, materials damages, and aesthetics. In some of the individual sources of benefits, the empirical models have been developed as if there were thresholds below which no effect would be experienced.

have been based on the results of experimental analyses of risk-taking behavior along with actual observations of the decisions of individuals in accepting specific risks. Starr [1969] appears to have been the first to consider this latter approach to compare risks in order to provide an indirect basis for identifying the characteristics of risks that influence individuals' willingness to accept them. While the studies following this tradition have been rather crude, they are nonetheless suggestive of a general issue that seems to emerge from both the experimental (field and laboratory) and indirect approaches to understanding behavior under uncertainty. It is best summarized by suggesting that there is a need for a type of hedonic function to describe risks. In effect, an individual's appraisal of the subjective level of risk may well depend on the characteristics of that risk. Many psychological studies have contributed to identifying some of them. They would include (using primarily Litai's [1980] terms): volition, severity, origin, effect manifestation, exposure pattern, controllability, familiarity, ambiguity, and necessity.

What is really at issue in modeling individual behavior in response to risk is how we choose to reflect these characteristics in describing how individuals make specific decisions under uncertainty. As Arrow [1974] observed some time ago, the expected utility framework separates the tasks of risk perception and preference formation. For a state-independent specification of preferences, this separation is especially clear; with state-dependent specifications additional information describing the source of the state dependency is needed to maintain the separation.

To begin operationalizing a hedonic view of the types of risks as they are perceived by individuals, there are two distinct modeling strategies. The first, which maintains the separation of preferences and perceptions, proposes what are often ad hoc rules for describing how one or more attributes of risk would affect the perceived risk level. This perceived risk is then used in an expected utility model to describe behavior. In effect, optimal choices are separated from risk perception decisions. This is the approach implicitly used by Kahneman and Tversky [1979] with prospect theory and by a wide variety of other proposed alternatives to the expected utility framework (see Schoemaker [1982]). Hogarth and Kunreuther's [1984] analysis of the role of ambiguity in risk perception is another interesting example of this approach.

The second approach would require a behavioral model of individual decisionmaking under uncertainty that includes an explanation of risk perception decisions. This second strategy is an especially difficult one. It would describe the hedonic function for risk as an outcome of the optimizing decisions of households in relationship to the range of alternative sources of risk and thereby remove the separation of risk perception and preferences that is central to the expected utility model.*

At present, there are a few attempts that are moving in the direction of developing such a model, but none of the frameworks offers a complete analysis of individual decisionmaking (see Bell [1982], and Loomes and Sugden [1982, 1983] as examples). Nor will our conceptual analysis attempt to develop such a general framework. Rather, we have selected a more conventional expected utility model, which allows for state-dependent preferences, and then, in our empirical analysis, we control the attributes of the risks presented to individuals. By presenting two different types of risks (each carefully controlled through the descriptions given to our survey respondents), the empirical analysis proposes to add to the information available on the the role of the attributes of risk on individual behavior, but not to develop a framework that would deal with these attributes in a general way. The primary reason for our discussion of these issues at the outset of the analysis is to acknowledge that the attributes and context of the risks are important to individual behavior. Consequently, valuation estimates of risk changes for certain types of risks in specific contexts may not be relevant to comparable (in numerical terms) risk reductions of other types in other settings.

2.5 THE SOURCES OF EXPOSURE RISK

The basic premise that provides the link between our conceptual analysis of how households value hazardous waste management policies and changes in

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*It is important to note that in the hedonic models used in economics the market plays a crucial role in converting the hedonic function into a technical function for the individual, thereby providing a similar type of separation as to what has been used in expected utility analysis. While the hedonic price function is an equilibrium relationship, no one individual can affect it. Consequently, it is treated as a given for any single individual's decisions and choices are constrained by it. The risk perception process does not seem to have a comparable institution exerting discipline on the decisions of the household involved in appraising risks.

those policies is the assumption that those policy changes lead to risk reductions. More stringent regulations for the disposal of hazardous wastes reduce the risk of exposure to those wastes for individuals. Consequently, the values attributed to the risk reductions become the consumers' valuation of the policy changes. In this section we discuss whether this view of the problem is reasonable and its implications for the interpretation of our valuation estimates for policy decisions. This is accomplished by first describing hazardous materials, particularly the characteristics of those materials that are likely to be important to any evaluation of the impacts of exposures for ecological systems and human welfare. Following this discussion, we describe some examples or scenarios of how hazardous substances might enter the environment. These examples are then related to the types of exposure risks we have sought to model in our conceptual analysis and to estimate values for in our empirical work.

2.5.1 Six Categories of Functional and Chemical Characteristics

Hazardous materials can be placed in one of several categories based on their toxicity and degree of persistence in the environment. In a recent study of instances of environmental contamination by hazardous materials, the U.S. Environmental Protection Agency [1980, p. vi] offered a classification of hazardous substances with six categories reflecting the functional characteristics of substances in commerce and industry and their chemical characteristics. The following is a brief discussion of the most likely major environmental impacts and fates of each of these categories.

Solvents and Related Organics. This category includes such substances as benzene, trichloroethylene, chloroform, and toluene. Many of these substances are acutely toxic in high doses to humans and other organisms. On the other hand, most of these substances disperse rapidly in the environment and are subject to breakdown to relatively innocuous substances by a variety of chemical and biological processes. Accordingly, they have relatively short half lives in the environment. Some of these substances are known or suspected human or animal carcinogens and thus present a potential threat to human health, especially from long-term exposures at low levels. But due to the short half lives of these substances, such long-term chronic exposures are not likely except in the case of contamination of biologically inactive groundwater aquifers or in the case of biogenic sources such as chlorination of drinking water containing naturally occurring organic compounds.

Polychlorinated and Polybrominated Biphenyls. Polychlorinated biphenyls (PCBs) and polybrominated biphenyls (PBBs) are not readily degraded in the environment. PCBs are known to be widely dispersed throughout the environment, and detectable amounts of PCBs are present in the atmosphere around the earth, in the water column and sediments, and in the tissues of a variety of organisms (National Academy of Sciences [1979]). PCBs can cause a variety of adverse effects on nonhuman species and have been classified as a possible human carcinogen (International Agency for Research on Cancer [1979]).

Pesticides. This is a heterogeneous category in terms of environmental impacts and persistence. Some types of pesticides--e.g., the organophosphates--are acutely toxic but degrade quickly in the environment under most conditions and are not subject to bioaccumulation. On the other hand, the chlorinated hydrocarbon pesticides have long half lives in the environment and are subject to bioaccumulation. Long-term exposures to these substances and some of their degradation products are known to have adverse effects on nonhuman species even at low levels. And several of these substances are suspected human carcinogens.

Inorganic Chemicals. This category includes such things as ammonia, cyanide, and various acids and bases. While many of these substances may be highly toxic and/or corrosive, they tend to have short half lives in the environment because of processes such as oxidation (e.g., as for cyanide) or neutralization.

Heavy Metals. Examples of this category include mercury, lead, chromium, and cadmium. Heavy metals are obviously persistent in the environment. But they may become immobilized in sediments. Not all chemical forms of heavy metal compounds are subject to bioconcentration. Some compounds are known to be toxic at relatively low doses over long periods of time. And some are known or suspected carcinogens.

Waste Oils and Grease. Some components of waste oils and grease may be toxic and/or carcinogenic. But most of the components of waste oil and grease are biodegradable and have relatively short half lives in the environment. Waste oils are often contaminated with heavy metals and persistent organic compounds such as PCBs.

In terms of enviromental impacts, the categories of hazardous materials described here differ primarily with respect to two characteristics--the nature of their toxicity to humans and other organisms (acute or chronic toxicity) and their degree of environmental persistence (highly persistent or relatively short half lives). Furthermore, those substances that are acutely toxic also tend to have short environmental half lives, while those substances that are toxic in long-term doses (some of which are known or suspected carcinogens) also tend to be highly persistent in the environment. For this reason, two types of scenarios are offered in the following subsection. One type involves large quantities of acutely toxic substances with short environmental half lives, e.g., organic solvents, some forms of pesticides, and such inorganic chemicals as cyanide and acids. The other type involves lower quantities of environmentally persistent and chronically toxic substances, such as PCBs, some forms of pesticides, and heavy metals.

2.5.2 Three Exposure Scenarios

To provide a more tangible connection between the ways in which hazardous wastes might enter the environment and the role of management policies in affecting these events, we have constructed three alternative scenarios of possible hazardous waste spills or uncontrolled releases and the patterns of health and ecological impacts likely to be associated with them. It should be noted that the scenarios described here are not meant to reflect all possible significant events and ecological end points. Rather, they are meant to represent the more typical or more likely events involving hazardous wastes and events for which significant health and ecological and intrinsic effects are likely. For each case the events are treated as random occurrences. The principal purpose of hazardous waste regulations is to reduce the probability of such events. Thus, these scenarios provide the basis for describing the ways in which risk reductions might arise from regulations on the disposal of hazardous wastes.

Table 2-1 provides a summary description of Scenario A: Groundwater Contamination and Human Exposure. In this scenario acutely or chronically toxic substances--e.g., PCBs, chlorinated hydrocarbon pesticides, heavy metals, organic solvents, or acids--are released from a poorly designed or unregulated surface or subsurface storage land disposal site. If these materials

TABLE 2-1. SCENARIO A: GROWING WATER CONTAMINATION AND HUMAN EXPOSURE

Substances:	PCBs, chlorinated hydrocarbon pesticides, heavy metals, organic solvents
Event:	Unregulated land storage or disposal leads to more or less continuous leaching of materials through the soil to a groundwater aquifer used as a source of drinking water.
Impact:	Human exposure to toxic materials with the probability of adverse health effects being an increasing function of the accumulated dose for many substances.

Forms of Economic Damages

1. Production/Market Values: Increased cost of treatment or finding alternative municipal water supplies, once contamination is detected.
2. Use Values: Poor health and increased probability of fatal disease.

Examples: As reported in U.S. Environmental Protection Agency [1980]:

1. Occidental Chemical Corp., Lathrop, California, 1980 (p. 3)
2. Rocky Mountain Arsenal, Colorado (p. 7)
3. McKin Site, Gray, Maine (p. 14)
4. Hooker Chemical, Muskegan, Michigan, 1979 (p. 18)
5. St. Louis Park, Minnesota (p. 20)
6. Jackson Township, New Jersey (p. 26)

reach a significant aquifer, they have the potential for contaminating municipal water supplies and private wells. Thus, there is a probability of human exposure to toxic materials that may cause cancer, mutations, and other adverse health effects. The probability of a specific adverse health effect given exposure depends upon the potency or toxicity of the substances, the dose received by each individual, and the genetic endowment and health of the individual exposed. For carcinogens, the probability of an effect given exposure is an increasing function of the accumulated dose.

Regulations governing the design of storage and disposal sites serve to decrease the probability of exposure. Furthermore, regulations establishing groundwater monitoring programs serve to decrease the expected time interval between the onset of exposure to contaminated water and the time of detection at which point avoidance actions can be taken. Thus, regulations of the second type may serve to reduce the probability of an effect given an exposure (depending on the substances involved). The combined effect is to reduce the probability of an effect--i.e., to reduce the risk of adverse health effects associated with exposure to hazardous wastes through the contamination of groundwater.

A second scenario describing long-term effects on aquatic ecosystems is outlined in Table 2-2. This scenario also begins with the unintended release of materials from storage or improper disposal. In this scenario these materials reach surface water systems where, because of their lack of biodegradability and persistence in the environment, they become widely dispersed. Many of these substances enter the food chain, which is likely to lead to reductions in the populations of sensitive species and their predators--e.g., fish and fish-eating mammals and birds such as ospreys and eagles. Also, accumulation of these substances in body tissues could render some species of fish unsuitable for human consumption.

In this scenario it seems reasonable to reflect on several reasons that individuals might value a risk change. First, contamination of surface waters increases the probability of exposure by increasing the potential pathways. Direct exposure through the water itself or "indirect" exposure through the effects of these substances in the food chain are two cases. Equally important, the contamination of fish or reduction in their populations could result in a loss

TABLE 2-2. SCENARIO B: LONG-TERM EFFECTS ON AQUATIC ECOSYSTEMS

Substances:	Polychlorinated biphenyls (PCBs), chlorinated hydrocarbon pesticides, or heavy metals such as mercury, lead, or cadmium.
Event:	Unregulated disposal or the breakdown of a poorly designed disposal site leads to the more or less continuous release of the substance into the environment. As a result of environmental transport via runoff, leaching, or migration through soils, the substance reaches surface water systems. As a result, the substance achieves wide distribution throughout the aquatic ecosystem.
Impact:	The accumulation of the substance in the food chain is likely to lead to reductions in the populations of sensitive species and their predators.

Forms of Economic Damages

1. Production/Market Values: Reduced productivity and harvests of commercial fish species; loss of marketability of fish because of tissue contamination.
2. Use Values: Lost recreation opportunities because of lower populations of fish, water fowl, etc. Risk to human health through direct or indirect (food chain) exposures.
3. Nonuse/Intrinsic Values: Losses due to increased threats to endangered species and fragile and/or unique ecosystems.

Examples: As reported in U.S. Environmental Protection Agency [1980]:

1. Hooker Chemical, Montague Plant, Muskegan, Michigan, 1979 (p. 18)
2. Waste Industries, Inc., New Hanover County, 1980 (p. 29)
3. ABM Wade, Pennsylvania (p. 35)
4. Taft Forge, Inc., Howell, Michigan (p. 125)

of use values associated with recreational activities related to that wildlife. Reductions in the populations of water fowl due to direct toxicity or changes in the food chain could affect recreational hunting and viewing uses. There could also be increased risk of the loss of amenity values to the extent that reductions in the populations of nongame species and the mammals and birds that feed on them--e.g., otters, seals, loons, ospreys--reduce the opportunities for wildlife observation. Also, there could be existence and other intrinsic values associated with avoiding threats to the populations of species of aesthetic or emotional significance such as eagles, loons, or seals.

Scenario C, summarized in Table 2-3, also focuses on ecological effects. Because of their short-term nature, the effects associated with this scenario are not likely to increase the risk of losing the services that would be associated with a form of existence values. The substances involved--organic solvents, acids, etc.--are either biodegradable or neutralized rather quickly in the environment. Thus, although there may be severe reductions in biological productivity and in populations of sensitive species, once the materials are dispersed, populations are restored through recolonization and in-migration. Of course, it is conceivable that for some substances, there could be long-term ecological effects as well as short-term impacts.*

As has been noted above, all three of these scenarios have a common structure in that there is a set of adverse effects that <u>might</u> occur. The probability of their occurrence depends in large part on the probability of the release of the substances to the environment. The conceptual analysis in Chapters 3 through 5 and all but one of the survey questions have been based on cases resembling Scenario A. Thus, the risks are treated in our model and described in the survey questionnaire as being experienced by the members of a household as a result of land-based disposal of hazardous substances.

There are two aspects of the description in the survey questionnaire that are important to these scenarios. First, the nature of the exposure to hazard-

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*There is also a probability of human exposure and adverse health effects associated with poorly regulated concineration of hazardous wastes and subsequent airborne emissions. And human exposure could occur through contamination of soils and subsequent absorption through the skin or ingestion. The formal structure of these alternative scenarios is essentially the same as the all too common groundwater contamination scenario.

TABLE 2-3. SCENARIO C: SHORT-TERM ACUTE ECOLOGICAL IMPACTS

<u>Substances</u>: Organic solvent, acid, or inorganic toxic such as cyanide. Such substances are acutely toxic but have relatively short environmental half lives.

<u>Event</u>: An accidental spill or breach from a poorly designed containment such as a lagoon. The substance quickly spreads to nearby streams or lakes.

<u>Impact</u>: Heavy losses of aquatic organisms including fish, and possible losses of fish-eating species. Because of dilution, neutralization, and/or biodegradation, concentrations of the substance in the environment fall to background levels relatively rapidly. Species population recover through recolonization and in-migration.

<u>Forms of Economic Damages</u>

1. <u>Use Values</u>: Activities such as sports fishing and boating are adversely affected until the toxic materials are dispersed or neutralized and the populations of the target species restore themselves.
2. <u>Nonuse/Intrinsic Values</u>: Not likely to be significant.

<u>Examples</u>: As reported in U.S. Environmental Protection Agency [1980]:

1. Kernersville, North Carolina, Reservoir (p. 27)
2. Byron, Illinois (p. 18).

ous wastes is not defined in physical terms but rather in terms of the outcome it implies. Exposure is described as sufficient to lead to death through an initially undefined health effect. The risk is described as the risk the interviewed individual (or other member of the household) will die in 30 years as a result of exposure. So the presentation maintains that the exposure level (an issue discussed in Scenario A) would be sufficient to impose a risk of the health effect. After questions associated with household exposures were discussed, our survey questionnaire did attempt to determine whether individuals had additional willingness to regulate the disposal of hazardous wastes to lower risks experienced by fish, wildlife, and plants. This is the second aspect of our framework that relates to the scenarios. That is, we attempted to capture just the ecological effects that were highlighted in Scenario B without a full description of the mechanism that leads to the risks to these species. It was done in a way that attempts to isolate each motivation for valuing a risk change, but did not explicitly distinguish user and nonuser motives for valuing the wildlife.

2.6 SUMMARY

This chapter has provided a brief overview of the organization of our conceptual analysis of individual decisionmaking under uncertainty and its relationship to the issues we suggest are important to valuing regulations governing the management of hazardous wastes. These regulations are treated as reducing the risk of exposure to hazardous substances. Risk in our analysis is treated as synonymous with the probability of a well-defined event. The event is an exposure to these materials that is sufficient to lead to a second stage risk of death. The second risk is explained to be the result of the individual's health and heredity.

Finally, to explain how our analysis can be related to specific events and the associated policy actions involving hazardous wastes, we presented three examples of how hazardous wastes might enter the environment and described the scenario that is most closely aligned with the implicit circumstances underlying our conceptual and empirical analyses.

CHAPTER 3

MODELING BEHAVIOR UNDER UNCERTAINTY: A HEURISTIC REVIEW

3.1 INTRODUCTION

Models of how individuals respond to uncertainty have been an important part of the theoretical contributions to microeconomics in the last 50 years. Today, interest in the results of these theoretical advances and in the prospects for extensions of this work seems especially great. There are at least two factors contributing to this interest. First, and perhaps most important to the objectives of this research, there has been a growing public concern over risks that are imposed on households without their consent. These risks can arise from the actions of firms, other households, or the public sector. They take many forms--ranging from what is perceived as inadequate testing of new products to insufficient safety provisions in new technologies. Moreover, in some cases, there may be the perception that past decisions were based on incomplete information or failed to give appropriate attention to the future risks accompanying specific actions. The past disposal practices for hazardous wastes are a good example of discussions in this last category. The "surprises" associated with past disposal practices in a large number of cases such as the widely publicized examples of Love Canal, New York; Times Beach, Missouri; or Newark, New Jersey contribute to this perception. As a consequence, despite what many observers have suggested is a relatively low risk environment in the United States,* public policy has increasingly focused

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*One of the most widely cited studies identifying this seemingly contradictory behavior is associated with Douglas and Wildavsky [1982]. More recently, Slovic [1984] has noted that recent polls of corporate executives, members of the banking and investment community, members of Congress and their aides, Federal regulators, and the general public seem to suggest that "regardless of whether things actually are riskier, most people think they are now more risky." (Slovic [1984], p. 2).

on the risk implications of new technologies and the role of social regulation, and public policies in general, for risk management.*

At the same time, there has been growing concern over the validity of economic models for describing individual behavior under uncertainty. Experimental tests of the assumptions and predictions of the most widely used framework for modeling behavior under uncertainty--the expected utility model--appear to have found important violations of the model's assumptions and inconsistencies with its predictions (see Schoemaker [1980] and Machina [1983]). These results have, in turn, stimulated research, both theoretical and empirical, to attempt to evaluate the plausibility of these findings and to understand the reasons for them. To date, there has not been a clear reconciliation of the available experimental evidence with the predictions of conventional economic models of individual decisionmaking. The available alternatives to the expected utility model all suffer from significant limitations that restrict (or preclude) any one of them from serving as an effective basis for empirical analyses of individual behavior.†

This chapter cannot do justice to the research in both of these areas. Summaries have already occupied several overview volumes of varying technical detail.‡ Our conceptual analysis will largely accept, as a maintained hypothesis, the expected utility model as a description of individual behavior under uncertainty. While the empirical analysis is based on this conceptual framework, it has been designed to allow consideration of the relevance of the expected utility model for explaining individuals' responses to risk. Chapter 7 describes the relationship between our conceptual and the empirical analyses. The objective of this chapter is to explain the overall features of the expected utility model and to discuss in more detail several specific aspects of the framework that will be particularly relevant to our empirical analysis. More-

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*See Lave [1981] and Huber [1983, 1984] for discussions of risk management issues in a policy context.

†See Weinstein and Quinn [1983a] for a good overview of some aspects of these models and their limitations.

‡See Hey [1979], Machina [1983], or Schoemaker [1980] for discussions of the theory and of limitations of the expected utility framework. See Fischhoff et al. [1981], Viscusi [1983], Lave [1981], or Crouch and Wilson [1982] for discussions of aspects of the treatment of risk in public policy decisions.

over, in developing this review we will consider, briefly, some of the difficulties raised with the expected utility framework in relationship to the objectives of our analysis.

Section 3.2 begins this overview with a review of the assumptions of the model, an outline of the state-preference approach for describing it, and a discussion of the implications of the treatment of contingent claims as claims to commodities versus claims to income. In Section 3.3, the expected utility model is used together with the assumption of state-independent utility functions to describe the implications of changes in the probability of detrimental events and the measurement of risk aversion. Section 3.4 describes the rationale for state-dependent preferences and reconsiders several of these issues using this specification for consumer preferences. Section 3.5 discusses some of the limitations of the expected utility model with special attention to the issues of potential relevance to our empirical analysis; Section 3.6 summarizes the chapter.

3.2 THE EXPECTED UTILITY FRAMEWORK AND CONTINGENT CLAIMS

Two conceptualizations of the process of individual choice under uncertainty have been frequently used in economics. In the one we shall use--the state-preference approach--the objects of choice are redefined from what is assumed in conventional descriptions of consumer choice under certainty. They become contingent commodity (or income) claims. This means that they are entitlements to goods or services under specified states of nature. If it is assumed that an individual is uncertain over the state of nature that will be realized at the time his consumption decisions must be made, then this framework describes the individual as <u>planning</u> consumption choices contingent upon which state of nature is realized. These plans are formalized through the selection of contingent commodities. These commodity claims are valid only if the state that is part of their description is realized. Thus, for example, an individual cannot exercise a claim to financial resources in the event of a disabling injury unless the injury is experienced.

An alternative description of behavior under uncertainty defines the objects of choice as specific parameters describing the probability distributions for something of interest to the individual, such as a commodity or income. What is important is that the specified source of uncertainty and the description of the features of that uncertainty affect the utility realized by the individual. For example, an individual might be selecting actions that would change the mean income or its variance. The state-preference approach is more general than this parametric formulation of the problem. Of course, as we might expect, there are assumptions that can be imposed on the state-preference formulation to reduce it to this more restrictive approach. However, for our purposes, these assumptions are too restrictive. Therefore, since our analysis will use the first format, no attempt is made here to summarize the second.

The origin of the contingent claims approach is usually associated with Von Neumann and Morgenstern [1947], who deduced maximization of expected utility as the type of behavior implied by a set of assumptions on the features of decisionmaking under uncertainty. These assumptions are usually described with some variation on three axioms: transitivity of preferences over lotteries (or prospects), continuity of preferences over lotteries, and the independence axiom. A prospect or lottery involves a listing of the outcomes in each state of nature and a specification of the probabilities for each state. Thus, if a prospect, A, involves two states, and if state one yields W_1 with probability p, and state two yields W_2 with probability (1-p), then prospect A would be described as follows:

$$\text{Prospect A} = (W_1, W_2, p, (1-p)) .$$

Transitivity implies that if prospect A is preferred to prospect B, and prospect B is preferred to prospect C, then A will also be preferred to C. Continuity is also similar to the assumption in conventional models without uncertainty. If a sequence of prospects converges to a given prospect, then the utility generated by the sequence will converge to that generated by the given prospect.*

Independence implies that if an individual prefers prospect A to B, then this preference should not be affected by whether the choice of A over B is in simple terms or if it is as a possible prize in a compound lottery (i.e., the choice of a lottery involving A and another event C versus B and C where

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*See Machina [1983], pp. 5-7, for a more complete description of these conditions.

the odds of A and B are the same in the two compound lotteries). The importance of the independence assumption is that it gives the expected utility framework its empirical content by restricting the form of the preference functionals (described over the distributions of lotteries) to be linear in the probabilities--or the expected utility.

With this background we can turn to the form of the model usually presented in describing specific decision problems. To start the process, assume we have a utility function, $U(X_1, X_2)$, expressed in terms of commodities X_1 and X_2. Since we are dealing with contingent claims, to describe the choice process we must distinguish claims by commodities and states. If there are N commodities and S states, we would consider N·S contingent claims for the commodities. The conditions governing the availability of any good can be different depending upon the state of the world one is considering. In our example, if there are two states of the world, then there must be four contingent claims for a complete description of all possibilities.*

If we assume the probabilities of states one and two are p and (1-p), respectively, then the Von Neumann-Morgenstern utility function, V(.), will be given as:

$$V(X_{11}, X_{12}, X_{21}, X_{22}; p, 1-p) = p\,U(X_{11}, X_{12}) + (1-p)\,U(X_{21}, X_{22}), \qquad (3.1)$$

where

X_{ij} = contingent claim to commodity j in state i.

To describe how the representative individual responds to uncertainty we must specify the constraints imposed on his maximization of Equation (3.1). Before doing this, however, we should note that concavity of U(.) assures that V(.) will be concave. Therefore, Von Neumann-Morgenstern indifference curves will resemble ordinary indifference curves as in Figure 3-1. This indifference map is drawn holding one of the commodities constant in both states (i.e., X_{12} and X_{22}) and allowing the state of nature to vary for the other. The slope of the indifference curve is given as:

*We have not discussed the potential role of securities markets as a basis for reducing the number of markets from N S to N + S. See Arrow [1964] and Nagatani [1975] for discussion of these cases.

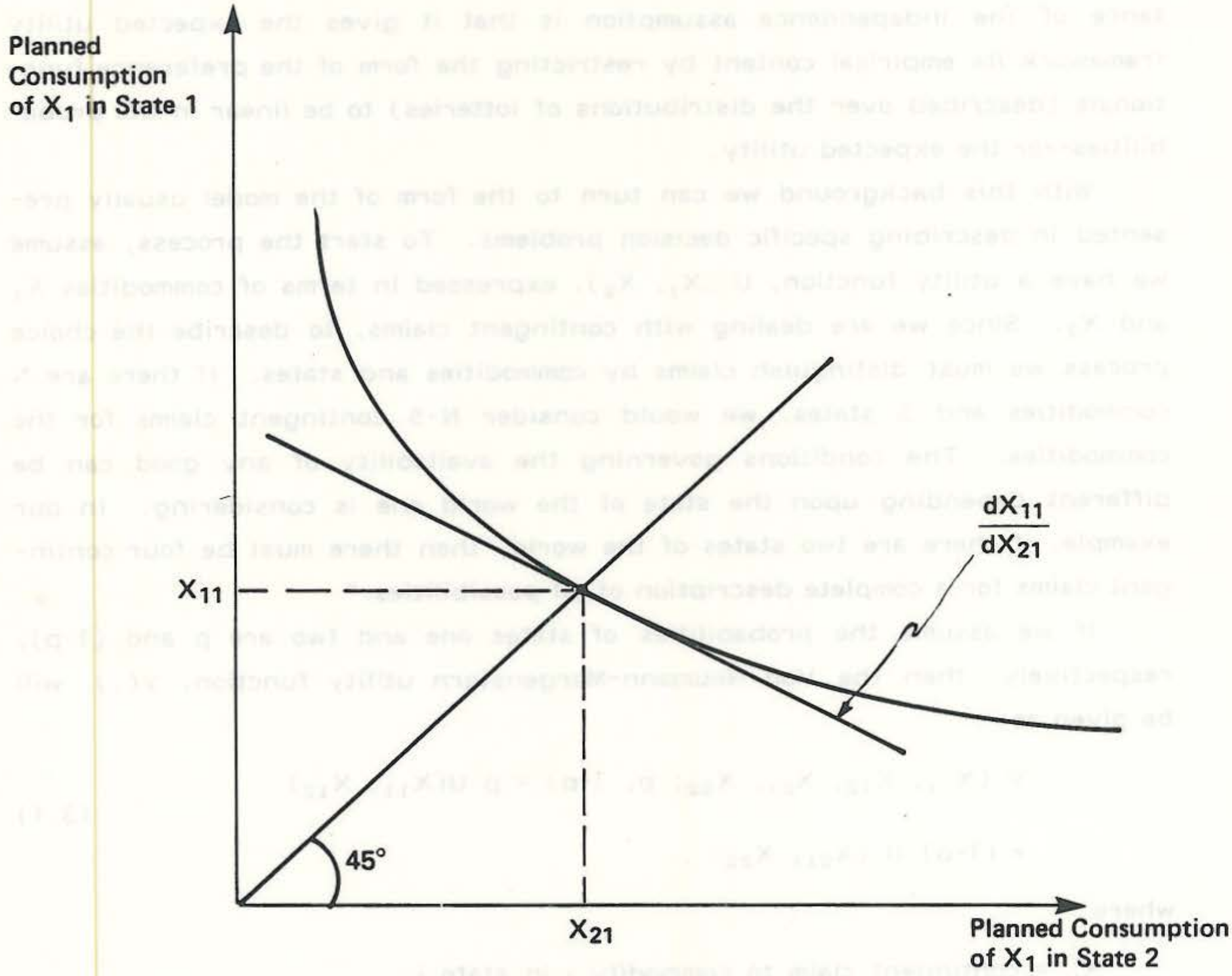

Figure 3-1. Illustration of Von Neumann-Morgenstern indifference curve.

$$\frac{d\ X_{11}}{d\ X_{21}} = - \frac{(1-p)\ \frac{\partial U}{\partial X_{21}}(X_{21},\ X_{22})}{p\ \frac{\partial U}{\partial X_{11}}(X_{11},\ X_{12})} \quad . \tag{3.2}$$

This is simply the negative of the ratio of the expected marginal utilities for the first commodity in each state. Of course, if we held state constant and considered the slope in terms of X_{11} and X_{12}, commodities one and two in state one, then it would be the conventional ratio of the marginal utilities without probabilities since they would be equal. This feature will be important to understanding the simplification of this model that has routinely been used in the literature. The contingent claims are generally described as claims to income and not claims to commodities. Moreover, it has been argued that this approach can be adopted without a loss in the generality of the conclusions. We shall argue in what follows that this conclusion is not entirely true. To do so, however, requires consideration of the constraints to individual choice. Therefore, we must describe what limits the individual's efforts to maximize expected utility.

The limits arise, as in conventional models of consumer choice, with a budget constraint. This constraint can be formulated in a variety of ways. In Equation (3.3) we maintain that the individual has an income level, y, that constrains the <u>planned</u> choices of contingent commodities:

$$y = s_{11}\ X_{11} + s_{12}\ X_{12} + s_{21}\ X_{21} + s_{22}\ X_{22}\ , \tag{3.3}$$

where

s_{ij} = price of the contingent claim for commodity j in state i.

We could have assumed that the individual was endowed with certain levels of contingent claims. Given fixed prices for the claims, this would also lead to a fixed income for planned consumption.

Optimal consumption plans in this framework require that the ratio of probability-weighted marginal utilities for claims associated with the same commodity in different states equals the ratio of the relevant prices and that, for different commodities in the same state, the ratio of the marginal utilities equals the relevant price ratio. These two cases are given in Equations (3.4) and (3.5) below:

$$\frac{(1-p)\ MU_{X_{21}}}{p\ MU_{X_{11}}} = \frac{s_{21}}{s_{11}}\ , \tag{3.4}$$

$$\frac{MU_{X_{11}}}{MU_{X_{12}}} = \frac{s_{11}}{s_{12}}\ , \tag{3.5}$$

where

$MU_{X_{ij}}$ = marginal utility of X_{ij}.

It is important to recognize that these prices are for contingent claims, not for the commodities themselves. Two aspects of this distinction will affect the interpretation of our analysis. The first concerns the relationship between the prices for claims and the prices of commodities and the probabilities of states of nature. The second concerns the relationship between what might be designated the ex ante relative prices of the commodities (not the claims) and the ex post prices of these commodities. The first of these issues is discussed below. The second relates to an exchange between Arrow [1975] and Nagatani [1975] and the extent to which a full set of markets for contingent claims would lead to an ex post efficient allocation of resources. Since this second issue is not directly relevant to our analysis, it will not be developed further here.*

Clearly, the interpretation of these first-order conditions depends on the relationship between the prices of contingent commodity claims and the probabilities for each state. If, for example, we assume that there exists a set of ex ante prices for the commodities X_1 and X_2 involved in these claims and that the prices for the contingent claims to them are simply the probability-weighted counterparts to these prices, then we can see directly an explanation for the simplifications used in most contingent claims models. With these assumptions, the prices for contingent claims would be defined as follows:

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*As Nagatani [1975] noted, it is important to recognize the prospects for differences in the ex ante and the ex post prices that might influence planning for purchases of contingent claims. If we are to assume individuals know the ex post prices, we must consider the mechanisms that permit this information to be realized ex ante. We will not consider these issues at this point but will return to the distinction between ex ante and ex post behavior in discussion of the appropriate basis for welfare measures associated with policies that affect risk in Chapter 4.

$$s_{11} = p\ t_1 \qquad s_{21} = (1-p)\ t_1$$
$$s_{12} = p\ t_2 \qquad s_{22} = (1-p)\ t_2 \tag{3.6}$$

where

t_j = the ex ante price for the jth commodity.

With substitutions it can be demonstrated that the allocation of resources to claims for commodities in a given state is determined by the same conditions as in the certainty case--the marginal rate of substitution between the two goods equals the ex ante price ratio. To the extent ex ante commodity prices are the same as ex post commodity prices, then we can expect that the planned consumption choices under fair markets for contingent claims will lead to the same relative consumption incentives as the ex post relative prices would. Moreover, the optimal allocation among claims to the same commodity for different states of the world implies that the relevant marginal utilities will be equalized.

These results and the assumptions associated with them provide the basis for understanding the implications of defining contingent claims in terms of income rather than in terms of commodities. In contrast to discussions of uncertainty used to develop models for analyzing option value (see, for example, Hartman and Plummer [1981], Plummer and Hartman [forthcoming], or Freeman [1984a]), our analysis has not "attached" the uncertainty to a specific variable affecting preferences. Rather, the individual is assumed to be uncertain over the state of nature but to have access to a complete set of markets for contingent claims. If these markets are actuarially fair, and if it is reasonable to assume ex ante commodity prices are equal to ex post prices, then it is clear that there is no need to distinguish commodities in evaluating an individual's allocation of resources with state-independent preferences. Indeed, we could further relax the assumptions specified above by allowing the prices of contingent claims to be a product of a function of the probabilities and the ex ante prices for each good. Provided this function was the same for all commodity claims associated with a common state of nature, the marginal conditions governing their selections would be equivalent to the certainty case. Of course, selections of a commodity claim differentiated across the states of nature would be affected. These effects could be as easily described using income claims in lieu of commodity claims. Consequently, in nearly all work with contingent claims models, it has been assumed that the utility function is actually an indirect utility function expressed in terms of income and commodity prices. Ex ante selections of commodities are assumed to be identical to ex post selections. Uncertainty and the ability to diversify risk were assumed to affect the allocations to income claims in each state. Since commodity choices are conditional upon available income, it was felt this simplification did not affect the description of individual behavior. We shall argue that, with state-dependent preferences, these same arguments do limit the relevance of the analysis.

3.3 RISK AVERSION AND PROBABILITY CHANGE: STATE-INDEPENDENT UTILITY FUNCTIONS

Risk aversion is associated with a concave utility function.* It is often convenient to have an index of the degree of risk aversion. One of the most popular of these measures is associated with the work of Arrow [1965] and Pratt [1964]. It has been described by absolute and relative measures of risk aversion. The first, absolute risk aversion, can be defined in terms of the change in the marginal utility of income. Using the arguments discussed in Section 3.2, we replace our utility function with the corresponding indirect utility function and assume the prices of commodities are held constant. Let $\mu(y_i)$ designate the state-independent, indirect utility function associated with claims to income in state i, y_i. Since the prices of commodities are held constant, they have been omitted for simplicity in exposition. The Arrow-Pratt index of absolute risk aversion, θ, is given in Equation (3.7), with the elasticity formulation--relative risk aversion, r--given in Equation (3.8):

$$\theta(y_i) = - \frac{\frac{d^2\mu}{dy_i^2}}{\frac{d\mu}{dy_i}} , \qquad (3.7)$$

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*The classic paper on the implications of risk aversion for behavior is Friedman and Savage [1948]. More recently, discussions of the concept of option value have debated the appropriate definition of risk aversion in the evaluation of the sign of option value. See, for example, Schmalensee [1972] and Bohm [1975].

$$r(y_i) = -y_i\,\theta(y_i) = -\frac{\frac{1}{y_i}\cdot\frac{d^2\mu}{dy_i^2}}{\frac{d\mu}{dy_i}}. \qquad (3.8)$$

While the first of these indexes can be seen as one means of measuring the concavity of the utility function, there are clearly many ways of providing a measure of curvature. The appeal of this measure arises from the fact that it bears a direct relationship to the maximum expected income a risk-averse individual would forego rather than bear actuarially fair risks.

This can be demonstrated using a fairly direct argument. Consider an individual who is offered the prospect we shall designate as the random variable, A, of an amount, a, in state one with probability, p, but a required payment of $-\frac{ap}{1-p}$ in state two with probability (1-p). The expected value of the prospect is zero. A risk averse individual will not be indifferent between a situation in which he accepts the prospect and where he does not. Indeed, there is some payment, π, that he would make to avoid it. The maximum value of this payment is one that equalizes his expected utility from making the payment and avoiding the risky prospect with expected utility of not making the payment but accepting the prospect as given in Equation (3.9):

$$p\,\mu(y-\pi) + (1-p)\,\mu(y-\pi) = p\,\mu(y+a) + (1-p)\,\mu(y-\frac{ap}{1-p}) . \qquad (3.9)$$

The left side of this equation reduces to $\mu(y-\pi)$, so we have:

$$\mu(y-\pi) = p\,\mu(y+a) + (1-p)\,\mu(y-\frac{ap}{1-p}) . \qquad (3.10)$$

To derive an approximate relationship for π, consider a Taylor series approximation for each side of Equation (3.10). Expanding about a constant income level y to first order terms for the left side and second order for the right, we have:

$$\mu(y-\pi) \sim \mu(y) - \frac{\pi d\mu}{dy} + \varepsilon \qquad (3.11a)$$

and

$$p\ \mu(y+a) + (1-p)\ \mu(y - \frac{pa}{1-p}) \sim \mu(y) + a\ p\ \frac{d\mu}{dy} - a\ p\ \frac{d\mu}{dy}$$

$$+ \frac{1}{2} a^2\ p\ \frac{d^2\mu}{dy^2} + \frac{1}{2}(\frac{p^2}{1-p})\ a^2 \frac{d^2\mu}{dy^2} + \tau\ , \qquad (3.11b)$$

where

ε and τ = the remainders fo the Taylor series expansions.

Simplifying terms in Equation (3.11b) and setting Equation (3.11a) equal to Equation (3.11b) (as implied by our definition of π in Equation (3.9) and Equation (3.10)), we have:

$$\mu(y) - \frac{\pi du}{dy} = \mu(y) + \frac{1}{2}\frac{d^2\mu}{dy^2}\left[p\ a^2 + (1-p)\left(\frac{ap}{1-p}\right)^2\right] \ . \qquad (3.12)$$

Further simplification yields

$$-\frac{\pi d\mu}{dy} = \frac{1}{2}\frac{d^2\mu}{dy^2}\ Var\ (A)\ , \qquad (3.13)$$

where

Var (A) = variance of a (i.e., Var (A) = $E(A^2) - (E(A))^2$).

E(A) = 0 by definition of the prospect as actuarially fair.

Therefore, the risk premium is a multiple of the variance associated with the uncertain prospect:

$$\pi = \frac{1}{2}\ \theta(y_i)\ Var\ (A)\ . \qquad (3.14)$$

The role of π in the shape of the utility function can also be illustrated with Von Neumann-Morgenstern indifference curves as in Figure 3-2. Let $\bar{y}$ designate the constant income starting point for evaluating the degree of risk aversion. It is given as point A on the 45° line with expected utility given a V_2. The uncertain prospect described earlier is illustrated by point B, a movement along the line designating state-dependent payments that are actuarially equivalent to $\bar{y}$. The expected utility of B, V_1, is less than at point A. To determine π, we need only consider the maximum constant payment (regardless of state) that would leave the individual indifferent to being at point B. This is given by the intersection of V_1 with the 45° line, as at point C. Clearly, the flatter the indifference curve, the smaller the difference be-

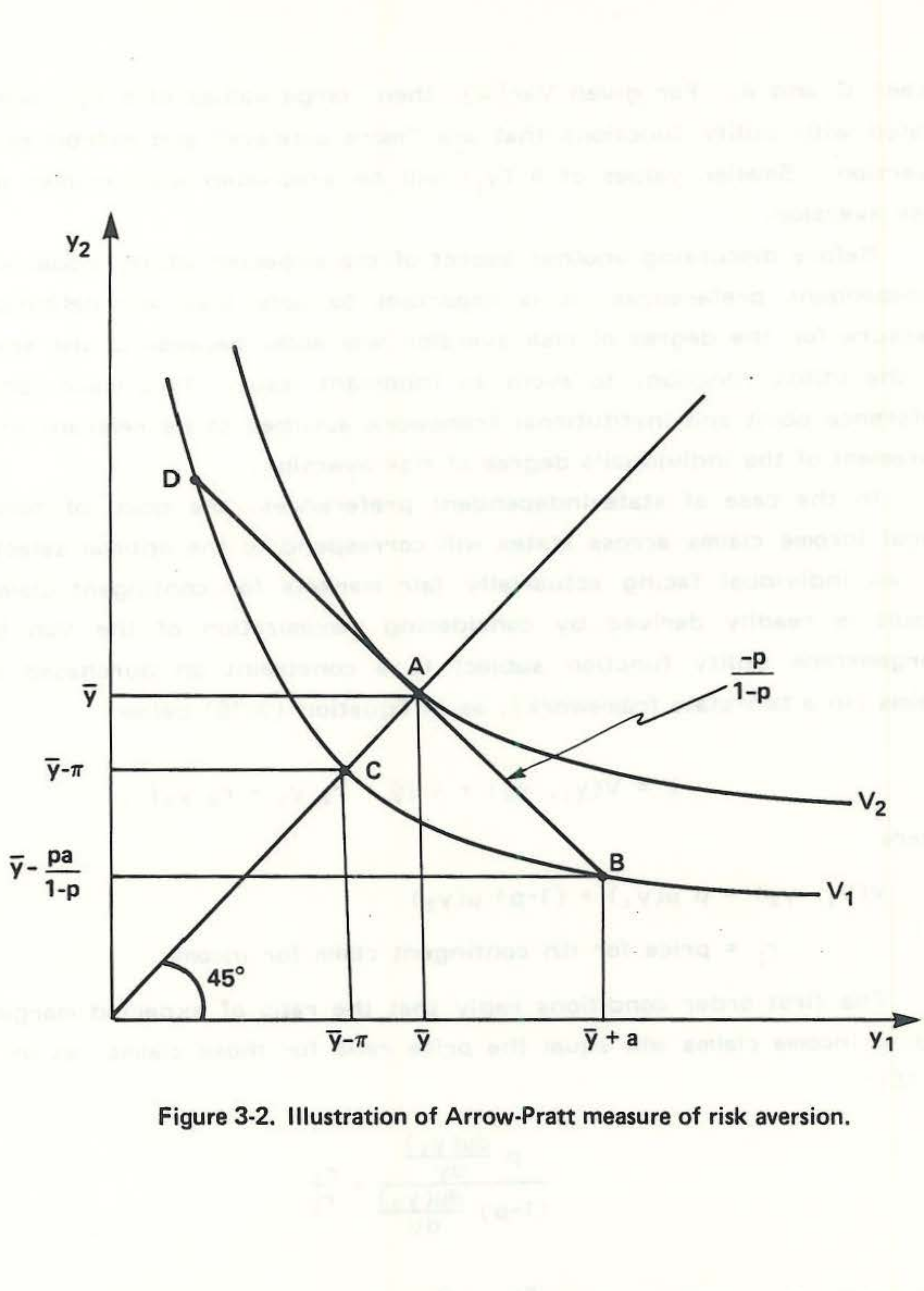

Figure 3-2. Illustration of Arrow-Pratt measure of risk aversion.

tween C and A. For given Var(A), then, large values of $\theta\ (y_i)$ will be associated with utility functions that are "more concave" and exhibit greater risk aversion. Smaller values of $\theta\ (y_i)$ will be associated with smaller degrees of risk aversion.

Before discussing another aspect of the expected utility model with state-independent preferences, it is important to note that our definition of the measure for the degree of risk aversion was able, because of the specification of the utility function, to avoid an important issue. This issue concerns the reference point and institutional framework assumed to be relevant in the measurement of the individual's degree of risk aversion.

In the case of state-independent preferences, the point of constant and equal income claims across states will correspond to the optimal selection made by an individual facing actuarially fair markets for contingent claims. This result is readily derived by considering maximization of the Von Neumann-Morgenstern utility function subject to a constraint on purchased of income claims (in a two-state framework), as in Equation (3.15) below:

$$L = V(y_1, y_2) + \lambda\ [\tilde{y} - r_1\ y_1 - r_2\ y_2]\ , \qquad (3.15)$$

where

$V(y_1, y_2) = p\ \mu(y_1) + (1-p)\ \mu(y_2)$

r_i = price for ith contingent claim for income.

The first order conditions imply that the ratio of expected marginal utilities of income claims will equal the price ratio for those claims, as in Equation (3.16):

$$\frac{p\ \frac{d\mu(y_1)}{dy}}{(1-p)\ \frac{d\mu(y_2)}{dy}} = \frac{r_1}{r_2}\ . \qquad (3.16)$$

Actuarially fair markets imply $\frac{r_1}{r_2} = \frac{p}{1-p}$. Therefore, claims will be allocated to equalize the marginal utilities realized in each state. Since the utility function is state independent, we can expect equality of total utility and of claims to income. Thus, the 45° line is simultaneously the locus of income certainty, utility certainty, and equality of marginal utilities. Selection of equal claims to income in deriving a relationship between the curvature of the utility function and the risk premium has rather special implications that we return to below.

As indicated earlier, our objective is to develop a conceptual framework and empirical estimates for a change in the probability of exposure to hazardous wastes. Thus, it is important to consider how a change in the probability of a state would affect an individual's planned consumption choices. In the state-independent case, this is easily described. The Von Neumann-Morgenstern utility function is a probability-weighted function of the utilities realized in each state. A change in the probability of any one state changes all of the weights (since these weights always sum to unity by definition). Thus the indifference map must shift as the probability changes.

For the state-independent specification, the indifference curves will pivot about the 45° line. Along this line the claims to income will be equal. Thus, the slope of the indifference curves are given by the probability ratio. The marginal utilities are equal at the point of income equality (see Equation (3.2) for the case of commodity claims or Equation (3.16) for that of claims to income). Figure 3-3 illustrates the process graphically. A movement from V_1 to $\bar{V}_1$ is associated with a flattening of the slope--a decrease in the probability of state one and increase of that for state two.

Changes in p affect the risk experienced by the individual. This is easily established by considering the change in the risk premium, as in Equation (3.17) below:

$$\frac{\partial \pi}{\partial p} = \frac{1}{2}\,\theta(y_i)\,\frac{\partial\ \mathrm{Var}\ (A)}{\partial p}\ . \qquad (3.17)$$

The results are not as clearcut when state-dependent preferences are used to describe the individual's responses. In this case, the measure of risk aversion will be seen to also be affected by changes in the probability. It is also important to recognize that the measure of risk itself depends on what is assumed about the opportunities available for adjustment to risk. The most direct way of illustrating the importance of this point is to note that we need not initiate our evaluation of an actuarially fair gamble at a point along the income certainty locus.

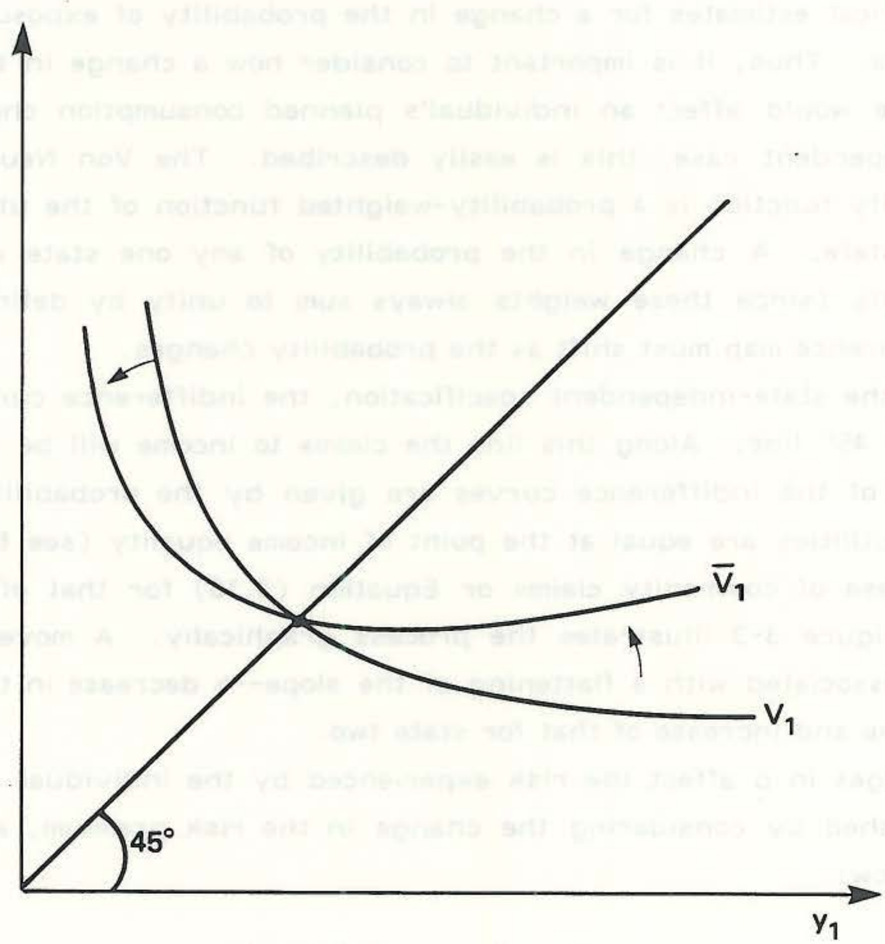

Figure 3-3. Illustration of change in probability on Von Neumann-Morgenstern indifference curve.

There are actually two distinct issues being raised in these comments. First, by starting the analysis along the income certainty locus, we implicitly assume that the gamble offered is the only risk facing the individual. Second, our analysis of the risk premia assumes the individual has the equivalent of access to actuarially fair markets. It is difficult to illustrate both points on a single diagram. The reason is that both the indifference curves and the potential budget constraints (in the case of actuarially fair markets) change in response to changes in the probabilities of states of the nature. To attempt to describe the effects of these problems we have made several simplifying assumptions. The individual is uncertain about which of two states of nature will prevail. The likelihood of each state corresponds to the odds of a hypothetical fair gamble that will be presented to him. In the absence of the gamble, but with access to fair markets for contingent claims, the individual would select a point along a budget constraint with slope $\frac{-P}{1-P}$ and the position would be affected by the income assumed to be available for contingent claims. Since the utility functions are state independent, this selection would lie along the 45° line and would yield a starting point for evaluating the effects of the fair gamble that is equivalent to the case of certainty. However, if the individual's choices for adjustment to the first type of risk are not actuarially fair (i.e., his budget constraint does not have slope $\frac{-P}{1-P}$), then the starting point is not along the 45° line. For example, using Figure 3-4, if the individual faces a budget constraint given by the line labeled T (with slope $-\frac{r_1}{r_2}$), point A would be selected as the constrained expected utility maximizing choice of planned claims. It would not correspond to equal allocation of the planned budget to income claims for each state.

Starting at this reference point and evaluating the second source of uncertainty, the fair gamble leads to the potential for several different measures of the risk premium. One could, for example, consider following the Arrow-Pratt logic by asking what is the maximum amount the individual would pay regardless of the state (i.e., state-independent payment) rather than experience the gamble. The fair gamble is given by the line with slope $\frac{-P}{1-P}$ through A to B. With expected utility held at the level given by V_1, we could consider equal payments from the point A to reach expected utility V_1. Constructing a line through A parallel to the 45° line, we can determine the risk premia by

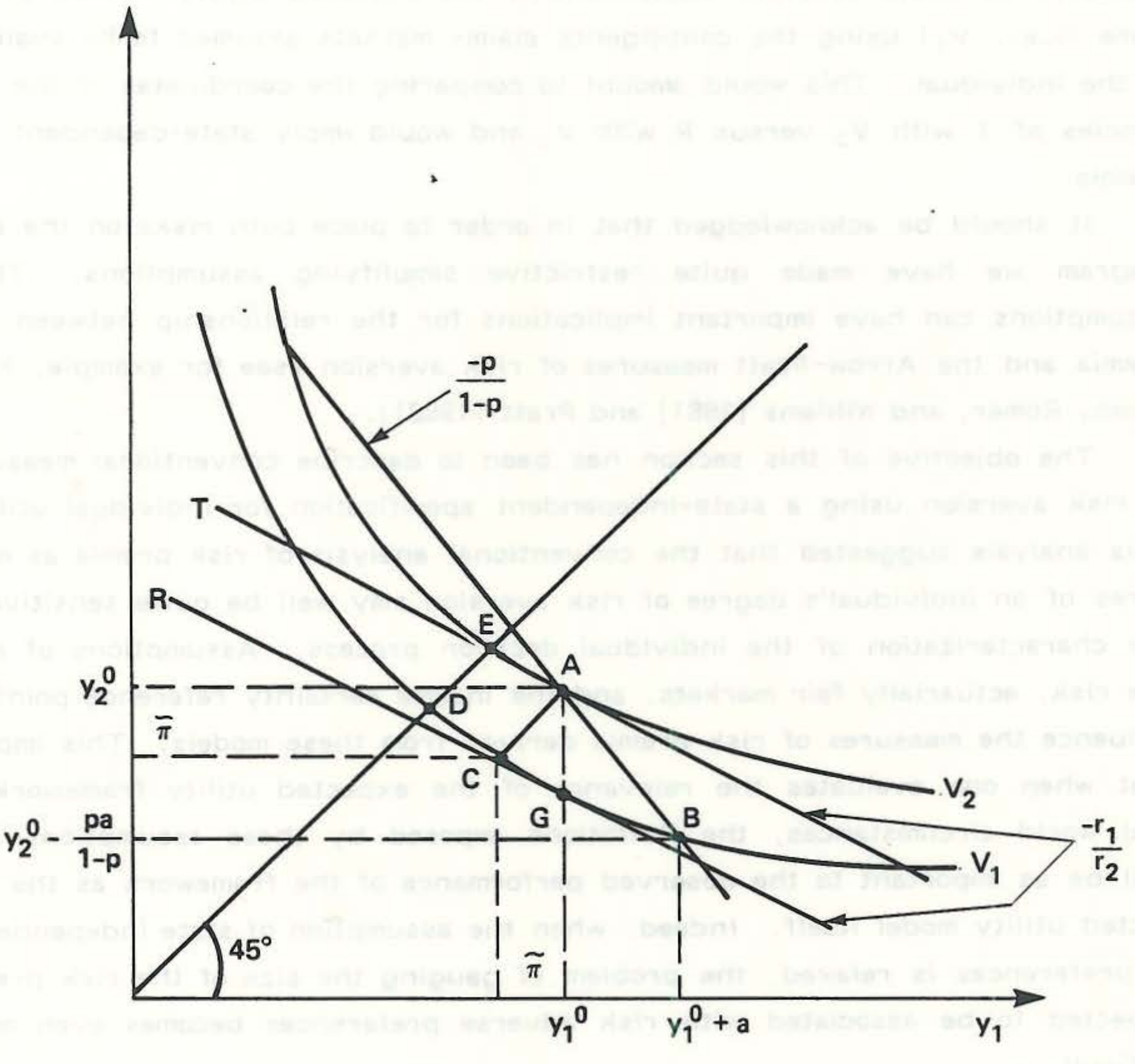

Figure 3-4. Measuring risk aversion in absence of actuarially fair markets.

the difference in the coordinates of A and C, or $\tilde{\pi}$ in the diagram. This will differ from the value implied by initiating the analysis on the 45° line. Alternatively, we could consider adjustment to the expected utility implied by the game (i.e., V_1) using the contingents claims markets assumed to be available to the individual. This would amount to comparing the coordinates of the tangencies of T with V_2 versus R with V_1 and would imply state-dependent risk premia.

It should be acknowledged that in order to place both risks on the same diagram we have made quite restrictive simplifying assumptions. These assumptions can have important implications for the relationship between risk premia and the Arrow-Pratt measures of risk aversion (see for example, Kihlstrom, Romer, and Williams [1981] and Pratt [1982]).

The objective of this section has been to describe conventional measures of risk aversion using a state-independent specification for individual utility. This analysis suggested that the conventional analysis of risk premia as measures of an individual's degree of risk aversion may well be quite sensitive to the characterization of the individual decision process. Assumptions of only one risk, actuarially fair markets, and the income certainty reference point all influence the measures of risk premia derived from these models. This implies that when one evaluates the relevance of the expected utility framework in real world circumstances, the limitations imposed by these assumptions may well be as important to the observed performance of the framework as the expected utility model itself. Indeed, when the assumption of state independence of preferences is relaxed, the problem of gauging the size of the risk premia expected to be associated with risk adverse preferences becomes even more difficult.

3.4 THE IMPLICATIONS OF STATE-DEPENDENT UTILITY FUNCTIONS

A state-dependent description of preferences has often been regarded as a controversial, if not an inconsistent, specification for an individual's preferences. Early discussion of this possibility by Malinvaud [1972] seemed to imply that the specification simply reflected an inadequate specification of the model. The recent literature has seen a change in attitude, with growing acceptance of arguments made by Cook and Graham [1977] and Arrow [1974] (earlier in a somewhat obscure source) on the potential importance of the state-dependent specification.* While Arrow's arguments focused on the modeling of insurance decisions involving health risks, we will argue that they have relevance to a wide range of risks. In justifying the state-dependent specification for his example, Arrow observes that

> income is not the only uncertainty, especially in the context of health insurance, and only under special and unrealistic circumstances can it be held that the other uncertainties have income equivalents. Put loosely, <u>the marginal utility of income will in general depend not only on the amount of income but also on the state of the individual or, more generally, on the state of the world</u>. (Arrow [1974] p. 2, emphasis added)

Arrow also suggests that a state-dependent formulation can be derived from an axiomatic framework provided that we maintain that there are effects to an individual of being in a state that do not correspond to or translate into decisions on purchases of goods or services or other types of income allocations. Thus, an individual's utility is affected by the state of nature, but there is no explicit relationship between how it is affected and changes in market-based economic activities. The state-dependent formulation implies that some consequences are not only impossible but irrelevant to some states of the world. As a result, the axiom (often postulated in the conventional framework) suggesting that a consequence under any one state of the world is possible under any other cannot be accommodated with the state-dependent specification.

The use of a state-dependent formulation has a number of implications. Three are of direct relevance to our analysis:

1. Under a state-dependent specification, planned consumption activities will be distinct from ex post consumption choices even if the individual is assumed to face complete and actuarially fair markets for contingent claims with ex ante and ex post commodity prices equal.†

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*More recently, state-dependent utility functions have received considerable attention. See Karni [1983a, b], Karni, Schmeidler, and Vind [1983], and Dionne and Eickhoudt [1983].

†This conclusion is simply an alternative statement of the fact that, with state-dependent preferences, the ex ante or planned expenditure function will not necessarily equal the expected value of the ex post expenditure functions associated with consumption choices made under each state of nature.

2. Measurement of risk aversion in a state-dependent framework is a more complex and arbitrary process when the measures are required to have a relationship with a risk premium.

3. Violations to the behavior implied by the expected utility framework can largely be explained within a state-dependent specification for utility.

We will consider the first two of these implications in this section and return to the last as part of the brief overview, in the next section, of some of the violations to the expected utility framework encountered in studies of individual behavior under experimental conditions.

To consider the first implication of the state-dependent formulation, we must return to the specification of individual choice developed in Section 3.2 and modify Equation (3.1) to reflect the state dependency as given below:

$$\bar{V}(X_{11}, X_{12}, X_{21}, X_{22}; p, (1-p)) = p\, U_1 (X_{11}, X_{12}) + (1-p)\, U_2 (X_{21}, X_{22}) \,. \tag{3.19}$$

The subscript to each utility function indicates different preferences for commodities one and two. These differences can arise, as Arrow [1974] and Cook and Graham [1977] have suggested, through some omitted factor that affects preferences and is conveyed "outside the available markets" with the state of nature (i.e., $U_i(X_{i1}, X_{i2})$ might equal $U(X_{i1}, X_{i2}, z_i)$). For our purposes, this source of state dependency need not be specified at this stage of our analysis. However, it will be more important to the planning for our empirical results. Indeed, state dependency can be regarded as a reflection of our ignorance of the factors that influence individual utility. Therefore, by adopting this specification to model decisions under uncertainty, we are acknowledging that there are aspects of the events at risk (or the risk itself) that affect individual well being and that we cannot identify. Given our incomplete information, it is prudent to assume that state of the world can matter to an individual's utility.

Repeating the constrained maximization of Equation (3.19) subject to a budget constraint as defined with Equations (3.3) and (3.6) yields requirements for equality between the marginal rates of substitution and relative prices for the two commodities in each state and equality of the marginal utility for each commodity overstates as in Equation (3.20) below:

$$MU^1_{X_{11}} = MU^2_{X_{21}}$$
$$MU^1_{X_{12}} = MU^2_{X_{22}} \quad (3.20)$$

However, these conditions do not imply that the levels of contingent claims for each commodity will be equalized across states. Accordingly, the allocation of income to each state will differ. Thus, the locus of income certainty and that for utility certainty will diverge, as illustrated in Figure 3-5. As Arrow's justification for state-dependent preferences suggested, the nature of the change in the marginal utility of income across states will determine where the optimal allocation of income among contingent claims will be in relationship to these loci. Indeed, this relationship forms the basis for the Cook-Graham classification of commodities into irreplaceable (both normal or inferior) and replaceable.

Moreover, these considerations have direct implications for the use of the expected utility framework. Consider, for example, the expenditure function that would describe an individual's planned consumption of the two commodities as price, income, and probabilities changed. This function is defined, for the two-state, two-commodity case, by Equation (3.21):

$$\text{Minimize } E = s_{11}X_{11} + s_{12}X_{12} + s_{21}X_{21} + s_{22}X_{22}$$
$$\text{subject to } \bar{V} = pU_1(X_{11}, X_{12}) + (1-p)U_2(X_{21},X_{22}) \quad (3.21)$$

The planned expenditure function would then be given as follows:

$$E = E(s_{11}, s_{12}, s_{21}, s_{22}; p, (1-p), \bar{V}) . \quad (3.22)$$

With the state-independent specifications, we assume $U_1(.) = U_2(.)$. Moreover, with actuarially fair markets for contingent claims, Equation (3.6) would describe the relationship between the prices of claims and the probabilities.

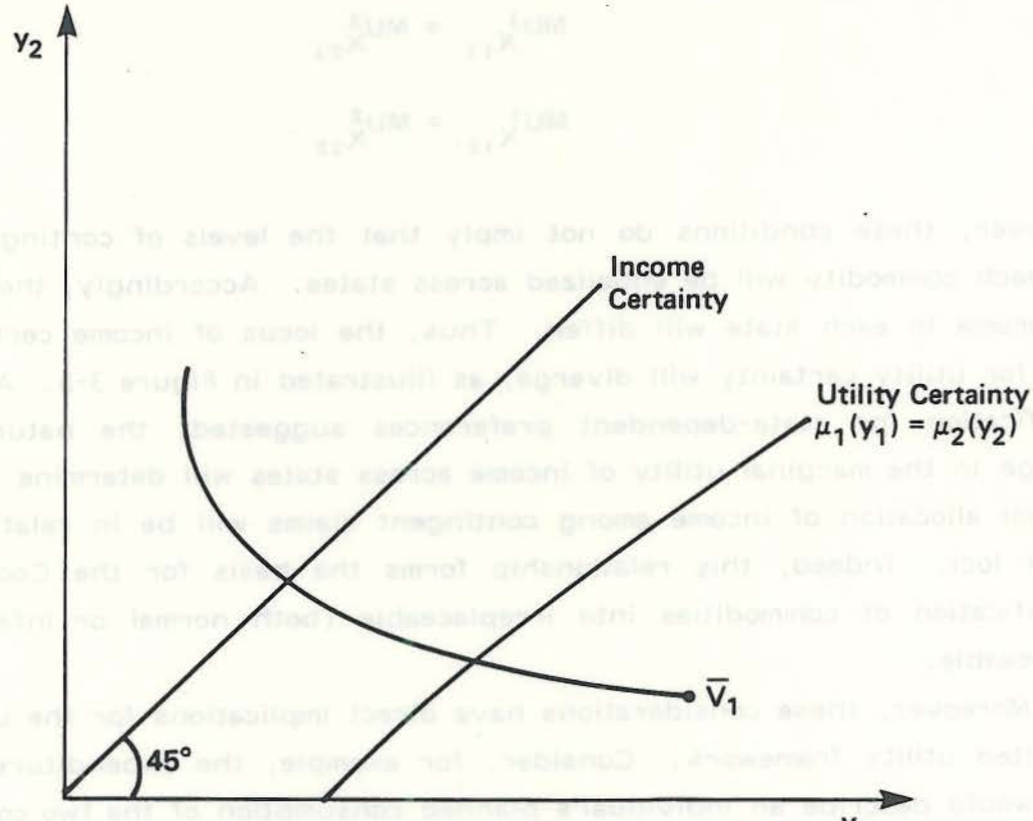

Figure 3-5. The distinction between income certainty and utility certainty loci with state-dependent preferences.

Taken together, they imply that $\partial E/\partial p = 0$ and that the planned or ex ante expenditure function would correspond to conventional static expenditure function.* In effect, the choice of the two commodities is unaffected by the existence of uncertainty. Moreover, the valuation of policies that might affect the prices of one or both of the commodities, provided it does not affect the actuarially fair nature of these markets, can be determined using the static expenditure function. This appears to be one of the implications of Debreu's [1959] characterization of the process. Uncertainty does not affect the nature of planned behavior.† Moreover, it provides the basis for reassessing the definition of concepts of welfare change in the presence of uncertainty. We have referred to this reassessment as a consideration of the perspective for benefit analysis. When ex ante and ex post characterizations of the determinants of an individual's expenditures are equivalent, there is no distinction between ex ante and ex post measures of a welfare change (provided, of course, that ex ante and ex post commodity prices are the same). However,

*If we describe the constrained optimization as

$$G = pt_1X_{11} + pt_2X_{12} + (1\text{-}p)t_1X_{21} + (1\text{-}p)t_2X_{22} + \lambda[\bar{V} - pU(X_{11},X_{12}) - (1\text{-}p)U(X_{21},X_{22})]$$

with first order conditions

$$\text{(a)} \quad \frac{\partial G}{\partial X_{11}} = pt_1 - \lambda p \frac{\partial U}{\partial X_{11}} = 0$$

$$\text{(b)} \quad \frac{\partial G}{\partial X_{12}} = pt_2 - \lambda p \frac{\partial U}{\partial X_{12}} = 0$$

$$\text{(c)} \quad \frac{\partial G}{\partial X_{21}} = (1\text{-}p)t_1 - \lambda(1\text{-}p) \frac{\partial U}{\partial X_{21}} = 0$$

$$\text{(d)} \quad \frac{\partial G}{\partial X_{22}} = (1\text{-}p)t_2 - \lambda(1\text{-}p) \frac{\partial U}{\partial X_{22}} = 0$$

$$\text{(e)} \quad \frac{\partial G}{\partial \lambda} = \bar{V} - pU(X_{11},X_{12}) - (1\text{-}p)U(X_{21},X_{22}) = 0 \text{ ,}$$

then (a) and (c) together with (b) and (d) imply that $X_{11} = X_{21}$ and $X_{12} = X_{22}$. Consequently, the problem can be reduced to an equivalent statement omitting distinctions for states of nature.

†This requires that ex ante and ex post prices will be the same.

when these expenditure functions are different, the measures of changes in well-being they imply will be different. Consequently, we will return to the specific implications of these distinctions in Chapter 4.

However, when we relax the assumption of state-independent preferences, this reduction of the planned expenditures to the ex post function is not possible. This is easily established by considering the change in planned expenditures with a change in the probability of state one under the two cases.

We can, without loss of generality, use claims to income in the state-independent case. Maximization of expected utility subject to fair markets will imply that $\frac{d\mu}{dy}(y_1) = \frac{d\mu}{dy}(y_2)$, that $\mu(y_1) = (y_2)$, and, therefore, that $y_1 = y_2$. The change in the ex ante expenditure function is given in Equation (3.23) below:

$$\frac{\partial E}{\partial p} = (y_1 - y_2) + p\,\frac{\partial y_1}{\partial p} + (1-p)\,\frac{\partial y_2}{\partial p} = 0\ . \qquad (3.23)$$

This result follows because the first term on the left of Equation (3.20) is zero and the last two sum to zero, since expected utility is held constant.*

By contrast for the case of state-dependent preferences, maintaining the four contingent commodities identified in Equation (3.19), we have

$$\frac{\partial E}{\partial p} = \frac{t_1\ (U_2 - U_1)}{\frac{\partial U_1}{\partial X_{11}}} + (t_1\ X_{11} + t_2\ X_{12}) - (t_1\ X_{21} + t_2\ X_{22})\ . \qquad (3.24)$$

If we treat claims to income as akin to Hicksian composite commodities (i.e., with fixed prices t_1 and t_2), we can rewrite Equation (3.24) as follows:

$$\frac{\partial E}{\partial p} = \frac{\mu_2 - \mu_1}{\frac{\partial \mu_1}{\partial y_1}} + (y_1 - y_2)\ , \qquad (3.25)$$

---

*The total differential for the Von Neumann-Morgenstern utility function in this case is given as:

$$dV = \mu(y_1) - \mu(y_2) + p\ \mu'(y_1)\ \frac{\partial y_1}{\partial p} + (1-p)\ \mu'(y_2)\ \frac{\partial y_2}{dp}\ .$$

Since $\mu(y_1) = \mu(y_2)$, and $\mu'(y_1) = \mu'(y_2)$ $y_1 = y_2$. In addition, the constancy of expected utility implies that

$$p\ \frac{\partial y_1}{\partial p} = -\ (1-p)\ \frac{\partial y_2}{\partial p}\ .$$

where the marginal utility of income for state one is given as follows:

$$\frac{\partial \mu_1}{\partial y_1} = \frac{\frac{\partial U_1}{\partial X_{11}}}{t_1} .$$

The measurement of risk aversion with state-dependent preferences must also be distinguished from the state-independent case. Of course, it should be acknowledged that the difficulty arises in relating measures of the concavity of each state's utility function to a single risk premium (or to a set of risk premia). It is always possible to measure risk aversion in terms of the degree of concavity of each state's utility function. What is at issue is developing a numerical index of how concavity would affect a risk averse individual's required risk premium when confronted with an actuarially fair gamble.

Two aspects of the extension to the state-dependent case are important. First, as we noted for the state-independent case, we must define the appropriate reference point. Second, it is important to consider the role of the institutions available for diversifying risk in judging an individual's risk premium. However, that analysis did not pursue the full implications of institutions for risk premium. Indeed, the Arrow-Pratt definition imposes an institution (or payment mechanism) by assuming constant payments across states.

This requirement is not essential to the characterization of the individual's attitude toward risk. Before developing this argument in detail, consider Karni's [1983a] approach for measuring risk aversion with state-dependent preferences. He observed that, in the state-independent case, the coincidence of the income and utility certainty loci together with the locus of equilibrium selections of claims to income in the presence of actuarially fair markets eliminates a difficult choice--what is the relevant reference point and how should it affect the adjustments assumed possible for the individual?

Karni [1983a] argues for the locus of claims to income that will assure equality of the marginal utilities of income. In evaluating an actuarially fair gamble, regardless of the starting point, his analysis would measure risk premia in terms of points equivalent to the starting and ending positions in terms of expected utility but lying on the locus of equal marginal utilities. Figure 3-6 illustrates his case, where A designates the individual's initial

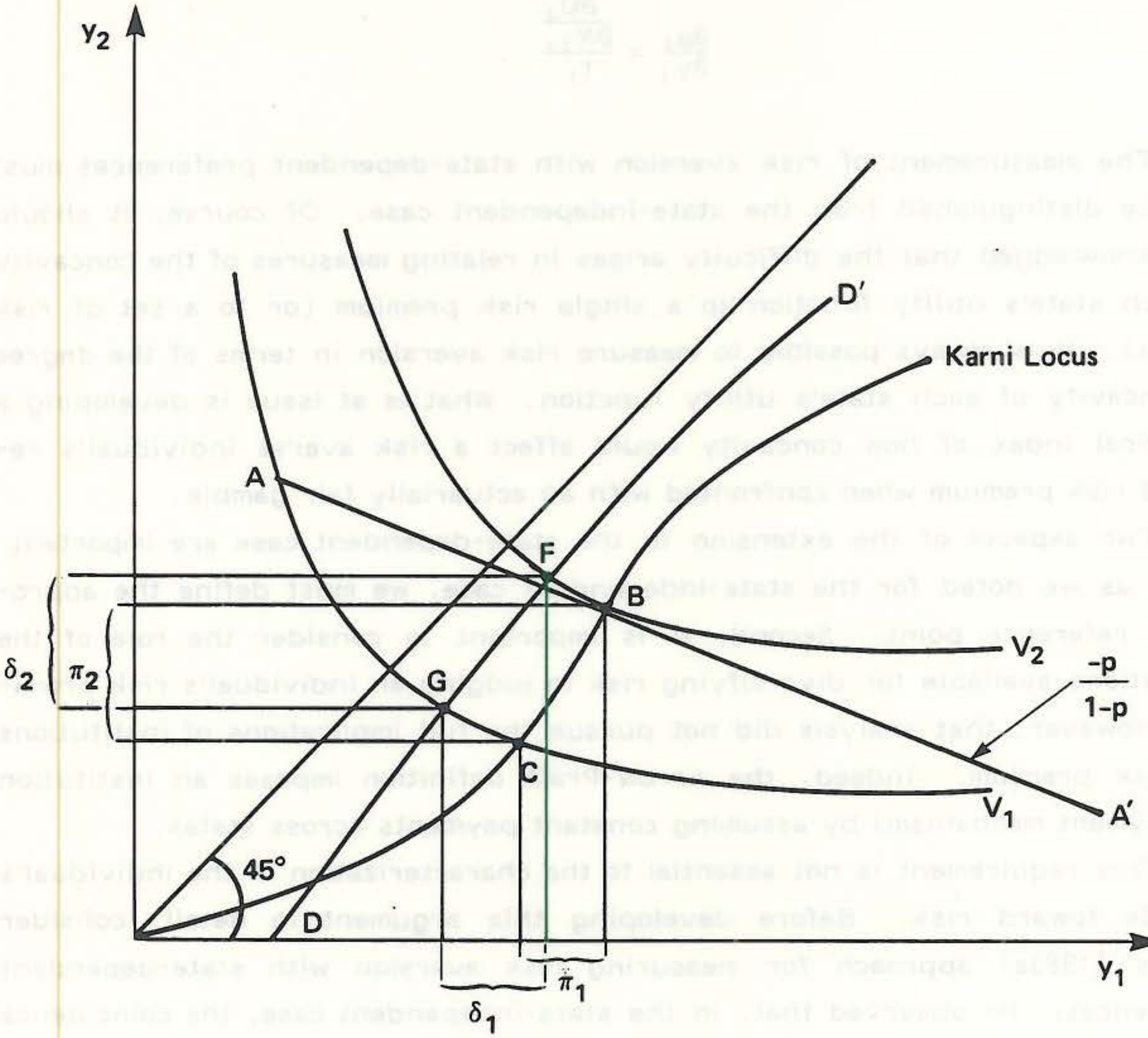

Figure 3-6. Illustration of Karni's measure of risk aversion with state-dependent preferences.

endowment. Regardless of the size of the change that is offered as a fair gamble, Karni's proposal focuses on the most preferred point along AA'--the point B where expected utility would be greatest. At point C, the individual realizes the same expected utility as A. The maximum amount that would be paid for these fair prices corresponds in this setting to state differentiated payments--π_1 in state one and π_2 in state two (with $\pi_2 \neq \pi_1$ in general).

This analysis could also have considered measuring risk in terms of the utility certainty locus, where there is no risk experienced. If D D' designates this locus in Figure 3-6, a different set of premia would have been relevant--namely, δ_2 and δ_1. Which choice is best depends on how the risk measure is to be used. And it is for this reason that our discussion of the role of different opportunities for diversifying risk must be considered in appraising the degree of risk aversion of an individual. Simply stated, an individual's aversion to the risk introduced by an uncertain situation will depend on his existing opportunities to adjust to risk.

The definition of the Arrow-Pratt measure selects as a reference point the riskless locus of equal total utility in each state for the case of state-independent utility functions. This is only relevant if this point characterizes an individual's initial position. Moreover, the definition of the risk premia maintains state-independent payments. For the case of state-independent utility with actuarially fair adjustment opportunities, this point will be the selection. However, it will not be the selection if opportunities for adjustment do not imply constant risk premia regardless of state. Consider the case given in Figure 3-4. If the individual were allowed to adjust based on the existing prices of claims (i.e., r_1 and r_2), the expected utility equivalent of B selected would have been G, not C. Our measure of risk aversion would depend upon how we treated the state-differentiated premia implied by G. Similarly in the state-dependent case, the Karni reference set could be redefined to be the locus of income claims where $MU_{y1}/MU_{y2} = r_1/r_2$ and risk premia measured with reference to it. This approach would also yield state-differentiated premia, and its implications would depend on how they were weighted in deriving a composite index of risk.

At first this may seem to simply add to the confusion associated with characterizing the degree of risk aversion. We think this is an inappropriate interpretation. The Arrow-Pratt concept of a risk premium is simply one way of characterizing an individual's valuation of avoiding a risky situation. By demonstrating that it is sensitive to the specification used to characterize individual preferences and the opportunities available for adjusting to risk (i.e., the nature of markets for contingent claims), this section provides the basis for our conclusion, in Chapter 4, that the valuations of risk changes derived from the planned expenditure function will themselves depend on what is assumed about the individual's opportunities to adjust. The problems associated with defining an index of risk aversion with state-dependent preferences are reduced in this case because the changes in state-dependent payments are combined using prices of claims to form the change in planned expenditures. Thus, these results are a tangible reflection of the point made by Cook and Graham [1977]: the valuation of a change in p depends on the individual's existing opportunities to adjust to risk. We have simply generalized this argument to acknowledge its importance to the characterization of an individual's risk aversion.

3.5 THE PERFORMANCE OF THE EXPECTED UTILITY FRAMEWORK

For the most part, evaluations of the expected utility framework, based on laboratory experiments, have questioned its relevance to real-world decisions. Indeed, Schoemaker's [1982] recent review article concluded its appraisal by noting that

> As a descriptive model seeking insight into how decisions are made, expected utility theory fails on at least three counts. First, people do not structure problems as holistically and comprehensively as expected utility theory suggests. Second, they do not process information, especially probabilities, according to the expected utility role. Finally, expected utility theory, as an "as if" model, poorly predicts choice in laboratory situations. Hence, it is doubtful that the expected utility theory should or could serve as a general descriptive model. (Schoemaker [1982], p. 552)

A comparably pessimistic view of the prospects for the expected utility framework can be found in Slovic and Lichtenstein's [1983] interpretative evaluation of the evidence on the extent of preference reversals in the literature. They concluded by calling for a radical modification in the expected utility framework. More specifically, they observed that

> This review has attempted to show how preference reversals fit into a larger picture of information-processing effects, that as a whole, pose a collective challenge to preference theories for exceeding that from reversals alone. These effects seem unlikely to disappear, even under rigorous scrutiny. Moreover, anything less than a radical modification of traditional theories is unlikely to accommodate these phenomena. (Slovic and Lichtenstein [1983], p. 603)

These are two of a number of examples of the criticisms of the expected utility framework that could be cited based on the contradictions to it observed in laboratory experiments involving individual decisionmaking under uncertainty. While the typical advocate for the expected utility model can always argue that the laboratory is not the real world and that a contradictory performance pattern in the former does not necessarily imply the same for the latter, this position has nonetheless become an increasingly difficult one to adopt. Indeed, as Machina [1983] has observed in discussing a similar criticism of the results from experiments that did not involve real money,

> if the primary defense of the expected utility mode as a real world descriptive model rests on the presumed "rationality" of the typical economic agent, it seems odd to then assert that such agents are not rational or competent enough to correctly state how they would behave in some simple proposed choice situations. (Machina [1983], p. 90)

There has been a growing tendency to argue that analyses involving the expected utility model are purely theoretical and to "apologize" for its use in empirical analysis. Since our theoretical analysis as well as our specification of hypotheses and models for analysis with the survey results will begin from conceptual analysis of individual behavior based on the expected utility framework, it is important to review these experimental violations and to consider how they might influence our research efforts.

Machina [1983] has recently prepared a detailed state-of-the-art appraisal of the theory of individual behavior involving risk including a careful appraisal of this experimental work. Our review will be based in large part on his work, supplemented by the earlier work of Schoemaker [1980, 1982], Slovic and Lichtenstein [1983], and others who are identified as they become relevant.

Evaluations of the expected utility model have tended to focus on two axioms--the independence axiom, the most specific assumption in terms of its effect on the model--and the transitivity axiom. The examinations of independence have found a wide variety of conditions that appear to lead to violations. For example, a common outcome is that consistent ratios of probabilities across pairs of prospects can lead to violations of choices that would have been expected based on the expected utility framework. Equally important, experimental behavior exhibits responses that are overly sensitive to changes in low probabilities for extreme or outlying events, a result that is inconsistent with the independence axiom. The violation of the independent condition is important because it is crucial to our ability, using expected theory, to recover the Von Neumann-Morgenstern utility function. Under this theory, all legitimate recovery methods should yield the same utility function up to a positive linear transformation. Yet, a number of studies have found contradictions to this result. Equally important, violations have been found with the transitivity assumption, with the most important of these involving preference reversals. These reversals arise in the rankings individuals assign to risky prospects in comparison to the certainty equivalents they describe to be relevant to those prospects. Clearly, these findings are important for any attempt to measure empirically the values of reducing hazardous waste risks.

The most relevant question for benefits measurement is: How does one proceed in light of the empirical evidence for expected utility theory? Rather than consider the specific details of each of the types of experiments that have led to this questioning of the expected utility framework, we accept findings at "face value." Yet, we do not conclude that the framework is irrelevant for describing behavior under uncertainty. There are several reasons for this conclusion. First, all of the models have been based on a state-independent specification for the utility function. Once this assumption is changed, predictions concerning real world responses become much more difficult. Arrow [1974] anticipated this conclusion in his discussion of the role of state dependency of the utility for the insurance decisions of households. Indeed, he observed that the state-dependent specification for utility posed significant problems for the behavioral interpretation of probability. Specifically, he noted that

> The expected utility theorem or hypothesis, especially in conjunction with the Bayesian concept of subjective probability, implies the meaningful separation of tastes (as represented by the utility func-

> tion) from beliefs (as represented by probabilities). But in the form (3) [the state-dependent specification], this separation is no longer operational... No set of observations can distinguish the probabilities from the utilities. (Arrow [1974], p. 6, n.1.)*

Unfortunately, this potential explanation for observed violations has not been considered in any of the literature that is critical of the expected utility framework.† This is surprising since all of the proposed alternatives address the violations by specifying decision frameworks in which the separation of tastes and probabilities is also not really preserved.

Of course, we would not want to "over interpret" the importance of state dependency for the simple laboratory setting. In most of these cases, potential sources of state dependency for individuals' utility functions cannot be identified. Winning or losing is not a sufficient explanation. Thus, state dependency offers, in our judgment, a more plausible explanation for violations observed in real world settings.

There are alternative explanations short of the "radical modifications" called for by Slovic and Lichtenstein [1983]. Indeed, they build upon much of the research in psychology on risk-taking behavior. This work has tended to call for models that replace either or both of the tastes/probability formation dimensions of the expected utility framework. For example, the assumption of cognitive limitations to decisionmaking has often led to the acceptance of a model that assumes bounded rationality to describe individual behavior. Individuals are postulated as using simplified models of complex processes or decision circumstances and as acting according to those models. These frameworks could be consistent with probability assessments as they have been used in the expected utility framework. Clearly, this interpretation is consistent with the recent results of Viscusi and O'Connor [1984] with respect to compensating wage differentials and job risks.

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*Arrow attributes this insight to an unpublished paper by Herman Rubin.

†Machina's [1982] work comes closest to identifying this point. His paper on the expected utility framework without the independence assumption analyses behavior in response to distributions of probability mass defined over payoffs rather than states and does recognize that the assumption of the equivalent of a state dependency would be one means of establishing consistency between the violations to the independence axiom and a reformulated expected utility hypothesis.

Alternatively, we might assume individuals utilize judgmental heuristics (Tversky and Kahneman [1974]) to appraise probabilities. In this case, assessments of probabilities for specific events or outcomes depends on how representative the event is, the availability of information, and use of the most familiar aspect of the event to form an initial judgment with subsequent adjustment based on its other aspects.*

Both of these views of individual decisionmaking are part of a process of trying to model how individuals process information. In our view, this processing need not be inconsistent with the expected utility framework. Analysts may simply have done a poor job at communicating the experimental conditions or the problems at risk with respondents. In the real world, some situations involve repeated experience with uncertain phenomenon. With repeated trials, individuals are likely to improve their ability to form assessments of probabilities, and we would therefore expect this experience to influence the results of evaluations of the expected utility model. By contrast, in the context of laboratory experiments, the same opportunities for learning are usually not available. Consequently, the analyst must communicate the information to participants to assure that this information can be acted upon in ways that are comparable to decisions in the real world.

To deal with this requirement in our own analysis, we report in Chapter 8 the results of an extensive set of discussion, or focus group, sessions conducted as a part of the process of questionnaire development. These activities were used to determine the wording, the methods for explaining probabilities, and the events at risk. They build on the experience of psychologists in their attempts to model decisonmaking under uncertainty but do not dismiss the expected utility framework. They were an essential dimension of the research design and were required to respond to these violations to the expected utility framework.

3.6 SUMMARY

This chapter has provided a brief review of the state-preference approach to modeling individual behavior under uncertainty. This framework offers the

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*See Wallsten [1980] for a comparative analysis of the psychological approaches to decisionmaking under uncertainty.

most flexible approach for evaluating the role of risk in decisionmaking. States of nature can be defined to conform to the specific features of each problem. The individual is viewed as planning consumption contingent upon which of these states is realized. The constraints to these plans define the opportunities the individual has to adjust to the risk posed by uncertainty in the state of nature.

Our review has largely focused on the expected utility model to describe individual behavior. Within this framework we have considered the implications of how individual preferences and constraints are defined. Since most of the literature has adopted a state-independent specification of preferences and implicitly adopted the case of actuarially fair markets as a reference point, the analysis in this chapter has considered the effects of modifications in this assumption for the expected utility description of behavior.

Two points are especially relevant to the empirical analysis reported later in this volume. First, conventional measures of the extent of risk aversion have been based on state-independent preferences and have implicitly maintained a specific institutional mechanism for adjustment to risk. When both state-independent preferences and fair markets are maintained, the restrictive nature assumptions used to define the Arrow-Pratt index of risk aversion is not as easily identified. However, once each of these assumptions is relaxed, the definition of risk premia associated with actuarially fair gambles will depend on what is treated as the reference point and the opportunities the individual is assumed to have available for adjusting to risk.

Second, the violations to the expected utility framework's assumptions found in experimental studies do not necessarily imply it is an inappropriate basis for organizing our survey results. We have argued that these findings imply the approach used in our questionnaire and survey must reflect an understanding of how to communicate risk and changes in risk to individuals. Moreover, these findings provide support for the adoption of a state-dependent specification of preferences. All of the tests of axioms of the expected utility framework have maintained a state-independent specification for individual preferences. As Arrow observed, state dependency, by eliminating the separation of tastes and beliefs, provides a mechanism for accommodating most of the informal and formal models of individual decisionmaking proposed as alternatives to the expected utility framework. Of course, it is simply a reflection of our ignorance. Until we can specify the factors that lead to state-dependent preferences and identify how they affect the marginal utility of income, we do not have a framework that offers sufficient understanding of individual decision-making to permit predictive evaluation of individual responses to risk. Consequently, one dimension of our empirical analysis will be to identify the attributes fo risk that might affect how individual preferences vary with the states of nature associated with our problem--the management of the disposal of hazardous wastes.

CHAPTER 4

THE ROLE OF THE EX ANTE AND EX POST PERSPECTIVES IN MEASURING WELFARE CHANGES UNDER UNCERTAINTY

4.1 INTRODUCTION

The need to value reductions in risk, which result from regulatory actions pertaining to hazardous wastes, has significant implications for trying to use conventional benefits measurement practices. In an attempt to address the most important of these implications, this chapter reconsiders the conventional practices of benefits measurement in the absence of uncertainty and then addresses the role of analytical perspective--i.e., ex ante versus ex post--for the process of measuring changes in welfare under uncertainty. Section 4.2 outlines the ways in which the effects of policy actions have been described in the past and how these effects would differ under conditions of uncertainty. Section 4.3 explores the applicability of the ex ante and ex post analytical perspectives for measuring the welfare changes from policy actions governing hazardous waste management. Section 4.4 defines use and intrinsic values within the ex ante framework, and Section 4.5 summarizes the implications of the ex ante framework for the definition of valuation concepts for risk reductions and further research on welfare measurement in the presence of uncertainty.

4.2 BACKGROUND

As it has been developed in applied welfare economics, the theory and practice of benefit measurement has largely been concerned with valuing goods or services under conditions of certainty. In evaluating the benefits associated with a regulation or other policy action, the practice has been to relate the action involved to some change in the prices facing individual households (and firms) or to the quantities of goods or services they consume under defined conditions of access.* Once these changes are described, valuation measures can be defined in a Marshallian (i.e., holding household income constant) or Hicksian (i.e., holding household utility constant) framework. As a rule, the household has been assumed to select its consumption choices in a world of certainty, and the policy change itself is assumed to be certain. Of course, most of the specific applications of benefits analysis have acknowledged the difficulties associated with translating the specific policy decision into an implied price or quantity change. In some cases, these difficulties have led to efforts to define a range of scenarios in an effort to capture the uncertainties inherent in describing the intervening mechanism that connects the policy to the outcome. Indeed, the use of scenarios designed in this way has come to be accepted as one way of reflecting the implications of this form of uncertainty for the results of benefit-cost analyses.

This kind of uncertainty might be called planner's or policy uncertainty. Analytical models and concepts such as statistical decision theory, the value of information, and quasi-option value have been developed to help policy analysts deal with this type of uncertainty. In particular, these methods attempt to develop approaches to organize information and decision rules that explicitly take account of the uncertainty concerning the magnitudes of variables relevant to their decisions (e.g., benefits and costs). However, none of these analytical tools recognizes that individuals will modify their decisions in the presence of uncertainty. Consequently, uncertainty facing economic agents can affect how they will value the services (or price change) delivered by a policy.

In this chapter, we develop a working description of <u>individual uncertainty</u>--that form of uncertainty faced by individuals who are users or potential users of an environmental resource. For example, individual users of a

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*The term <u>conditions of access</u> in this context refers to how the individual is allowed to use a resource. Where private firms do not decide the amounts to be available (e.g., a government agency providing "protection" from risks of exposure to hazardous wastes through regulations), conditions of access can involve nonprice rationing conditions and/or uncertainty over the levels available for any specified set of terms. This means that an individual might be viewed as bidding for an improved likelihood of realizing some desirable state. Mäler [1984] has recently demonstrated that a change in the probability of some desired state characterized in terms of having more of some environmental amenity (or other commodity) can be treated as equivalent to a change in the quantity of the amenity with unchanged odds.

contaminated groundwater aquifer may face a higher probability of developing cancer. Similarly, individuals may also be uncertain whether a particular unique and irreplaceable environmental resource will be available for their use at some future date, or they may be uncertain whether they will actually want to use that resource in the future.

To consider the implications of this type of uncertainty, we need to specify the model describing how household choices are made in the presence of the uncertainty of interest and then evaluate the welfare implications of the proposed changes within it. That is, the analytical problem is to explicitly incorporate uncertainty in the models of individual choice and to deduce the implications of that uncertainty for the measurement of welfare changes associated with policies dealing with environmental resources. The resulting benefit measures will differ from those derived under the assumption of certainty.

As we noted in the preface to Part I, we have adopted the expected utility framework as the basis for describing individual choice under uncertainty. Based on this framework, Chapter 5 develops the specific benefit measures proposed for valuing reductions in the risks of exposure to hazardous wastes. However, before proceeding to a discussion of these proposed benefit measures, it is important first to consider the implications of individual uncertainty for existing benefit analysis and the analytical perspective used in benefit analysis.

Most conventional analyses have described policies in terms of changes in either prices or quantities (because these have been the basis used to define the available welfare measures). Using this type of approach to incorporate individual uncertainty would require that we specify a model of individual decisionmaking under uncertainty to describe how individuals would value some changes in the price or quantity of an environmental resource under these circumstances and then use it to evaluate the policy-induced change. Alternatively, we might describe the policy as changing the nature of the uncertainty itself. In this case, we would be focusing on a set of new parameters that are added to the exogenous factors that affect household behavior with the introduction of uncertainty--namely, the probabilities of the states of nature. These probabilities could reflect the individual's uncertainty as to the vector of prices in alternative states of nature, the incomes to be received in alternative states, or the magnitude of some other state variable describing conditions that are important to an individual's utility, including health status, availability of an environmental resource, and so forth.*

The second aspect of this reconsideration concerns the measure of individual welfare--what we have designated the "perspective for welfare analysis," ex ante or ex post?† An ex ante perspective is one in which we view the individuals as planning actions that he would take contingent upon the state of the world. It may be tempting to suggest that, in an ex ante framework, a measure of the change in an individual's welfare as a result of a policy increasing the likelihood of some desirable outcome is the individual's willingness to pay for the change before the uncertainty over states of nature is resolved. Indeed, several studies have used this convention (e.g., see Jones-Lee [1974]). However, this definition makes a subtle assumption. When we consider an individual's planned consumption, we define those plans for each state of nature. That is, consumption choices are described as contingent in that they suggest what the individual would plan to do as if the state of nature were realized. By specifying a constant willingness to pay, we are implicitly assuming it will be made irrespective of the state of nature. Therefore, this very definition includes an assumption about the mechanisms constraining how an individual can plan. If plans involve contingent consumption choices, there is no reason that we cannot define contingent payments--the payments an individual would be willing to make in each state of nature if the policy was implemented. Indeed, the appropriate welfare change measure would be the set of payments with the policy that yielded the same expected utility available without the policy and without the payments. Of course, there is not one such set of payments but an infinite set of payments. Indeed, this is simply one description of the Graham [1981] willingness-to-pay locus.

How, then, does one define a welfare change in an ex ante framework? It would seem that the definition itself requires an assumption with respect to what characterizes the institutions available for individual adjustments. In short, what are the constraints to how these payment vectors might be defined?

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*This is consistent with the approach adopted by Cook and Graham [1977] and more recently proposed by Simmons [1983].

†This question was first raised in the context of environmental regulation by Smith and Desvousges [1983].

Once this is specified, the appropriate welfare measure is the change in the planned expenditures required to realize a constant expected utility under the policy compared to the planned expenditures required for that level of utility without the policy. Clearly, that expenditure function is defined conditional upon the specification of mechanisms constraining the state-dependent payments.

By contrast, an ex post definition requires two analyses to define the willingness to pay. The first considers an individual's willingness to pay for the outcomes implied by the policy action under each of the possible states of nature. These evaluations must be conducted with each outcome considered as a choice <u>in the absence of uncertainty</u>. The second step involves the calculation of the expected value of these individual state-specific welfare measures--i.e., generally, the expected value of the compensating surplus values associated with each state.

It should be clear that these two perspectives on the treatment of uncertainty (i.e., ex ante and ex post) need not yield the same valuation estimates.* One important element affecting differences in these valuation estimates is the set of opportunities available for diversifying risk. An individual's valuation of a change in the probability of some adverse event will depend upon the extent to which the event can be insured against.† For example, if the events can be expressed exclusively in financial terms, a risk-adverse individual, with access to actuarially fair insurance, will insure until he is indifferent to the outcome (in ex ante terms).‡ These two features are further discussed in Section 4.3 below.

Use values have generally been defined as some form of consumer surplus (either Marshall's consumer surplus or the Hicksian compensating or equivalent measures). These are ex post measures of benefits. By contrast, the timeless

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*As we show in Section 4.3, it turns out that much of the controversy over option value can be interpreted as a question of perspective. See Bishop [1982] and Smith [1983] for recent reviews of the option value problem. The question of perspective has considerable relevance to the controversy over estimating the value of "statistical lives." See Ulph [1982] for further discussion.

†This point was clearly demonstrated by Cook and Graham [1977].

‡This conclusion assumes state-independent utility functions.

definition of option price is based on an ex ante perspective. Therefore, one component of the nonuser benefits, the option value, actually mixes these two perspectives by decomposing the option price into the expected consumer surplus and the option value. This mixing of perspectives arises because measures for distinct components of the total benefits derived from environmental resources have been defined from what are fundamentally different models of the individual's decision process. Yet the results are treated as if they were fully compatible. In the next section we present an introduction to the issues associated with classifying the types of benefits within an ex ante framework.

4.3 EX ANTE VS. EX POST PERSPECTIVES

An ex ante social welfare function makes social welfare a function of the expected utilities of the individuals in the society, while an ex post social welfare function makes social welfare equal to the expected value of the social welfares realized in alternative states of nature. The choice of an ex ante versus an ex post welfare measure involves fundamental questions of welfare theory--in particular, the role of equity in societal welfare and the way equity is defined. Broadly speaking, ex ante social welfare functions reflect a social concern with the equity of opportunity in the expected value sense, while ex post social welfare functions reflect a concern with the equity of outcomes.

Consider a society that has adopted a social welfare function reflecting its ethical judgments concerning equity and has undertaken the redistributions of wealth and/or taxes and transfer payments necessary to achieve a social welfare maximum at some given point in time. Suppose also that new investment opportunity is being considered that would alter the distribution of incomes and utilities in different ways in various states of nature. If the project is undertaken, then society will wish to levy taxes and make compensating payments to restore the optimum distribution of outcomes after the state of nature has been revealed. The consumer surplus changes provide a basis for determining the required taxes and compensation, and the expected value of aggregate consumer surplus is an indicator of whether the payments can be made without making anyone worse off.

Now let us assume that the society has chosen an ex ante social welfare function. Thus, the focus of attention for benefit-cost analysis is changed to expected utilities and their monetary equivalents. How are these monetary equivalents to be measured? Option price is only one of many possible ways of defining a monetary equivalent for a change in expected utility. We will show that the appropriate way of defining the monetary equivalent depends upon particular circumstances, including the opportunities for diversifying risks through contingent claims markets and the institutional feasibility of enforcing alternative contingent payment schemes.

The expected value of consumer surplus is an ex post measure in that it focuses on the realized outcomes of policy choices. Evaluating policies in terms of the planned expenditures required to maintain a constant expected utility, which may reflect risk aversion, is the basis for ex ante welfare measurement. Option price is an ex ante measure of the increment associated with planned expenditures under one institutional framework for making state-specific payments. In particular, it is that state-independent payment that makes the expected utility with the policy exactly equal to the expected utility without the policy.

The presence of uncertainty for measuring individual welfare creates distinctions between ex ante and ex post perspectives analogous to those discussed by Ulph [1982] and discussed above for the specification of society's welfare function. To illustrate these differences in specific terms, consider the ex post case and the conventional description of consumer choice, where individual decisions are assumed to be made under conditions of certainty. In this setting we can describe the individual as minimizing the expenditures made on all goods and services to realize a given utility level. If X_i describes the consumption of the ith commodity, P_i its price, and $U(X_1, X_2, \ldots, X_n)$ the individual's utility, then Equation (4.1) defines the expenditure (or cost) function for the individual:

$$E(P_1, P_2, \ldots, P_n, \bar{U}) = \text{Min} \left[\sum_{i=1}^{n} P_i X_i \,\middle|\, \bar{U} = U(X_1, X_2 \ldots, X_n) \right] . \quad (4.1)$$

Two further assumptions must be made. First, we will assume that the resource is a nonmarketed good, some of whose services are available without any need to travel or otherwise gain access to them. Second, we will assume there is at least one observable (and implicitly priced) measure of the use.

Adding an argument (Q) to U(.) for the resource's contribution to satisfaction that is disassociated with the individual's use of it satisfies the first requirement, and selecting one or more X_i's as measures of use is consistent with the second.

If there is only one measure of "priced" use, say X_1, then the compensating variation (CV) measure of the value of the site when the level available of the resource is $\bar{Q}$ is given in Equation (4.2):

$$CV = E(P_1(\bar{Q}), P_2, \ldots, P_n, \bar{Q}, \bar{U}) - E(P_1, P_2, \ldots, P_n, \bar{Q}, \bar{U}) . \quad (4.2)$$

Introducing Q into the utility function together with the specification of a fixed level of the resource that is available for uses not necessarily reflected in X_1 (namely $\bar{Q}$) leads to the expenditure functions in Equation (4.2). Compensating variation is the difference in the expenditures that would be made at the "choke," $P_1(\bar{Q})$ (i.e., the price at which $X_1 = 0$), and those at the actual price, P_1, for a given level of utility, given values for all other prices and $\bar{Q}$. It is the maximum amount an individual would pay for the lower price of X_1 (i.e., from P_1 $(\bar{Q})$ to P_1). It is important to note that the choke price for X_1 is assumed to also be related to the level of $\bar{Q}$.

It is also possible to use the framework to describe other motivations for valuing the resource, $\bar{Q}$--the nonuser or intrinsic values that individuals might realize as a result of the existence of the resource amenities at particular levels or the increments to these values because of increments to the resources. This distinction has played an important role in the classification of the benefits associated with changes in environmental resources, and we will return to it in the next section and in Chapter 6. Our objective here is to compare the ex ante and ex post perspectives for welfare measurement. Thus, consider the description of a measure of change in ex ante well-being. Here we will also use a different type of expenditure function. In this case, the individual is viewed as planning consumption so that each commodity is defined as a claim for consumption of that commodity contingent upon realization of a state of nature. Following the same format developed in Chapter 3, we have the planned expenditure function (given state-dependent preferences) defined as follows:

$$\bar{E}(P_{11}, P_{21}, \ldots, P_{K1}, P_{12}, P_{K2}, \ldots, P_{1N}, \ldots P_{KN};$$

$$\pi_1, \pi_2, \ldots, \pi_{K-1}, 1 - \sum_{i=1}^{K-1} \pi_i; \overline{EU}) = \tag{4.3}$$

$$\text{Min} \left[\sum_{i=1}^{K} \sum_{j=1}^{N} P_{ij} X_{ij} \,\middle|\, \overline{EU} = \sum_{i=1}^{K} \pi_i U_i (X_{i1}, X_{i2}, \ldots, X_{iN}) \right],$$

where

X_{ij} = contingent claim to commodity j in state i

P_{ij} = the prices of contingent claims (the s_{ij} in the notation of Chapter 3).

Equation (4.3) is simply a generalization of the two-commodity, two-state case developed in Chapter 3. In this case, there are N commodities and K states. If we assume a complete set of markets for contingent claims, there are N·K such prices.

To define option price in this framework, however, we must make some additional assumptions. In particular, if we assume that Q enters at least one of the state-dependent utility functions and that X_{i1} designates the state-dependent, planned consumption of use of Q, then option price can be defined in terms of the expenditure function (with Q as an argument) given in Equation (4.4):

$$OP = \bar{E}(O, P_{12}, P_{22}, \ldots P_{K2}, \ldots, P_{1N}, P_{2N}, \ldots, P_{KN};$$

$$\pi_1, \pi_2, \ldots, 1 - \sum_{i=1}^{K-1} \pi_i; O; \overline{EU})$$

$$- \bar{E}(O, P_{12}, P_{22}, \ldots, P_{K2}, \ldots, P_{1N}, P_{2N}; P_{KN}; \tag{4.4}$$

$$\pi_1, \pi_2, \ldots, 1 - \sum_{i=1}^{K-1} \pi_i; \bar{Q}; \overline{EU})$$

Two points should be noted in this definition. A zero value for Q (as in the first term on the right side of Equation (4.4)) is assumed to imply that no use of the resource can take place when Q = 0. Q must be positive for use to take place. In this case, the option price is for a level of $\bar{Q}$ of the resource. Also the price of use in any state, P_{i1}, has been assumed to be zero in all states. We will argue that this is consistent with the original definition of the option price. It precludes state-dependent payments for use of the services of the resource. However, it should be acknowledged that our original definition of option price was unclear about the per-unit charges for the use of the resource. Under one interpretation, only a constant price for X_{i1} over all states of nature is required. While this would hold constant the per-unit charge for across states, planned total expenditures for use would be state dependent because the planned state-dependent consumption levels could vary. This would seem to violate the intentions of the original definition of the option price. Alternatively, it could be suggested that the payment of an option price was only to ensure access. Therefore, under this view, one would define the option price as the payment for access. The fact that payments for consumption levels would be state dependent does not in this case affect the constancy of the payment for access and the definition of option price as a statement independent payment for access. Either assumption can be accommodated in our analysis. Regardless of the view of the process that describes how the resource is allocated (i.e., one payment for guaranteed access and then payments for use or simply a payment for use), the basic point of the analysis remains unchanged.

With this background, it is now possible to use the two types of expenditure functions in the definition of the option value (OV). The conventional definition for option value is given in Equation (4.5):

$$OV = OP - \sum_{i=1}^{K} \pi_i \, CV_i \ . \qquad (4.5)$$

Substituting from Equation (4.4) for the option price (assuming the price for planned use is constant at zero), we have

$$OV = \bar{E}\ (O;\ \bar{P},\ \bar{\pi};\ O;\ \overline{EU}) - \bar{E}\ (O;\ \bar{P};\ \bar{\pi};\ \bar{Q},\ \overline{EU}) - \sum_{i=1}^{K} \pi_i\ CV_i\ . \qquad (4.6)$$

To reduce the complexity of the notation, we have represented the set of zeros for the prices of contingent claims to X_1 with a single zero, the prices of other contingent claims with $\bar{P}$, and the set of probabilities with $\bar{\pi}$.

We can also replace each of the CV_i's in Equation (4.6) using their definition in terms of the ex post expenditure function (e.g., Equation (4.2)). That is, we repeat the process defining the ex post expenditure function with each state-dependent utility function, derive the corresponding expression for CV_i, and substitute each expression in Equation (4.6). Option value, OV, is now given as Equation (4.7):

$$OV = \bar{E}\ (O;\ \bar{P},\ \bar{\pi},\ O,\ \overline{EU}) - \bar{E}\ (O;\ \bar{P};\ \bar{\pi};\ \bar{Q},\ \overline{EU})$$
$$- \sum_{i=1}^{K} \pi_i\ [E_i(P_1(\bar{Q}),\ P_2,\ P_3,\ \ldots,\ \bar{Q},\ \bar{U}) - E_i\ (P_1,\ P_2,\ \ldots,\ \bar{Q}\ \bar{U})]\ . \qquad (4.7)$$

Equation (4.7) illustrates how option value mixes two perspectives for individual decisionmaking. The first is the planned or ex ante view of consumption, while the second utilizes the ex post orientation in defining benefits from use of the resource. This conclusion that option value mixes perspectives is unchanged if we assume that consistency requires we assume that the actual price for use of the services of the resource (i.e., P_1) is nonzero.

To illustrate the importance of the difference, consider an alternative definition for user values based on the expenditure function associated with planned consumption. Letting X_{i1} designate the contingent claim associated with use in the ith state, the value of planned use would be the difference in expenditures when the prices of the contingent claims for X_1 are at the choke levels for planned consumption and the expenditures are at existing prices, as in Equation (4.8):

$$CV_p = \bar{E}(P_{11}^{c}, P_{21}^{c}, \ldots, P_{K1}^{c}, P_{12}, \ldots, P_{KN}; \pi_1, \pi_2, \ldots, 1 - \sum_{i=1}^{K-1} \pi_i; \bar{Q}; \overline{EU}) - \bar{E}(P_{11}, P_{21}, \ldots, P_{K1}, P_{12}, \ldots, P_{KN}; \pi_1, \pi_2, \ldots, 1 - \sum_{i=1}^{K-1} \pi_i; \bar{Q}; \overline{EU}) . \quad (4.8)$$

With state-dependent preferences we do not, in general, expect that CV_p will equal the expected compensating variation calculated ex post from each utility function (i.e., $CV_p \neq \sum_{i=1}^{K} \pi_i CV_i$). The difference between option price and the planned consumption value appears to offer yet another potential definition for option value. However, this interpretation is misleading. CV_p describes planned user values under one set of institutional arrangements for the contingent claims, including those that have been identified to be associated with use of the resource (i.e., the X_{i1}'s). These institutions are not compatible with either definition of the option price.

We could, of course, modify our definition of the option price and assume it was defined with constant, but nonzero, prices per unit of use (i.e., P_{i1} = constant for all i). Of course, without payment of the option price, no consumption would be possible. In this case, we have a different value for the option value. It is also important to acknowledge in evaluating this definition that it appears to be similar to the McConnell [1983] definition of existence value. In comparing these two definitions, option price plays a role analogous to the total value of the resource. However, there is a difference that again reflects the importance of the opportunities for adjustment. Our definition of CV_p allows the prices of claims to X_1 to vary with the state of nature. The definition of option price precludes this possibility since it assumes they are either all zero or all constant.

The difference between option price and use value based on the expenditure function derived from planned consumption choices is not an option value. It is a reflection of both nonuse values and the institutions we assume are available to individuals. Equally important, it highlights an additional dimension of modeling individuals' behavior under uncertainty and the implications of these models for benefits analysis. Basically, this issue relates to the reference point at which we initiate the analysis.

Option value, as conventionally defined, compares the option price with a point on the income certainty locus that is defined by the expected consumer surplus. It compares two institutional regimes--one with uncertainty where the option price is paid and another where there is no uncertainty in the decision process. Benefits are constant at the expected consumer surplus. This point is easily seen using Graham's [1981] willingness-to-pay locus. This function offers an alternative means (to the expenditure functions defined earlier) for illustrating the implications of institutions for adjustment. Figure 4-1 reproduces Graham's discussion of option price and option value. Option price is compared with the expected surplus as a certainty concept. The reference point is one of a certain income given by E(S), or $\Sigma \pi_i CV_i$ in terms of our notation. This may seem to be a natural reference point because it was the one used in nearly all work following the Arrow-Pratt analysis of risk aversion. While it may be natural from an analytical perspective, it is not a natural reflection of the world in which these choices must be made. Graham [1981] provided a similar argument in his critique of the attention given to the sign and magnitude of option value. He observed that

- Option price is the appropriate measure of benefits in situations involving similar individuals and collective risk.
- Expected value calculations are appropriate to situations involving similar individuals and individual risk.
- Whether or not option price exceeds the expected value of surplus is largely irrelevant to the evaluation of risky project. [Graham, 1981, p. 716]

Graham's analysis adopted an ex ante perspective and focused on the types of institutions available for adjustment to risk. Expected value measures of benefits were specified as appropriate for individual risks because his analysis also assumed that in these cases there existed actuarially fair insurance. It is important to recognize that his argument was not advocating the use of the expected consumer surplus as the benefit measure in this case but, rather, the

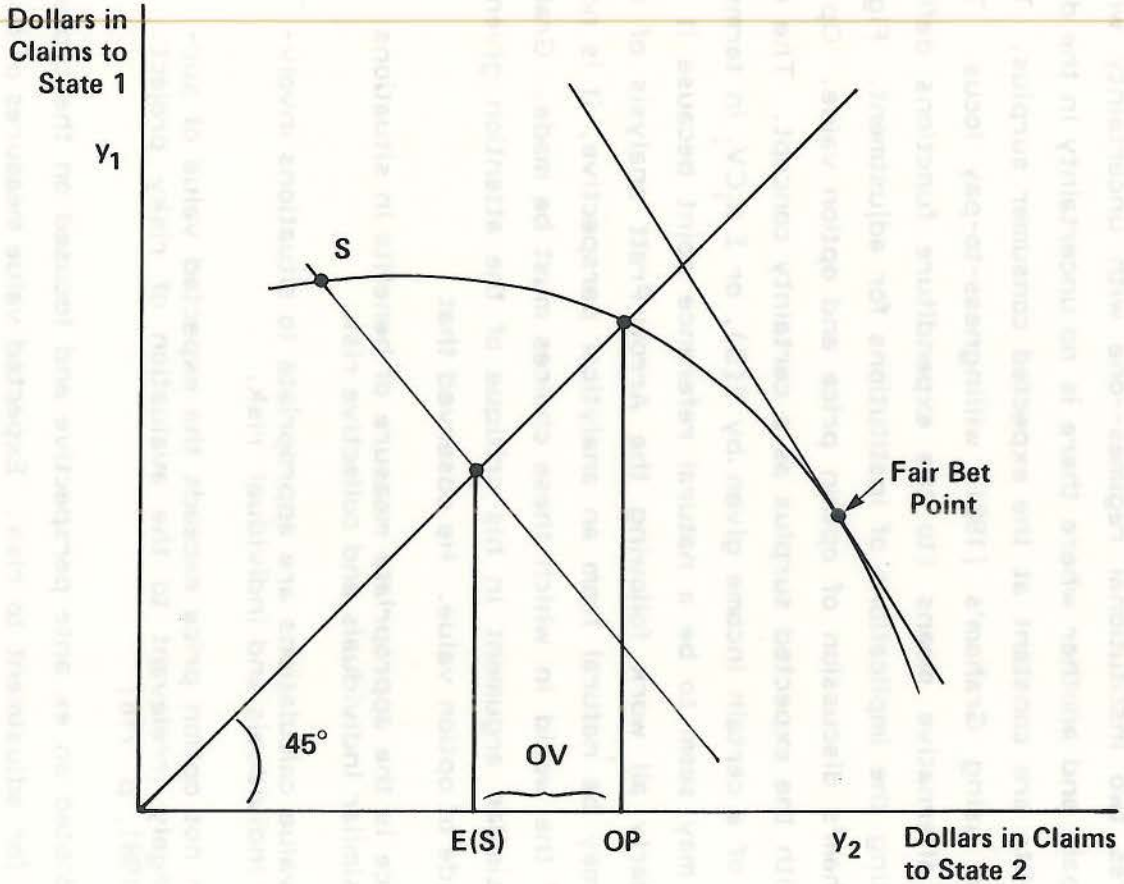

Figure 4-1. Graham willingness-to-pay locus and option value.

expenditures associated with the fair bet point. In the presence of state-dependent preferences, this point would not fall on either the income certainty or the utility certainty loci. It would correspond to the expected expenditure on the contingent claims associated with each commodity and state of nature.

Thus, in developing a benefits taxonomy, it is important to clearly identify the perspective used in describing individual behavior because it is directly relevant to any evaluation of actions designed to affect that behavior. This discussion has suggested that the choice depends on the reference point from which we start the analysis and the mechanisms we assume are available to the individual to adjust in response to risk. Once we propose to evaluate a policy that changes the risk an individual faces, then the ex ante framework is the appropriate basis for defining the benefits associated with that policy, since it corresponds to how the individual would have to make the valuation decision in judging the action in advance. Of course, this judgment in itself does not imply the option price is the relevant concept.

Option value is a valuation measure that compares an uncertain situation with a certain reference point. The reference point is defined in terms of income certainty and presumably is of interest because of the history of the development of measures of risk aversion.

Once the ex ante perspective is accepted and it is acknowledged that individuals' decisions do not take place in circumstances that begin with certainty, then benefit measures must be defined in terms of our planned expenditure functions. These functions can be defined to reflect all the risks faced by the individual and the mechanisms available for adjustment. Option price is seen (as in Equation (4.4)) as one valuation concept based on specific institutions and risks. Moreover, policies can be considered to change either the level of availability of the resource (as in our definitions thus far) or the probabilities of specific states of nature. Moreover, this analysis need not assume that the risks are limited to those specifically associated with the policies under study. Risks can be added to existing uncertain income streams. Consequently, an income certainty reference point may not be of practical relevance. Even for analytical purposes--to measure the extent of risk aversion--comparison of the risk premia (i.e., the payment over the expected value to avoid risk) of different individuals need not be equivalent to the ordering implied by the Arrow-Pratt index of risk aversion when background risk is present.

4.4 USER AND INTRINSIC VALUES IN AN EX ANTE FRAMEWORK: AN INTRODUCTION

The analysis of the previous section argues that the relevant basis for valuation is the planned expenditure function (i.e., Equation (4.3)). In the process of defining the option price we have introduced two ways in which an environmental resource can affect planned expenditures--through planned uses (i.e., the contingent claims for X_1 in all states of the world) and through the availability of the resource itself (i.e., the presence of Q in the expenditure function). This specification opens the prospect for distinguishing benefits into categories according to whether they are associated with planned use or independent of those plans.

To define these components in an ex ante framework with uncertainty is somewhat more complex than in the certainty case. First, we must identify the nature of the conditions of access to the resource and the institutions available for adjustment. Second, we must specify the nature of the change to be evaluated. Given this information, it is possible to specify the user and existence or intrinsic components of the value of the policy. Before proceeding to develop these in specific terms, it is important to highlight a key difference between this case and classification of use and existence benefits under certainty. In the certainty case, the use benefits are often capable of being measured from the actions of individuals. That is, they can be indirectly inferred as a result of the actions of individual economic agents through their use. By contrast, the existence values are usually not observable, since they do not involve tangible (or at least observable) actions by these agents. Thus, we would want to identify the distinction to recognize that benefit estimates based on use may well understate the full benefits provided by the resource.

The same arguments are more difficult to apply in the ex ante framework, where all actions are planned. We do not observe the plans. While we shall argue that these plans may be associated with observable actions in our discussion of the relationship between estimates of the value of risk based on hedonic property value studies and the survey-based estimates, the full details of these plans will not be known. Assumptions must be used to substitute for observed behavior in attempting to understand the motivations for behavior. Consequently, it is not clear that the distinction is as meaningful or desirable. In effect, if we are to estimate individuals' valuations in an ex ante framework, we may have to rely on direct survey methods. It is not clear that we can successfully elicit individuals' values and request that these values be assigned to specific motivations. While one can argue that this is an empirical question, this argument in itself may be misleading. We will not know the true values for benefits in this ex ante framework; thus, it is not clear that we can judge whether an analysis leads to a meaningful separation of the two types of benefits.

With this background it is now possible to use the ex ante framework to propose a general approach for classifying benefits. In Chapter 6 we return to this classification in relation to the classification of user and existence values under conditions of certainty. Planned user benefits, PUB, can be defined in general terms using Equation (4.9):

$$PUB = \bar{E}\ (\bar{P}_1\ (\bar{Q});\ P;\ \bar{\pi};\ \bar{Q},\ \overline{EU}) - \bar{E}\ (\bar{P}_1;\ \bar{P};\ \bar{\pi};\ \bar{Q},\ \overline{EU})\ . \qquad (4.9)$$

We have used the same notation for summarizing the prices of contingent claims (separating the prices of the claims associated with use) from those of other commodities, and $\bar{P}_1(\bar{Q})$ represents the vector of choke prices--where planned consumption would be zero in all states. The existence value (planned existence benefits, PEB) would compare expenditures with no planned use with those when there was none of the resource available, as in Equation (4.10):

$$PEB = \bar{E}\ (\bar{P}_1;\ \bar{P},\ \bar{\pi};\ O;\ \overline{EU}) - \bar{E}\ (\bar{P}_1\ (\bar{Q});\ \bar{P},\ \bar{\pi};\ \bar{Q},\ \overline{EU})\ . \qquad (4.10)$$

It is important to point out that the assumed relationship between the measure of planned use X_{i1} and the level of the resource available is crucial to the interpretation of Equation (4.10). We have assumed that without $\bar{Q} > 0$ there can be no consumption of X_{i1} irrespective of the price. This implies that

$$\bar{E}(\bar{P}_1;\ \bar{P};\ \bar{\pi};\ O,\ \overline{EU}) = \bar{E}(\bar{P}_1(\bar{Q});\ \bar{P};\ \bar{\pi};\ O;\ \overline{EU})\ . \qquad (4.11)$$

Use is effectively precluded as it would be if the price were at the level of the choke price. Thus, PEB could also be written as follows:

$$PEB = \bar{E}(P_1(\bar{Q}); \bar{P}; \bar{\pi}; O; \overline{EU}) - \bar{E}(P_1(\bar{Q}); \bar{P}; \bar{\pi}; \bar{Q}; \overline{EU}) . \quad (4.12)$$

The sum of PUB and PEB corresponds to a planned counterpart to McConnell's total resource value. In this framework, however, we can consider a variety of amendments:

- Changing the terms of access to the resource. For example, these definitions might be recast with an option price that would hold all P_{ij}'s constant (either at a specified value or zero). This would imply the option price included both planned user and existence values.
- Changing the character of the description of the way in which policies affect how individuals gain access to the resource. This modification might imply a fixed Q but that policies change the probabilities of access (i.e., the π_i's). For these cases, it would also be possible to define use and existence values as well as to specify an option price.*
- Finally, we can expand the detail in the model by describing the source of uncertainty (i.e., identifying components to the π_i's). Within such a framework it is also possible to consider additions to risk as a result of changes in one of these components and valuation concepts for each type of change.

We return to consider in more detail the measurement of nonuse values associated with the reduction of risks to ecological systems in Chapter 6. In that chapter we develop in formal terms the benefit taxonomy under certainty and use a single institutional framework for adjustment, the option price, to discuss the measurement of these nonuser benefits.

4.5 SUMMARY

This chapter has discussed the implications of how we define valuation concepts. In the past, valuation or benefit concepts have mixed benefits defined under conditions of certainty with those defined to arise because of the

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*We return to this case in Chapter 6 by considering use and existence values in a framework where it is only possible to make constant state-independent payments for an improvement in the probability of a desirable state.

existence of uncertainty. Each of the two types of benefit, then, is defined under a different perspective on valuation. Should we consider valuation in terms of planned actions or only when these actions are undertaken?

We have argued that when the policies to be evaluated change one or more aspects of the risks facing an individual, then an ex ante perspective is warranted for welfare analysis. Within an ex ante framework two features are especially important to valuation concepts. The first is the reference point. Does the individual whose valuation is to be defined start from a position that has no other sources of uncertainty but the risk to be evaluated, or is the policy induced change simply an effect on one component of a number of risks faced? The second concerns the ability to diversify the risk. That is, what opportunities does the individual have to adjust to risk and ameliorate its effects?

Of course, these features are not independent. Moreover, the resolution of how one aspect is treated affects the others. For example, the definition of option value is based on selecting a certainty point for comparsion and on specifying a particular institutional system on how payments for claims can be made. Payments must be constant across states and the valuation concepts of interest, and in the size of the payment in relationship to the expected consumer surplus.

These features can be reflected in a planned expenditure function. Consequently, it is possible to define use and existence values (not option values) based on how a policy changes parameters important to these planned expenditures. This planned expenditure function allows one to evaluate the effects of institutions for adjustment as well as the nature of the change--prices, resource quality, or likelihood of access. Within each, one can define use and existence value concepts provided the resource is hypothesized to have two distinct effects on individual utility through use (that requires existence of a positive amount of the resource) and the level (or quality) of the resource itself.

CHAPTER 5

A CONCEPTUAL FRAMEWORK FOR VALUING RISK REDUCTIONS

5.1 INTRODUCTION

Chapters 2, 3, and 4 have set the stage for developing a conceptual basis for valuing the risk reductions that are assumed to accompany increased regulation of hazardous waste disposal. Chapter 2 introduced the overall problem by describing why the valuation of these regulations must be treated differently from the valuation of many other environmental policies. In the latter cases, it is often reasonable to maintain that a policy leads to a certain increment in some desired output--e.g., cleaner air in a specific region or improved water quality in a given river or lake. In contrast, given the uncertainty that surrounds both the disposal of hazardous substances as well as the ultimate effects of exposure to them, we cannot assume any policy provides a certainty of protection. We have argued that at best we can assume policies reduce the risk (i.e., the probability in our context) of some adverse outcome. Consequently, the development of a set of procedures for valuing policy outcomes requires specific consideration of how to model individual behavior under uncertainty. Chapter 3 provides a heuristic review of this literature.

With this description of the problems posed by any attempt to value policies associated with the disposal of hazardous wastes, and with our acceptance of the expected utility framework for modeling individual behavior under uncertainty,* one remaining question must be considered before defining the specific

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*This approach contrasts with one recently suggested by Weinstein and Quinn [1983b]. They observe that in light of the contradictions to the expected utility framework observed in individuals' decisions under uncertainty, it may well be reasonable to inquire as to whether they should be reflected in normative decision rules. More specifically, they describe this issue as a fundamental motivation for their evaluation of the models used to value changes in the risks to life, noting that

> The fundamental question raised in this paper is to what extent the contextual and psychological attributes of a risky decision have suf-

valuation concepts. This point has often been overlooked or confused. It concerns what we describe in Chapter 4 as the perspective for decisionmaking. That is, do we evaluate actions from an ex ante or planning perspective, or do we use individuals' values of the ex post outcomes? We have explicitly argued for an ex ante approach. With this perspective, changes in the probability of a detrimental event are valued based on the changes in planned expenditures an individual would undertake to maintain a constant level of expected utility.

Given this background, it is now possible to proceed to a description of how this chapter completes the conceptual analysis of one component of an individual's valuation of risk changes--the "use" component of these values. This chapter uses a simple two-state model to describe the specific features of the planned expenditure function described in Chapter 4 and discusses the importance of these features to the valuation of risk changes. Our example is now explicitly tied to the framework we have used to present the risks posed by hazardous wastes to individuals in our contingent valuation survey. The chapter also identifies the relationship between the model and what can be expected in an empirical analysis of individuals' valuations of risk changes.

Section 5.2 describes a simple two-state model to illustrate the valuation concepts and the role of the opportunities for adjustment that are available to the individual in influencing these values. Section 5.3 relates the model's implications to the psychological literature describing how individuals make decisions under uncertainty. This section also reconsiders the review of past results discussed in Chapter 3 as tests of the expected utility framework and to determine whether aspects of these findings would help in identifying factors that have been found (or are thought) to influence individual choice under uncertainty and should therefore be included in the empirical analysis. Section 5.4 provides a brief summary of the chapter.

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ficient normative status to justify their formal inclusion in methods for valuing risk. Stated in terms of environmental decisionmaking, the question becomes the following: which psychological and contextual concerns do citizens want their decisionmaking agents to reflect as normative principles in environmental decisionmaking, and which would they want them to treat as irrationalities, psychological weaknesses, or otherwise unjustifiable perturbations of rational decisionmaking. (pp. 2-3)

5.2 VALUING RISK CHANGES

Following the analysis discussed in Chapters 3 and 4, we maintain that an individual seeks to maximize expected utility subject to a budget constraint that describes his opportunities for adjustment. Our descriptions of these adjustment possibilities will enter the decision problem through the specification of different definitions of the markets for contingent claims facing the individual. Given an ex ante perspective for valuation, the relevant conceptual basis for valuing a risk change is in terms of what we defined in Chapter 4 as the planned expenditure function. This function defines minimum planned expenditures on contingent claims that would be required to meet a given level of expected utility. It is a function of the prices for contingent claims, the probabilities of the states of nature that are assumed to be uncertain, and the level of expected utility that is to be realized. Thus, an individual's valuation of a risk change, defined using this function, will depend on the nature of the markets for contingent claims. We noted this point in Chapter 4 and now propose to use a simple two-state model to illustrate both how these values are affected by the assumed nature of the markets for contingent claims and, in turn, what these results imply about the testable hypotheses derived from the model.

Consider the following planning problem for the representative individual. There are two possible states of the world. In the first, an individual will experience a detrimental health effect that could (but need not) lead to death for the purpose of our analysis.* The effect is assumed to be associated with exposure to hazardous wastes; however, exposure does not ensure that the health effect will be incurred. It introduces the individual to a second stage lottery, which can be avoided if exposure is avoided. Thus, our analysis emphasizes the distinction in outcomes by assuming that the probability of the health effect is zero when the individual is not exposed to the substance.

The health effect leads to preferences that differ depending on whether or not it is incurred. This follows the state-dependent preference arguments

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*In the empirical analysis associated with evaluating individuals' valuations of risk reductions, we consider the effects of a selected set of variations in this end state. However, the basic scenario used to describe what is at risk describes the outcome as death after 30 years from the time of the exposure to the hazardous substances.

proposed for the case of life-death decisions by Jones-Lee [1974] and Weinstein, Shepard, and Pliskin [1980] and described in more general terms by Cook and Graham [1977]. As we noted in Chapter 3, a state-dependent specification for utility is simply a means of acknowledging that the marginal utility of income may be different across the states of nature described in any particular problem.* To keep notation relatively simple, each state-dependent utility function is specified to be a function of claims to income in that state. As we observed in Chapter 3, it is possible to generalize this formulation to identify claims for individual commodities. This generalization will be important if the relative prices for these claims across states of nature for a given commodity bear a different relationship to the relative odds of those states as the commodity in question changes. While this can be an important dimension of the problem in some applications, it was not judged to be important for our discussion here.

To highlight the two-stage nature of the lottery, we have identified two probabilities--the likelihood of being exposed to a hazardous waste, defined as R, and the probability of incurring the detrimental effect once exposed, defined as q. Equation (5.1) defines the expected utility realized from allocating claims to income, the W_i's between the two states, with state one representing the case of experiencing a detrimental health effect and state two representing the case of remaining unaffected:

$$EU = R[qV_1(W_1) + (1-q)V_2(W_2)] + (1-R)V_2(W_2) . \qquad (5.1)$$

In this case the health effect can be incurred only through exposure to the hazardous wastes. Therefore, the specification in Equation (5.1) can be reduced to Equation (5.2):

$$EU = RqV_1(W_1) + (1-Rq)V_2(W_2) , \qquad (5.2)$$

where

EU = expected utility

$V_i(.)$ = utility realized in state i

W_i = contingent claim to income in state i .

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*This is also the point of Marshall's [1984] recent discussion of the role of indivisibilities in modeling decisionmaking under uncertainty.

The individual seeks to allocate total income for planning purposes, E, among these claims to income in each state to maximize Equation (5.2). We introduce the role of opportunities for adjustment to uncertainty through the specification of the prices for these claims to income and the budget constraint. This is given in general terms in Equation (5.3):

$$E = r_1 W_1 + r_2 W_2 , \tag{5.3}$$

where

r_i = the price for the claim to income in state i .

The problem can be stated equivalently as one of minimizing the planned expenditures required to realize a given level of expected utility. This approach provided the basis for the derivation of the planned expenditure function in Chapter 4. For our simplified example, the conditions for a constrained minimum imply a function defined from the expenditure minimizing demands for claims, as in Equation (5.4):

$$E[r_1, r_2, Rq, \overline{EU}] = r_1 W_1 (r_1, r_2, Rq, \overline{EU}) + r_2 W_2 (r_1, r_2, Rq, \overline{EU}) . \tag{5.4}$$

The marginal value of a change in risk is simply the partial derivative of the expenditure function with respect to the component of the risk that is assumed to change. Thus, for a change in R, the marginal value, MVR, would be defined as follows:

$$MVR = \frac{\partial E}{\partial R} = r_1 \frac{\partial W_1}{\partial R} + r_2 \frac{\partial W_2}{\partial R} , \tag{5.5}$$

where

MVR = marginal value of risk increment .

The principal objective of this section is to demonstrate how these marginal values change with changes in the assumed opportunities available for individual adjustment. However, before proceeding to that discussion, it is important to relate MVR to the incremental analysis developed in Chapter 4 and to earlier literature on valuing risk changes.

Consider a discrete change in risk from R_0 to R_1 (with $R_0 < R_1$). The value (loss) of the change is defined by Equation (5.6):

$$\Delta VR = \int_{R_0}^{R_1} \frac{\partial E}{\partial R}\, dR = E[r_1, r_2, R_1 q, \overline{EU}] - E[r_1, r_2, R_0 q, \overline{EU}] \ . \quad (5.6)$$

In this case, the individual must plan to allocate more income to realize the same level of expected utility. Thus, the change in VR is the maximum amount he would be willing to pay to avoid the change. This value is completely analogous to the values defined in Chapter 4, although it, of course, does not distinguish a user or existence component. The reason is simple: we have not provided a basis for the distinction in our description of the choice process. If the state-specific preference functions were expanded to define more specifically the implications of the exposure beyond a simple health effect, then the total value and use value components specified in Chapter 4 can also be defined for this case. We return to this issue in the next chapter and discuss the relationship between use and nonuse, or intrinsic, values of a risk change. Of course, it should be recognized that all of these classification schemes for benefit components simply reflect the introduction of additional information into the choice process.

It should be also acknowledged that this valuation concept is more general than what has been used in earlier analyses of the value of risk changes. For example, Jones-Lee [1974] defined the value as the maximum amount an individual would pay to realize a reduced probability of a detrimental event. For a comparable risk change (i.e., R_0 to R_1), his definition would be as follows in our notation:*

$$R_0 q V_1 (W_1 - P) + (1 - R_0 q) V_2 (W_2 - P) = R_1 q V_1 (W_1) + (1 - R_1 q) V_2 (W_2), \quad (5.7)$$

where

P = payment for reduced probability of exposure (with $R_0 < R_1$ as before).

This payment, P, was described by Jones-Lee as the Hicksian compensating variation in wealth. It is not the compensating variation, but rather the option price for a change in the probability. The definition is directly comparable to what Freeman [forthcoming b] has described as the option price correspond-

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*See his Equation (10) on p. 839 for his definition of the "compensating variation" for a risk change.

ing to a change in the conditions of uncertainty. Moreover, use of this definition as the basis for defining individuals' valuations for risk changes is less general than our formulation because it assumes the individual is unable to make state-specific payments.

This conclusion is easily appreciated using the Graham [1981] willingness-to-pay locus. Values are defined with respect to changes in one point on the Graham willingness-to-pay locus rather than in terms of expenditures as defined in Equation (5.5). Depending on how the locus shifts with a change in R, we can expect different individual valuations for the risk change. That is, the valuations in this case are described by measuring how each of the points of the locus shifts with the change in R. This is the point emphasized by our planned expenditure function. Since the Graham locus is an alternative means of describing the effects of the opportunities for adjustment on an individual's valuation of a risk change, it provides the basis for a graphical illustration of how opportunities for adjustment affect an individual's valuation of risk changes.* To illustrate the difference graphically, it is convenient to consider a small modification in Graham's framework. His locus describes the alternative set of payments that would be made to realize some desirable access conditions or level of a commodity that is valued by the individual under one of his state-dependent preference sets. The locus maintains a constant expected utility when the favorable access or quantity is realized, but state-dependent payments must be made with that level realized without making these payments and without the improved conditions (or increased quantity).

We could easily modify this framework by assuming a given level of expected utility as our reference point, without specifying where it came from

*It may be tempting to draw parallels between the relationship of the planned expenditure function to the Graham willingness-to-pay locus and the relationship of the expenditure function to the indirect utility function under certainty. However, this would be incorrect. Total planned expenditures do not enter the Graham locus. The Graham locus is not specific to one statement of the constraint set facing an individual but, rather, provides the basis for characterizing all of them and their implications for what total utilities can be realized. This is one source of error in the recent comment on Graham by Mendelsohn and Strang [1984]. It should also be noted that Graham's use of the locus is different than ours. His objective was to describe the valuation measures for a certainty of supply of a resource in the presence of demand uncertainty. Ours is to illustrate the implications of institutions for the valuation of risk changes.

and consider an individual making state-dependent payments under two sets of conditions. These payments, taken together with the level of exposure risk R, maintain the constant expected utility level. The Graham locus incorporates the change in a single locus, and our proposed modification breaks up the process. Thus, the Graham payments would be equivalent to the changes (or increments) in payments under this format.

Consider the change from R_0 to R_1 again. In this case, we will consider the change consistent with a risk reduction from R_1 to R_0 (since it was earlier assumed that $R_0 < R_1$). Equation (5.8) defines the conditions implied by a change in R from R_1 to R_0 and its implications for the definition of two modified willingness-to-pay loci. The equation on the left of the equality defines the original level of risk and the payments (γ_1 and γ_2) that would be made for it, and the equation on the right side of the equality defines the new, lower risk and the consequent higher payments:

$$R_1 q V_1 (W_1 - \gamma_1) + (1-R_1 q) V_2 (W_2 - \gamma_2) = R_0 q V_1 (W_1 - \tilde{\gamma}_1) \qquad (5.8)$$
$$+ (1-R_0 q) V_2 (W_2 - \tilde{\gamma}_2) ,$$

where

$R_1 > R_0$.

This case is illustrated in Figure 5-1 by the shift in the Graham locus from A (with R_1 describing the risk of exposure) to B (with R_0 describing the risk of exposure). The option price is the maximum constant payment (across states) that an individual would be willing to make to realize the lower risk. In this case it is given by the difference between the intersections of the two Graham loci corresponding to the left and right sides of Equation (5.8) with the 45° line. When the opportunities for adjustment are taken into account, the model is then explicitly acknowledging the prospects for varying the payments across the states of nature. If the terms of payment are given by the slope of TT', then a measure of difference in the implied value of the change in R is given by the difference in the intersection of these tangents to the Graham locus (with slope $(-\frac{r_1}{r_2})$) with the 45° line, EF.* Clearly, the

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*EF will describe the change in expenditures normalized by r_1+r_2. Thus, if we assume that W_1 and W_2 are measured so that $r_1+r_2=1$, then it can be interpreted as the change in expenditures.

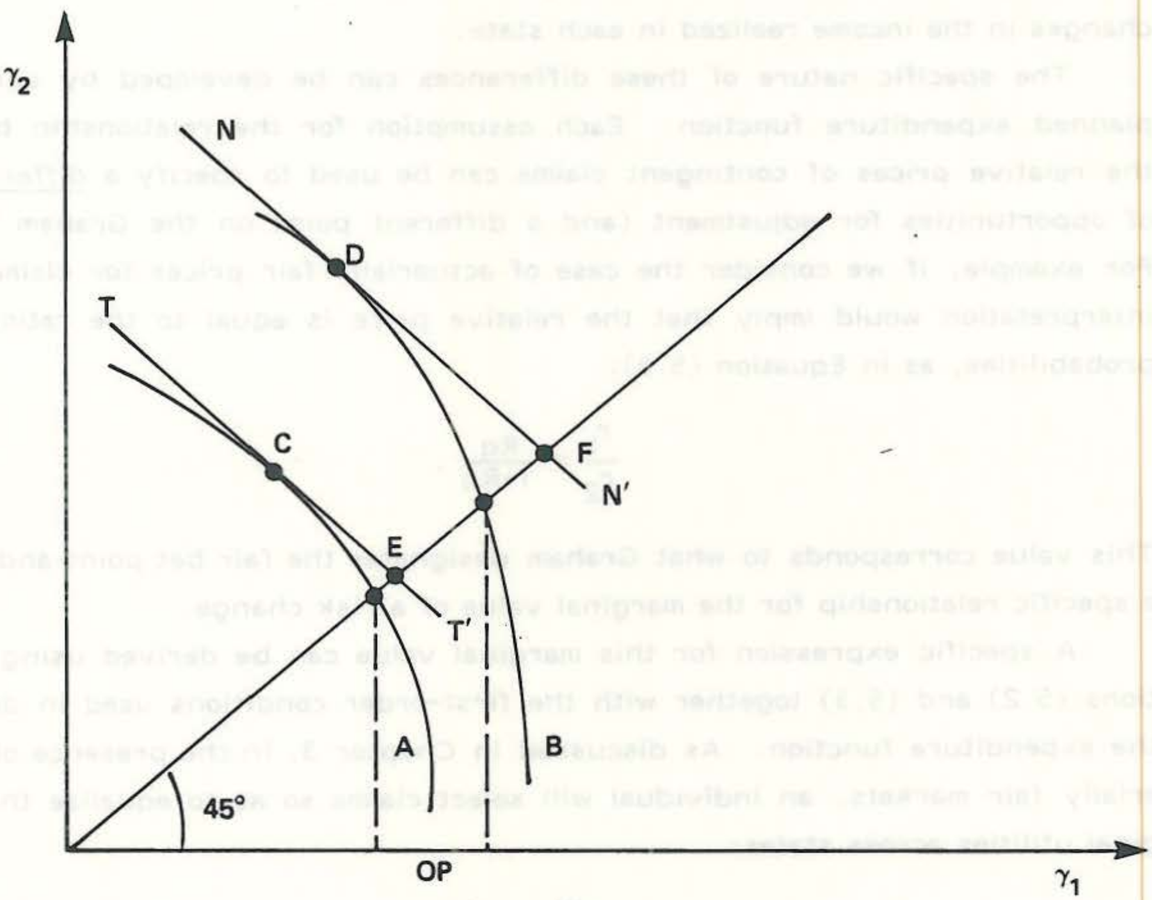

Figure 5-1. Graham locus with change in probabilities.

values can differ from the option price because there is no necessity that the locus will shift in a parallel fashion. The shift in the locus will depend on the change in risk and on the change in the marginal utilities of income with changes in the income realized in each state.

The specific nature of these differences can be developed by using the planned expenditure function. Each assumption for the relationship between the relative prices of contingent claims can be used to specify a <u>different</u> set of opportunities for adjustment (and a different point on the Graham locus). For example, if we consider the case of actuarially fair prices for claims, this interpretation would imply that the relative price is equal to the ratio of the probabilities, as in Equation (5.9):

$$\frac{r_1}{r_2} = \frac{Rq}{1-Rq} \ . \tag{5.9}$$

This value corresponds to what Graham designates the fair bet point and yields a specific relationship for the marginal value of a risk change.

A specific expression for this marginal value can be derived using Equations (5.2) and (5.3) together with the first-order conditions used in defining the expenditure function. As discussed in Chapter 3, in the presence of actuarially fair markets, an individual will select claims so as to equalize the marginal utilities across states:

$$\frac{dV_1}{dW_1} = \frac{dV_2}{dW_2} \ . \tag{5.10}$$

Together with the partial differentials of Equations (5.2) and (5.3), this condition with respect to R can be used to describe the marginal value of a risk change as follows. The total differentials for Equations (5.2) and (5.3), assuming dq = 0 (substituting for r_1 and r_2 for Rq and (1-Rq)), are given in Equations (5.11) and (5.12):

$$\frac{\partial EU^*}{\partial R} = 0 = q[V_1(W_1^*) - V_2(W_2^*)] + Rq\frac{dV_1}{dW_1}\frac{\partial W_1}{\partial R} + (1-Rq)\frac{dV_2}{dW_2}\frac{\partial W_2}{\partial R} \ , \tag{5.11}$$

$$\frac{\partial E}{\partial R} = q(W_1{}^* - W_2{}^*) + Rq \frac{\partial W_1}{\partial R} + (1-Rq) \frac{\partial W_2}{\partial R}, \qquad (5.12)$$

where the asterisk designates the expenditure minimizing values.*

Using Equation (5.10) to simplify Equation (5.11) and substituting in Equation (5.12), we have

$$\frac{\partial E}{\partial R} = q(W_1{}^* - W_2{}^*) + \frac{q\,[V_2(W_2{}^*) - V_1(W_1{}^*)]}{\dfrac{dV_1}{dW_1}}. \qquad (5.13)$$

Since it is reasonable to assume that $V_2\ (W_2{}^*) > V_1\ (W_1{}^*)$, we can conclude that an individual will value a risk change by more than the expected insurance $(q\ (W_1{}^* - W_2{}^*))$ that would be purchased at actuarially fair rates. This is a variation on the case described by Cook and Graham [1977]. Under these conditions, we can expect that $\frac{\partial E}{\partial R} > 0$ and $\frac{\partial^2 E}{\partial R^2} > 0$. Thus, the marginal value of an incremental reduction of, say ΔR, in the risk of exposure to hazardous waste will be greater at higher levels of risk. Differentiating Equation (5.13) with respect to R and simplifying, we have

$$\frac{\partial^2 E}{\partial R^2} = - \frac{(V_2(W_2{}^*) - V_1(W_1{}^*)) \dfrac{d^2 V_1}{dW_1{}^2} \dfrac{\partial W_1}{\partial R}}{\left(\dfrac{\partial V_1}{\partial W_1}\right)^2}. \qquad (5.14)$$

This conclusion is readily established once it is recognized that our model implies that $V_2\ (W_2{}^*) > V_1\ (W_1{}^*)$ and $\frac{d^2 V_1}{dW_1{}^2} < 0$.

This same conclusion was derived by Jones-Lee [1974] in the case where an option price was assumed to be the mechanism for paying for the risk re-

*In what follows, all derivatives are assumed to be evaluated at the relevant optimal values, depending upon which constrained optimization problem is discussed.

duction and in somewhat more general terms by Weinstein, Shepard, and Pliskin [1980] for the same payment mechanism. Of course, in the case of the option price, it is a payment made to avoid an increase in the risk of exposure that could lead to detrimental health effects. Thus, these option price results are simply special cases of this more general framework.

The rationale for adopting this more general framework follows from the fact that the mechanisms available to the individual for adjustment affect the change in the marginal valuation of risk changes with the level of the risk. That is, we cannot unambiguously sign $\frac{\partial^2 E}{\partial R^2}$ under alternative assumptions concerning the opportunities for adjustment. To illustrate this conclusion, we consider two such cases: (1) when relative prices of claims are related to the likelihood of exposure, but not to the conditional probability of the health effect given the exposure and (2) when relative prices bear no specific relationship to either of the probabilities involved.

The first of these cases contrasts with what conventional practice would define as actuarially fair markets, where the relative prices of claims would be tailored to the individual's circumstances by adjusting them to reflect the conditional probability, q. If we assume that q (the conditional probability of the health effect given exposure to hazardous wastes) reflects an individual's health and overall heredity, then we might assume the first case gives each individual a "fair" opportunity to adjust to the risk under policy control but does not attempt to make distinctions for individual circumstances.*

Following the same logic outlined earlier to derive the expression for $\frac{\partial E}{\partial R}$ under actuarially fair markets, we have for this case

$$\frac{\partial E}{\partial R} = (\bar{W}_1 - \bar{W}_2) + \frac{(V_2(\bar{W}_2) - V_1(\bar{W}_1))}{\frac{dV_1}{dW_1}} , \qquad (5.15)$$

*An alternative definition would be to pick a value for q--a threshold--and define the "fair" opportunities in terms of the joint probabilities at that value of q. This approach could be considered analogous to the definition of a sensitive group in the specification of the primary standards for the criteria air pollutants. See Smith [1984a] for further discussion.

where

> the bar designates the expenditure minimizing values for this definition of the relative prices of contingent claims.

It is clear that $\frac{\partial E}{\partial R} > 0$. Indeed, increases in risk require greater planned expenditures to maintain a given utility level. Unfortunately, without specific assumptions concerning the nature of the utility functions, it is impossible to establish a precise relationship between the marginal values implied by each set of institutions.

We can establish the ambiguity in the size of the marginal value of a risk change with the level of risk by differentiating Equation (5.16) with respect to R:

$$\frac{\partial^2 E}{\partial R^2} = \left(\frac{\partial \bar{W}_1}{\partial R} - \frac{\partial \bar{W}_2}{\partial R}\right) + \frac{\frac{dV_2}{dW_2} \frac{\partial \bar{W}_2}{\partial R} - \frac{dV_1}{dW_1} \frac{\partial \bar{W}_1}{\partial R}}{\frac{dV_1}{dW_1}} \tag{5.16}$$

$$- \frac{\left(V_2(\bar{W}_2) - V_1(\bar{W}_1)\right) \cdot \frac{d^2 V_1}{dW_1^2} \cdot \frac{\partial \bar{W}_1}{\partial R}}{\left(\frac{dV_1}{dW_1}\right)^2} .$$

Substituting for $\frac{dV_2}{dW_2}$ in terms of $\frac{dV_1}{dW_1}$ from the necessary conditions for an expenditure minimum for this constraint, we have

$$\frac{\partial^2 E}{\partial R^2} = \left(\frac{q - 1}{1 - Rq}\right) \frac{\partial \bar{W}_2}{\partial R} - \frac{\left((V_2 (\bar{W}_2) - V_1 (\bar{W}_1)\right) \frac{d^2 V_1}{dW_1^2} \cdot \frac{\partial \bar{W}_1}{\partial R}}{\left(\frac{dV_1}{dW_1}\right)^2} . \tag{5.17}$$

The first term in Equation (5.17) will have a sign opposite to $\frac{\partial \bar{W}_2}{\partial r}$, since $q < 1$, and $Rq < 1$. It is clear that $\frac{\partial E}{\partial R} > 0$ since, by the equivalent of Equation (5.11) for this case, $Rq \frac{\partial \bar{W}_1}{\partial R} + q(1-R) \frac{\partial \bar{W}_2}{\partial R} > 0$ and $\bar{W}_1 > \bar{W}_2$. We would therefore expect $\frac{\partial \bar{W}_2}{\partial R} > 0$ in this case and, in turn, that the first term in Equation (5.17) will be negative. The second term in Equation (5.17) is clearly positive. Since the relative magnitudes of these two terms cannot be gauged a priori, we cannot suggest how the marginal value of incremental reductions in the exposure risk will change with the level of that risk.

The same conclusion arises for the case where no specific relationship is assumed for linking the relative prices of claims and the relative odds of the two states of nature. Equation (5.18) presents the marginal valuation for this case, and Equation (5.19) the second partial derivative:

$$\frac{\partial E}{\partial R} = \frac{r_1 \left(V_2 (\tilde{W}_2) - V_1 (\tilde{W}_1) \right)}{R \frac{dV_1}{dW_1}}, \tag{5.18}$$

where

the tilda (~) designates the expenditure minimizing values for this specification for the contingent claims markets.

$$\frac{\partial^2 E}{\partial R^2} = \frac{r_1 \left(\frac{dV_2}{dW_2} \cdot \frac{\partial \tilde{W}_2}{\partial R} - \frac{dV_1}{dW_1} \frac{\partial \tilde{W}_1}{\partial R} \right)}{R \frac{dV_1}{dW_1}} - \frac{r_1 \left(V_2 (\tilde{W}_2) - V_1 (\tilde{W}_1) \right) \cdot \left[\frac{dV_1}{dW_1} + R \frac{d^2 V}{dW_1^2} \right]}{R \left(\frac{dV_1}{dW_1} \right)^2}. \tag{5.19}$$

In this case neither term can be signed unambiguously.

As part of their analysis of individual valuation of risk changes in the presence of state-dependent preferences, Cook and Graham [1977, p. 152, n.18.] identified three components of the benefits of any risk change: (1) the pure protection benefit associated with the risk reduction, (2) the value of moving from an initial wealth distribution to an efficient (or more efficient) one, and (3) the cost of financing the action inefficiently if the post-investment distribution of wealth is inefficient.

The theoretical analysis of this section has extended past efforts at defining a conceptual basis for valuing risk changes to permit an explicit treatment of the character of the opportunities for adjustment to risk within a framework that is consistent with this benefit taxonomy. It represents a specific example of how the properties of the planned expenditure function can be used to consider an individual's valuation of risk changes. Moreover, this modification leads to a change in one of the more important testable implications of past research on the valuation of risk changes. That is, it has been suggested that the individuals' incremental value of a risk change will increase with the level of the probability of the detrimental event. While this conclusion holds where individuals have access to actuarially fair markets for contingent claims or where they must make state-independent payments for the risk change, it does not necessarily hold in other cases. As a consequence, a failure to observe an increasing incremental valuation of risk reductions may not imply rejection of the expected utility model. It can also reflect the individual's perceived opportunities to undertake state-dependent adjustments in income claims.

Most of the literature in this area (see, e.g., Jones-Lee [1974] and Weinstein, Shepard, and Pliskin [1980]) has used the option price as the benefit concept for defining how individuals would value risk changes. It has not specifically described the role of institutions in influencing individuals' valuations of changes in the conditions of uncertainty and therefore has not dealt with the issues that are posed by our more general framework. Of course, in the final analysis, the importance of this refinement depends on its empirical relevance. For our purposes, this means that how individuals respond to a contingent valuation question that elicits a state-independent bid may well be affected by their ability, or indeed their perceived ability, to make state-dependent adjustments. That is, if individuals accept the terms of the contingent valuation questions eliciting a bid for a risk reduction as the only means available to them for adjusting, then the results of the existing literature on changes in the incremental option price with the level of risk are relevant. In effect, option price is the relevant measure of the benefits of reducing hazardous waste risks. However, if individuals perceive themselves as having the ability to take specific actions that would be the equivalent of state-dependent payments, option price may not be the relevant measure.

5.3 IMPLEMENTING THE THEORY: PHYSOLOGICAL CONSIDERATIONS

To this point, our analysis has implicitly accepted the expected utility framework as the basis for describing individual behavior under uncertainty. While Chapter 3 briefly discussed violations of this framework, it argued that these violations could be explained by either of two amendments to the framework--the introduction of state-dependent preferences or the recognition that individuals may adhere to an expected utility model but form their judgments on the probabilities of state of the world in ways that have not been properly modeled in past applications of the expected utility framework. These modifications change what Arrow [1974] refers to as the separation or independence of the information on risk and that on preferences. As a consequence, it becomes impossible, without additional information, to distinguish the reason (i.e., taste or risk perception) for specific behavior in the presence of uncertainty. Moreover, either explanation is simply an alternative means of expressing the analyst's ignorance of the factors influencing individual choice. In the first case, state dependency acknowledges that utility (and, in particular, the marginal utility of income) may vary with the state of the world. It usually does not offer an explanation of the features of the state or of the individual that account for the dependency in general terms. While it may be possible to identify some factors in specific applications, no attempt has been made to provide a complete or comprehensive descrption that would accommodate all cases.

Similarly, in the case of the available alternative explanations for processes used by individuals to estimate the probabilities of the states of nature, a number of approaches for information processing were identified as offering the potential for reconciling observed contradictions with the expected utility model. However, the frameworks discussed were not part of an integrated explanation of how individuals process different types of information or appraise the likelihood of different types of risk. This is a reflection of the limited nature of our understanding of behavior under uncertainty.

As we noted at the outset of this report and this chapter, the primary objective of this research has been to develop estimates of individuals' valuations of reductions in the risk of exposure to hazardous wastes. Since there are specific aspects of this problem that may affect how individuals respond to valuation questions, it is important to review the general features that past research has indicated may play a role in individual behavior. While this is not a substitute for a comprehensive model that describes the role of all the features of the circumstances that may influence behavior, it is nonetheless a complement to our conceptual model. That is, it serves to indicate the potential limitations of our framework and to highlight the factors that must be explicitly considered in implementing it for empirical purposes.

The most important of the factors influencing individual behavior for an analysis of hazardous waste risks would seem to be what Slovic [1984] refers to as "dread risk" and "known risk." Our case embodies both. The first involves the notion that an event is dreaded because it is potentially catastrophic. The second quality relates to both perceptions about the individual's knowledge of the risk and whether the events at risk are delayed in time. Based on the research of Slovic and his associates, Slovic has suggested that these factors influence how individuals respond to uncertainty. This would imply that individuals may well value incremental reductions in the risk of death from different sources quite differently.* Moreover, based on these

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*There is an important issue that arises in modeling an individual's valuation decisions concerning risk changes. It arises because the models have routinely assumed the risk of interest is the <u>only</u> one the individual faces. If instead the individual faces multiple risks, and policy is intended to change one of them, then the problem becomes much more complex. Kihlstrom, Romer, and Williams [1981] offer some initial insights into the general problems raised by these cases. They note that even if the risks are independent, ordering individuals by Arrow-Pratt measures of risk aversion will not necessarily correspond to the ranking implied by the certainty equivalents. Indeed, the whole problem of characterizing risk aversion and individuals' responses to risk becomes more complex in these cases. For example, to the extent sources of risk are correlated (especially negatively correlated), engaging in some risky activities may be an approach to risk diversification or have a role akin to institutions that affect the valuation of risk changes. We have not considered considerations, we might expect that an individual would have a greater valuation of risk reductions where the dread and known factors are present. To develop some information relevant to the potential effects of these factors we have designed our survey to include valuation questions for changes in two types of risk--exposures to hazardous wastes and fatal accidents on the job. In addition, in the process of questioning individuals about their valuations of reductions in the risk of exposure to hazardous wastes, we consider two variations on the questioning format. First, we investigated whether a change in the health end state (e.g., whether the cause of death was due to damage to the body's immune system or whether the risk was associated with birth defects severe enough to mentally retard or physically handicap children for a lifetime) would alter the individual's valuation of the risk change. Second, our experimental design allows for consideration of both low levels of risk (where an individual may well assume our knowledge of processes leading to rate events is imprecise) and bids for the elimination of risk. To the extent dread and the imprecision of knowledge of the risk would affect individuals' valuations of risk reductions, we would expect to see their effects evidenced in responses to these different elements in our design. Moreover, it was also possible to gauge the effects of these factors on risk perception by asking each individual their perceived risk of death from four causes--an automobile accident, heart disease, a disease caused by air pollution, and a disease caused by exposure to hazardous wastes. As the discussion of the design and structure of the questionnaire in Chapter 8 describes in more detail, these questions were posed before any valuation questions and provide the basis for evaluating how risk perceptions vary for these different types of risks.

In addition to these factors, the controllability and voluntariness of risk have been found to be important elements in psychological studies of risk perception. These features were also considered in the sturcturing of our analy-

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these issues here, but acknowledge that they are clearly relevant to any empirical efforts since, in the real world, individuals do face multiple risks. This extension provides another potential explanation for the difficulties experienced in interpreting the results of <u>field</u> experiments within an expected utility framework. For the most part, these efforts have tended to ignore other sources of risk. See Smith [1984b] for discussion of some of these issues as they relate to the measurement of risk aversion.

sis. Based on a series of focus group discussion sessions (described in more detail in Chapter 8), we found that individuals associated differing degrees of control with respect to the siting of disposal site for hazardous wastes with whether their community had a "say" in the decision.*

Equally important, and potentially related to the treatment of these two features of risk, is a concept discussed by Hershey, Kunreuther, and Schoemaker [1982] that might be described as assignment of the risk. That is, what are the assumed "property rights" of the individual for the level of risk to which he is endowed? Our design reflects all three considerations. First, in the structure of the contingent valuation experiment, we considered two types of scenarios--payments for reductions in risk and payments to avoid increases in risk. In the latter case, our survey design varied the sources of the risk according to whether it was allowed by the Federal government or voted for by the individual's town council. In addition, our design also allowed evaluation of a situation in which risk increased but so did an individual's income.† Finally, comparison of valuations for reduction in hazardous wastes with those for risks on the job will also reflect the effects of voluntary selection because the latter were posed as being associated with new jobs and the individual is asked a wage increment that would induce him to accept a job with the new risk conditions.

All of these factors fall within the general category of context effects. They imply that how a risk is explained to an individual may well influence his response to it (see Schoemaker [1982], pp. 547-48, for further discussion). Rather than interpret them as potentially implying some form of irrational behavior, they can also be interpreted to indicate that analysts have done a poor job at communicating their questions to survey respondents.

One of the important aspects of the design of the empirical component of this research has been the use of focus groups in the development of the

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*This is clearly consistent with findings observed in studies of the siting of nuclear facilities. See, e.g., Carnes et al. [1982], Carnes and Copenhaver [1983], and Carnes et al. [1983]. It is also consistent with the program of research recently described by Kunreuther and Kleindorfer [1984].

†This was done using a contingent ranking format that is described in Chapter 14. A general discussion on the use of the method in benefit estimation is given in Desvousges, Smith, and McGivney [1983].

wording of the questionnaire, the format of the vehicles used to explain risk, and in the pretesting and revisions to the questionnaire. Since the specific steps in this process are described in Chapter 8, it is sufficient to acknowledge here their role in adjusting the structure of the empirical component of this research to reflect what has been learned for the psychological research on decisionmaking under uncertainty.

5.4 SUMMARY

This chapter has used the framework of the planned expenditure function to describe how individuals would value risk reductions. It has illustrated how these valuation concepts will be affected by the mechanisms that are assumed to be available to the individual for adjustment. By using a simple two-state example, it has been possible to relate the valuation concepts to both the past literature on the valuation of risks of death and to the discussion of option price as a valuation concept in environmental economics.

As acknowledged at the outset, our focus to this point has been on what might be designated ex ante use values. It is reasonable to expect that individuals may hold a form of ex ante existence or intrinsic values for risk reductions because they serve to affect other aspects of the natural environment whose existence yields utility even though they do not provide user services in the conventional, consumptive sense. In the next chapter this general framework is used to discuss how these values might be defined and integrated into an ex ante perspective for benefit analysis. Following that, we introduce the discussion of the design of our questionnaire and survey with a chapter describing the relationship between the conceptual analysis and the constraints within which it was implemented.

CHAPTER 6

ECOLOGICAL AND INTRINSIC VALUES UNDER UNCERTAINTY

6.1 INTRODUCTION

As described in Chapter 2, hazardous wastes pose risks to ecological systems as well as to human health, and hazardous wastes regulations can reduce these risks. The purpose of this chapter is to extend the analysis of the valuation of risk reductions presented in Chapters 3 through 5 to consider the problems posed by developing a consistent system for valuing reduced risks to environmental and ecological resources. However, this extension first requires a consideration of the nature of the economic values people derive from ecological resources.

Ecological systems can yield benefits to people in a variety of forms. For example, both managed and natural ecosystems can yield food or fiber for market. In such instances, the ecological system is an input to a production process that also involves capital and labor in the cultivation and harvest of plant and animal species. We might call these production or market benefits because the harvest activities are undertaken in response to market forces and profit incentives. The benefits of changes to ecosystems used for market purposes come in the form of changes in the prices of goods and factor inputs. This is in contrast to those human actions involving uses of the ecological system that yield utility directly to the individuals concerned. Examples of such direct use benefits include the values attributable to recreation activities such as hunting, fishing, wildlife observation, and nature photography.

It has also been argued that natural environments, including their ecological components, can yield benefits that are not associated with their direct use. This class of benefits has been variously named intrinsic, nonuser, and nonuse benefits. Such benefits are said to arise from a variety of motives, including the valuing of the knowledge of the existence of a particular environmental or ecological attribute, a desire to bequeath certain environmental assets to one's heirs or to future generations, and a sense of stewardship or responsibility for preserving certain features of natural environments.

One of the objectives of this chapter is to develop a logical and consistent set of definitions and concepts that can guide further theoretical analysis and empirical testing of propositions about intrinsic values. Toward this end, Section 6.2 is devoted to a systematic examination of the several types of intrinsic benefits associated with ecological resources that have been discussed in the literature. This section also considers alternative ways of specifying preference functions to reflect the various forms of intrinsic benefits. One issue here is the particular circumstances under which it is possible (or meaningful) to partition a total benefit measure into components--e.g., use, bequest, pure existence, and so forth. Another issue concerns the relationship between intrinsic benefits and the benefits associated with the direct use of the environment. Section 6.3 extends the discussion of existence values to the situation in which a policy alters the probability that the resource will exist and considers further the implications of ex ante versus ex post perspectives for the valuation of risk changes. Section 6.4 offers some conclusions and discusses the implications of this analysis for approaches to measuring ecological values.

6.2 EXISTENCE AND USE VALUES UNDER CONDITIONS OF CERTAINTY

In this section we take up several questions concerning the relationship between use and existence values and possible motivations for existence value. In all cases this analysis maintains the assumption of certainty. Let us assume that an individual derives utility from the consumption of a vector of private goods, X, and some measure of the quality of the ecological system at the site, Q. In this general formulation, Q can be taken to be a scalar measure of some critical characteristic--e.g., the population or biomass of an important species or the number of different plant or animal species present in the ecosystem. Alternatively, Q could be interpreted as a dichotomous variable taking the value $Q_1 = 0$ in the absence of some critical ecological attribute and the value $Q_2 (> Q_1))$ when that attribute is present. In the latter case, the marginal utility of Q is assumed to be positive in the interval $Q_1 - Q_2$ and 0 otherwise.

To give the problem additional structure, let X_1 be some market good associated with use of the ecological resource. Examples could include the use of the services of a site for purposes of recreation, rental of a boat for fishing, or hiring the services of a guide to conduct a visit to an ecological resource. If $X_1 = 0$, we interpret this to mean that the ecosystem has not been used by the individual.

Assume that the individual maximizes utility subject to the budget constraint $M - P \cdot X = 0$, where P is a vector of goods' prices. The solution to this maximization problem yields a set of demand functions for X. In the absence of further restrictions on the form of this utility function, the demand functions can be written as Equation (6.1):

$$X_1 = X_1(P, M, Q) \ . \tag{6.1}$$

The minimum expenditure necessary to attain any given level of utility is

$$E = E(P, Q, U) \ . \tag{6.2}$$

If U* is the solution to the utility maximization problem given P, M, and Q, then the compensating surplus measure of the benefit of an increase in Q from Q_1 to Q_2 is given in Equation (6.3):

$$\begin{aligned} S &= E(P, Q_1, U^*) - E(P, Q_2, U^*) \\ &= -\int_{Q_1}^{Q_2} \partial E/\partial Q \cdot dQ \ . \end{aligned} \tag{6.3}$$

In this general formulation, S could be a pure use value, a pure nonuse or existence value, or some combination of the two. If the conditions defining Mäler's weak complementarity hold, then S is a pure use value (Mäler [1974]). Two conditions on the utility and demand functions must be satisfied in order to fit Mäler's definition of weak complementarity. First, there must be a value for P_1, designated as $P_1^*(Q)$, such that the demand for X_1 is zero:

$$X_1 = X_1(P_1^*(Q), P_2, \ldots P_n, M, Q_2) = 0 \ . \tag{6.4}$$

And, second, at that price, the marginal utility or marginal welfare of changes in Q must be zero:

$$\partial E\ (P_1^*(Q,\ P_2,\ \ldots,\ P_n,\ Q_2,\ U^*)/\partial Q = 0\ , \tag{6.5a}$$

or, equivalently,

$$\partial U\ (O,\ X_2,\ \ldots\ X_n,\ Q_2)/\partial Q = 0\ . \tag{6.5b}$$

As is now well known, the conditions defining weak complementarity also allow this pure use value for changes in Q to be estimated by appropriate analysis of the demand function for X_1. Specifically, S is equal to the area between the compensated demand curves for X_1 when Q increases from Q_1 to Q_2.* That is, S is defined by Equation (6.6):

$$\begin{aligned} S = & \int_{P_1'}^{P_1^*} H_1\ (P_1,\ P_2,\ \ldots,\ P_n,\ U^*,\ Q_2)dP_1 \\ & - \int_{P_1'}^{P_1^*} H_1(P_1,\ P_2,\ \ldots,\ P_n,\ U^*,\ Q_1)dP_1\ , \end{aligned} \tag{6.6}$$

where

H_1 = the compensated demand function for X_1

P_1' = the given market price.

The process of using ordinary demand functions to approximate the compensating surplus measure of a use value for a quality change can be complex. If we are willing to assume that the quality change affects the effective price (or the quantity of the resource services, X_1 in this case), then the analysis of Willig [1976] or Randall and Stoll [1980] can be used to describe how S can be approximated by the area between the ordinary (i.e., Marshallian) demand functions for X_1 at the two levels of Q. In the case of Q acting through the price, we are essentially maintaining that the effect of a change in Q is the same as the effect of the corresponding changes in the price of X_1. If the

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*For an elaboration, see Mäler [1974], pp. 183-89 or Freeman [1979], pp. 72-75.

role of Q in the demand for X_1 cannot be distinguished in this way, then the relationship between the Marshallian and Hicksian demand functions depends on properties of the expenditure function that are not considered in either the Willig or Randall and Stoll analyses. Consequently, these approaches cannot guide an evaluation of the relationship between Marshallian and Hicksian measures of the welfare change associated with a change in ecological quality.

Pure existence value occurs when $X_1 = 0$ at all $P_1 \geq 0$ but $\partial U/\partial Q > 0$--i.e., when the second condition defining weak complementarity is violated. Given this condition on use, pure existence value EX is given by Equation (6.7):

$$EX = E(P, Q_1, U^*) - E(P, Q_2, U^*) , \qquad (6.7)$$

where

$Q_1 = 0$
$Q_2 > 0$.

The necessary and sufficient condition for pure existence value is that the utility function be strongly separable in Q. One consequence of this strong separability is that changes in Q have no effect on market behavior. Thus, there is no basis for estimating pure existence values from observations of changes in market prices or quantities.

Some authors have questioned the plausibility of a pure existence value that is truely independent of any use of the site. In justification for pure existence value, Krutilla suggested that, "An option demand may exist, therefore, not only among persons currently and perspectively active in the market for the object of the demand, but among others who place a value on the mere existence of biological and/or geomorphological variety and its widespread distribution" [Krutilla, 1967, p. 781]. In an accompanying footnote, he also suggested that the "phenomenon discussed may have an exclusive sentimental basis, but if we consider the bequest motivation in economic behavior, discussed below, it may be explained by an interest in preserving an option for one's heirs to view or use the object in question" [Krutilla, 1967, p. 781, n].

Later, Krutilla and Fisher wrote,

> Perhaps closely associated with option value is the value some individuals derive from the knowledge of the existence of unspoiled wil-

> derness, wild and scenic rivers, and related phenomena of peculiarly remarkable quality. . . . In the case of existence value, we conceived of individuals valuing an environment regardless of the fact that they feel certain they will never demand in situ the services it provides . . . . however, if we acknowledge that a bequest motivation operates in individual utility-maximizing behavior . . . , the existence value may be simply the value of preserving a peculiarly remarkable environment for benefit of heirs. (Krutilla and Fisher [1975], p. 124)

While Krutilla and Fisher offer a bequest motivation as one of several possible explanations for a pure existence value, McConnell takes a different point of view:

> The notion that a good is valued only for its existence, that it provides no in situ services, is far fetched. In most cases, resources are valued for their use. Existence value occurs only insofar as bequest or altruistic notions prevail. We want resources there because they are valued by others of our own generation or by our heirs. Thus use value is the ultimate goal of preferences that yield existence demand, though the existence and use may be experienced by different individuals. (McConnell [1983], p. 258)

In contrast to McConnell's view, Randall and Stoll recognize that people might experience other than altruistically motivated benefits from the existence of a site without visiting the site. However, they argue that all such non in situ uses are associated with some aspect of market-related behavior and that these values thus constitute a form of use they label "vicarious consumption": "Thus, we consider the values generated by reading about Q in a book or magazine, looking at it in photographic representations, for example, to be use values. Clearly our definition of use includes vicarious consumption" (Randall and Stoll [1983], p. 267). In terms of our model, they view Q as enhancing the utility of perhaps several goods in the vector X.

Neither McConnell nor Randall and Stoll recognize concern for the existence of a species out of ethical considerations as a possible motive for pure existence values. While ethical philosophers are not in agreement as to the validity and proper form of such concern,* it is possible that some people hold such values and are willing to commit resources on that basis.

This discussion of the possible motivations for pure existence value is inconclusive. This is at least in part because some of the arguments of the

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*For discussion of these issues, see, for example, Norton [1982], Sagoff [1980], and Rescher [1980], pp. 79-92.

authors cited are misdirected in at least two respects. The first concerns various definitions of existence value. Definitions can be considered in part a matter of taste. A set of definitions can be considered useful if it furthers the research objectives and leads to useful answers to meaningful questions and if the definitions are based on operationally meaningful distinctions. If use values are limited by definition to those associated with in situ uses, these definitions have the virtue of distinguishing between cases where use of a site generates observable data and cases where no meaningful data can be obtained by observing market transactions.

One problem with so-called vicarious uses is that the observable market transaction--e.g., the purchase of a nature magazine--often entails the simultaneous or joint use of many environmental resources so that allocation of the market transactions to specific resources is not possible. Furthermore, vicarious use has the odd feature that use can occur--e.g., through viewing of film and photographs--even though the resource no longer exists. Finally, where vicarious uses involve information conveyed by photographs and so forth, the public good dimension of information seems likely to virtually destroy any meaningful relationship between observed market behavior and underlying values.

The second respect in which the preceding arguments may be misdirected has to do with the role of possible existence values in policy analysis. We are concerned with the question of existence values because resource misallocations will result if they are of significant size, unmeasured, and therefore omitted from benefit-cost calculations. The arguments about motivations for existence values seem to be offered for the primary purpose of persuading the reader of the plausibility of the hypothesis that existence values are positive. But the real test of this hypothesis will come from the data. Rather than further debating definitions and possible motivations, the most useful step would be to proceed with a test of the hypothesis that existence values (defined in a way to make testing of the hypothesis feasible) are positive. If the evidence supports this hypothesis, then further research efforts might be devoted to testing hypotheses about the determinants (motivations) or the size of existence values in different cases. Thus, consideration of the motivations for existence values is important (at this stage in our empirical research) only to the extent that these motivations affect the discussion used to explain the concept to individuals in a contingent valuation framework.

So far we have considered two polar cases in which value accrues to individuals only through use (weak complementarity) and in which value is entirely independent of use (pure existence value). Now we take up the intermediate case where value accrues through use but the conditions defining weak complementarity do not hold. Using the model of preferences developed in this section, we will show that there is a subtle distinction between existence value and nonuse value when there is some level of Q (e.g., Q = 0) at which no use is possible at any price for X_1. Finally, we will consider the problems of measuring the total benefit and its components by various techniques.

The use value of the site being visited is the increase in expenditure necessary to compensate for an increase in the price of a visit sufficient to reduce the number of visits to zero. Thus, this value provides a dollar measure of the welfare change associated with the use that takes place at the existing price, P_1. To measure the use value of a quality change, we are interested in how the welfare change associated with having these access conditions (i.e., the price of P_1) would itself change with a change in the quality of the resource. Thus, the use value of an increase in quality from Q_1 to Q_2 (where $Q_2 > Q_1$) is the increase in the use value of the site:

$$S_U \equiv E[P_1^*(Q), P_2, \ldots, P_n, Q_2, U^*] - E(P_1, P_2, \ldots, P_n, Q_2, U^*) \qquad (6.8)$$
$$- E[P_1^*(Q), P_2, \ldots, P_n, Q_1, U^*] + E(P_1, P_2, \ldots, P_n, Q_1, U^*) ,$$

where

$P_1^*(Q)$ = the price at which $X_1 = 0$

P_1 = the original price per visit.

Implicit in this formulation is the assumption that $X_1 > 0$ at P_1 and Q_1. Notice that S_U can be defined only if there is a price that chokes off demand. S_U can also be measured by the area between the compensated demand curves for X_1 at the two levels of Q.

Now let us define nonuse benefits as that change in expenditure that holds total utility constant given that the price of visits is so high as to eliminate use of the site. In terms of the expenditure function, nonuse benefits, S_N, are defined as follows:

$$S_N \equiv E[P_1^*(Q), P_2, ..., P_n, Q_1, U^*] - E(P_1^*(Q), P_2, ..., P_n, Q_2, U^*) . \tag{6.9}$$

According to this definition, existence benefits can be positive for potential users and even for those who do use the site when P_1 is less than P_1^*.

Now define an individual's total benefit from a change in Q as the sum of that individual's use benefit and nonuse benefit:

$$S \equiv S_U + S_N . \tag{6.10}$$

Substituting Equations (6.8) and (6.9) into (6.10) gives the following expression:

$$\begin{aligned} S = {} & E[P_1^*(Q), P_2, ..., P_n, Q_2, U^*] - E(P_1, P_2, ... P_n, Q_2, U^*) \\ & - E[P_1^*(Q), P_2, ..., P_n, Q_1, U^*] + E(P_1, P_2, ..., P_n, Q_1, U^*) \\ & + E[P_1^*(Q), P_2, ..., P_n, Q_1, U^*] - E[P_1^*(Q), P_2, ..., P_n, Q_2, U^*] \\ = {} & E(P_1, P_2, ..., P_n, Q_1, U^*) - E(P_1, P_2, ... P_n, Q_2, U^*) . \end{aligned} \tag{6.11}$$

This expression gives the increase in the value of a resource as it increases in size or quality. But it does not shed any light on the value of existence versus nonexistence of the resource. Let $\bar{Q}$ represent the minimum level of Q at which it can be said that the resource exists. Clearly, $\bar{Q}$ represents a threshold or minimum viable level of the resource. At $\bar{Q}$, use value is given in Equation (6.12):

$$S_U = E[P_1^*(\bar{Q}), P_2, ..., P_n, \bar{Q}, U^*] - E(P_1, P_2, ... P_n, \bar{Q}, U^*) . \tag{6.12}$$

Existence value is given in Equation (6.13):

$$S_E = E[P_1^*(Q), P_2, ..., P_n, Q_1, U^*] - E[P_1^*(\bar{Q}), P_2, ... P_n, \bar{Q}, U^*] , \tag{6.13}$$

where $Q_1 < \bar{Q}$.

Defining total value S as $S_U + S_E$ gives

$$S = E[P_1^*(\bar{Q}), P_2, \ldots, P_n, Q_1, U^*] - E(P_1, P_2, \ldots P_n, \bar{Q}, U^*) . \quad (6.14)$$

Comparing the first terms of Equations (6.11) and (6.14) is instructive. If Q_1 is less than $\bar{Q}$, the first term in Equation (6.11) does not accurately convey the implications of the connection between X_1 and Q, especially the manner in which that association constrains the decisions an individual can make. The conventional expenditure function is the solution to the dual of the utility maximization problem subject to the usual constraints. When the level of Q exceeds $\bar{Q}$, the constraint on X_1 is not binding, and, consequently, the form of the expenditure function will be different than when this constraint is applied. More specifically, with $Q < \bar{Q}$, X_1 must be zero, and greater expenditures are required to realize the utility level U*. The first term in the reduced version of Equation (6.11) does not make this apparent. It appears that the only constraint to the level of consumption of X_1 is the price, P_1. The distinction would be apparent if we solved analytically for the expenditure function using some specific functional form for the utility function. When Q_1 is assumed to exceed $\bar{Q}$, the selections of all X_i's can be assumed to be consistent with an interior solution. However, when Q_1 is not greater, then the solution involves a boundary value or corner in X_1 (i.e., with $X_1 = 0$). There is, however, some additional information we can use. This case must be equivalent to the expenditures made at level Q_1 when $P_1 = P_1^*(\bar{Q})$. Thus, we can use this information and substitute in Equation (6.11) for the first term to derive Equation (6.14).

In conclusion, the total nonuse benefits of an increase in Q can still be defined as in Equation (6.9). But if $Q_1 < \bar{Q}$, nonuse benefits have two components, one related to existence alone (S_E) and one related to magnitude or size of the resource.

What does this analysis imply about the measurement of existence and nonuse values? The first implication is that nonuse value and use value can only be meaningfully distinguished in those cases in which there is some price (P_1^*) above which use drops to zero. The definitions of both use and existence values are predicated on the existence of some price at which use falls to zero. And that can be assumed only if there is some nondivisibility in X_1 such that quantity demanded must be zero at $P_1 > M$. Otherwise, total value can be defined as in Equation (6.11), but no allocation between use and nonuse value is possible. Second, Mäler's definition of weak complementarity is equivalent to saying that nonuse values are zero. But if weak complementarity does not hold, and if the present price of the visit is equal to or greater than P_1^*, then use value is zero while existence value may be positive. And at any price, even "nonusers" might become users if the price of a visit were to fall sufficiently.

Third, as Mäler has shown, even if a complete system of demand functions for X has been estimated on the basis of market data, the expenditure function cannot be recovered unless the conditions for weak complementarity hold (Mäler [1974], pp. 121-25, 183-89). But positive existence value implies the violation of the weak complementarity conditions. Thus, if existence value is positive, the total value of a change in Q cannot be estimated from observations of market data. It appears that contingent valuation techniques must be relied upon in this case.

The fourth implication concerns the measurement of use value. The accurate measurement of use value requires knowledge of the compensated demand function for visits. But this demand function cannot be recovered from market data unless the conditions for weak complementarity hold--i.e., unless existence value is zero. Of course, in some cases (as described above), use value can be measured as a reasonable approximation through the use of the ordinary demand functions for visits.

What can be said about measuring S_E or S_N for users? One approach would be to use contingent valuation techniques to estimate total values for a set of users and use market techniques such as the travel cost model to estimate S_U for the same group. A comparison of the estimates of S and S_U would constitute a test of the hypothesis that nonuse values are positive for users. Another approach is to ask people their willingness to pay for an improvement in Q or to preserve an ecological site of given Q even if they knew they would never be able to visit the site. This is the approach taken by Desvousges, Smith, and McGivney [1983] to estimate existence values for water quality in the Monongahela River. One problem with this approach is that it asks people to place themselves in a counterfactual situation. It might be helpful to provide an explanation as to why they should imagine that they would not be able to visit the site.* For example, they might be told that the price of visits had been increased to some very high number, effectively choking off demand for visits. Or they might be told that all visits had been banned to prevent damage to some fragile component of the ecosystem.

Finally, individuals might be asked to reveal their total value and then asked to allocate this total between use and nonuse values. One problem with this approach is that respondents typically are given no guidance as to what conditions to assume when they perform the allocation. Since nothing is said in this sort of question about the assumed price of visits, there is no reason to believe that the respondent's mental processes will reproduce the conditions defining existence and nonuse values stated above.

6.3 UNCERTAINTY OF EXISTENCE

In this section we extend the discussion of use, nonuse, and existence values to the case where the individual is uncertain as to the existence or supply of the environmental resources. We assume the individual has assigned probabilities to the two states of nature--the resource exists, $Q = \bar{Q}$; and the resource does not exist, $Q = 0$. We develop measures of value for regulation that cause the individual to revise upward the probability that $Q = \bar{Q}$. And we consider the possible relationship between these measures of value and observable ex post measures, namely changes in expected use values.

Our analysis will also restrict the general framework for describing individual choice that was discussed in Chapters 3 and 4 by assuming there is a specific source for the state dependency in individual utility functions. Recall that, in Chapter 4, the planned expenditure function was defined by acknowledging the existence of state-dependent utility functions but without describing the factors that caused the marginal utility of income to vary with state. Here

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*In the Desvousges, Smith, and McGivney [1983] effort this was done through the use of the value card. This interviewer aid was used to explain to respondents the different potential types of values for a water quality improvement including the use, option and existence values. After a few questions designed to provide respondents practice with the proposed taxonomy, the framework was used to elicit the components of the total value of the resource. It is, of course, an open question as to whether this approach facilitates the task that confronts survey respondents.

we will assume that the state dependency arises exclusively as a result of the existence of the environmental resource. Our framework is completely consistent with a state-dependent specification with two states. We have simply given a somewhat more specific form to the function by specifying that

$$U_1(X_1) = U(X_1, 0)$$

and

$$U_2(X_2) = U(X_2, \bar{Q}).$$

Let q_1 and r_1 ($r_1 < q_1$) be the probabilities that the resource will not exist in the absence of and with the policy, respectively. So, $q_2(= 1 - q_1)$ and $r_2(= 1 - r_1)$ are the probabilities of existence or supply--with $r_2 > q_2$. Expected utility in the absence of the policy is given in Equation (6.15):

$$E(U)^* = q_1 \; U(X_1, 0) + q_2 \; U(X_2, \bar{Q}) \; . \tag{6.15}$$

The subscripts on the goods vectors X_i allow for the possibility that purchases of market goods--visits to the resource in particular--will be affected by the availability of the resource.

As discussed in Chapter 5, assuming that the individual minimizes the planned expenditures required to realize a given expected utility subject to the set of contingent prices, the planned or ex ante expenditure function can be written as Equation (6.16):

$$\bar{E}[P, q_1, \bar{Q}, E(U)^*] \; , \tag{6.16}$$

where

P = the vector of prices for contingent claims.

The ex ante benefit of the policy that raises the probability of supply is the decrease in expenditure to attain E(U)* made possible by the higher probability of supply as given in Equation (6.17):

$$S = \bar{E}[P, q_1, q_2, \bar{Q}, E(U)^*] - \bar{E}[P, r_1, r_2, \bar{Q}, E(U)^*] \; . \tag{6.17}$$

This measure captures both ex ante use and existence values. Estimates of S might be elicited by appropriately designed contingent valuation questions that describe the ecological resource and the change in risk associated with the policy.

Often analysts have estimates of ex post use values derived from observations of actual users based on, for example, the travel cost site demand model. A natural question is whether ex post use values can be the basis of estimates of ex ante values. Two kinds of problems are encountered in trying to calculate ex ante values from observed ex post use values. The first problem, of course, is that there is no logical relationship between use values and nonuse and existence values, even for users. So to the extent that nonuse values and existence values are significant, observations of use values will yield underestimates of total values. Moreover, the error potentially could be quite large.

The second kind of problem arises because of the difference in perspectives between the desired ex ante value and the observed ex post value. The remainder of this section expands upon the material developed in Chapter 4 by focusing on ecological values and the relationship between ex post and ex ante use values within a framework that assumes a specific source of the state dependency in utility and a specific institutional framework for individual adjustment in response to a risk change. This focus permits an evaluation of the nature and extent of possible errors involved in using ex post values as estimators of ex ante use values.

To focus attention on use values, we assume that nonuse and existence values are zero. We also assume that income and prices are constant across states of nature. Finally, we assume that there are no contingent claims markets and that state-dependent payments for the resource are not feasible, so that the maximum state independent payment or option price (OP) for the reduction in risk is the relevant ex ante welfare measure. Option price is that constant payment for the policy that makes the expected utility with the policy equal to expected utility without the project. It is the solution to Equation (6.18):

$$q_1V(Y, 0) + q_2V(Y, \bar{Q})$$
$$= r_1V(Y - OP, 0) + r_2V(Y - OP, \bar{Q}) \ , \qquad (6.18)$$

where $V(\cdot)$ is the indirect utility function associated with $U(\cdot)$. It is assumed constant in all states and Y is income.

Since the ex post use value, S_U, is the solution to Equation (6.19),

$$V(Y - S_U, \bar{Q}) = V(Y, 0) \ , \qquad (6.19)$$

Equation (6.18) can be written as Equation (6.20):

$$q_1V(Y - S_U, \bar{Q}) + q_2V(Y, \bar{Q}) = r_1V(Y - OP, 0) + r_2V(Y - OP, \bar{Q}) \ . \qquad (6.20)$$

In the most general analysis, four possible patterns of supply uncertainty and risk reduction can be distinguished on the basis of whether the policy eliminates uncertainty ($r_2 = 1$) or not ($r_2 < 1$) and whether or not there is a possibility of supply in the absence of the policy.* These cases can be summarized as follows:

<u>Case A</u>: No policy, no supply.
With policy, sure supply--$q_2 = 0$, $r_2 = 1$.

<u>Case B</u>: No policy, possible supply.
With policy, sure supply--$q_2 > 0$, $r_2 = 1$.

<u>Case C</u>: No policy, no supply.
With policy, possible supply--$q_2 = 0$, $r_2 < 1$.

<u>Case D</u>: No policy, possible supply.
With policy, possible supply--$0 < q_2 < r_2 < 1$.

The relationship between OP and the expectation of S_U can be analyzed for each of these cases by imposing the appropriate probability conditions on Equations (6.18) or (6.20) and solving for OP.

For Case A ($q_2 = 0$, $r_2 = 1$), Equation (6.20) reduces to Equation (6.21a):

$$V(Y - S_U, \bar{Q}) = V(Y - OP, \bar{Q}) \ . \qquad (6.21a)$$

*This analysis is based on Freeman [forthcoming b].

Therefore,

$$OP = S_U = (r_2 - q_2)S_U \ . \qquad (6.21b)$$

Option price equals the increase in expected surplus, and there is no error involved in using S_U as an ex ante welfare measure. But this should be no surprise. There is no uncertainty either with or without the program.

For Case B ($q_2 > 0$, $r_2 = 1$), Equation (6.20) becomes Equation (6.22):

$$q_1V(Y - S_U, \bar{Q}) + q_2V(Y, \bar{Q}) = V(Y - OP, \bar{Q}) \ . \qquad (6.22)$$

Bishop [1982] and Brookshire, Eubanks, and Randall [1983] present (respectively) mathematical and graphical proofs that option price is greater than expected use value for risk averse individuals.* A graphical proof can be presented with the aid of Figure 6-1, which shows utility as a function of income, given that the resource is available. Assume that $q_2 = 1/2$. The left side of Equation (6.22) gives E(U)* as shown in the figure. Now suppose that with the program the individual must make a state-independent payment equal to $(r_2 - q_2)S_U = 1/2\ S_U$. The expected utility of this payment scheme is E(U), > E(U)*. Thus, the maximum state-independent payment or option price is greater than $1/2\ S_U$. The intuition is straightforward. In the absence of the program, the individual, in effect, holds a lottery on Q. The risk-averse individual would pay more than the expected monetary equivalent of the lottery (expected S_U) to eliminate the uncertainty associated with the lottery. The excess of option price over expected S_U is a risk-aversion premium or supply side option value in Bishop's terminology.

For Case C ($q_2 = 0$, $r_2 < 1$), Equation (6.20) becomes Equation (6.23):

$$V(Y - S_U, \bar{Q}) = r_1V(Y - OP, 0) + r_2V(Y - OP, \bar{Q}) \ . \qquad (6.23)$$

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*Both papers were concerned with a different formulation of the question. They defined supply side option value as the difference between OP and expected S_U and asked whether supply side option value was positive or negative.

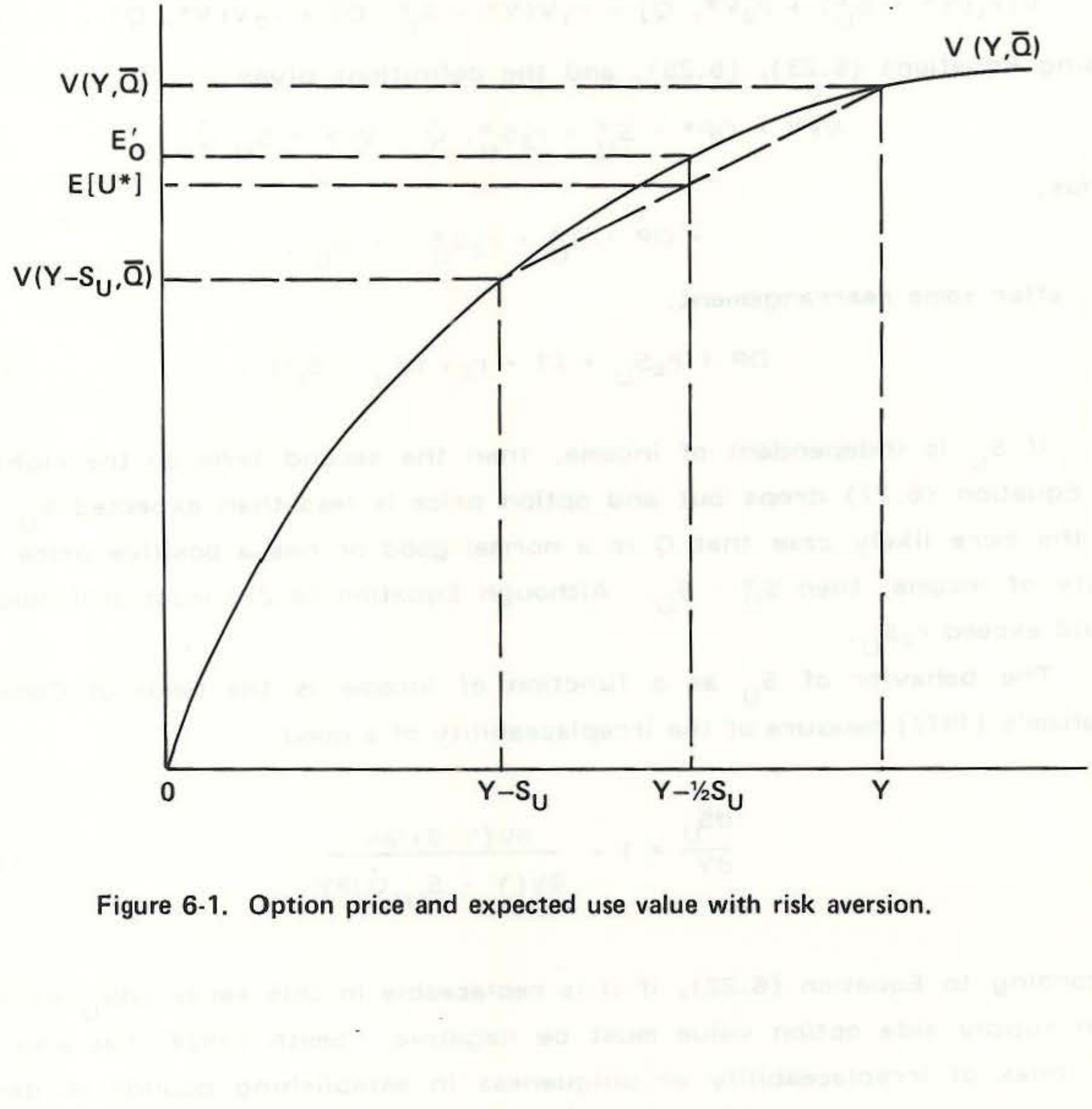

Figure 6-1. Option price and expected use value with risk aversion.

In this case, the sign of option value is indeterminate. A mathematical proof requires the introduction of two new terms.*

Let $Y^* = Y - OP$ and define S_U^* by

$$V(Y^* - S_U^*, \bar{Q}) = V(Y^*, 0) . \tag{6.24}$$

Strict concavity of V in income implies:

$$V[r_1(Y^* - S_U^*) + r_2Y^*, \bar{Q}] > r_1V(Y^* - S_U^*, \bar{Q}) + r_2V(Y^*, \bar{Q}) . \tag{6.25}$$

Using Equations (6.23), (6.25), and the definitions gives

$$V(Y - OP^* - S_U^* + r_2S_U^*, \bar{Q} > V(Y - S_U \bar{Q}) . \tag{6.26}$$

Thus,

$$- OP - S_U^* + r_2S_U^* > - S_U ,$$

or, after some rearrangement,

$$OP < r_2S_U + (1 - r_2) (S_U - S_U^*) . \tag{6.27}$$

If S_U is independent of income, then the second term on the right side of Equation (6.27) drops out and option price is less than expected S_U. But in the more likely case that Q is a normal good or has a positive price flexibility of income, then $S_U^* > S_U$. Although Equation (6.27) must still hold, OP could exceed r_2S_U.

The behavior of S_U as a function of income is the basis of Cook and Graham's [1977] measure of the irreplaceability of a good:

$$\frac{dS_U}{dY} = 1 - \frac{\partial V(Y,0)/\partial Y}{\partial V(Y - S_U,\bar{Q})\partial Y} . \tag{6.28}$$

According to Equation (6.22), if Q is replaceable in this sense ($dS_U/dY = 0$), then supply side option value must be negative. Smith (1984) has also used the index of irreplaceability or uniqueness in establishing bounds on demand side option value. It is important to draw attention to the role played by the

*We are indebted to John Fitzgerald for suggesting this proof.

Cook-Graham index in these analyses. It provides a gauge of the element in a state-dependent model of consumer behavior under uncertainty that is important for the outcomes and valuations of policy changes implied by the model. That is, it provides a simple description of the extent of the difference in the marginal utility of income at points that would be regarded as equivalent in terms of their respective levels of the total utility. That is, the point described by $Q = \bar{Q}$ and income at $Y - S_U$ has the same total utility as the point at which $Q = 0$ and income is Y. They are on the utility certainty locus. However, a marginal change in income means something quite different in the two states. It is this point that Arrow [1974] identified as the key element in a state-dependent specification. With our restriction in the source of the state dependency for the analysis of this chapter, this result then describes how the importance of the state dependency is realized through the change in a component (S_U) of the ex post measure of the change in Q.

In Case D, all of the probabilities are positive. We have not been able to find a general proof regarding the relationship between OP and $(r_2 - q_2)S_U$. However we have done sample numerical calculations with alternative utility functions, parameters, and probabilities and have found examples to show that $OP - (r_2 - q_2)S_U$ can be either positive or negative. Some of these calculations are shown in Appendix A. These calculations seem to suggest that the difference between OP and $(r_2 - q_2)S_U$ may be relatively small; but this is not a firm conclusion. The question requires further research.*

To summarize the results of this analysis, expected use value is an ex post valuation measure. But if the indirect or von Neumann-Morgenstern utility function is known, then it may be possible to derive analytical expressions for the calculation of option price as a function of expected S_U and the parameters of $V(\cdot)$. Thus, if option price is the desired ex ante welfare indicator, it may be possible to compute option price from the available ex post indicators and assumptions concerning degree of risk aversion and so forth. As we discussed in Chapter 4, option price is a measure of welfare change that assumes a specific set of opportunities for adjusting to risk are available

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*See Freeman [1984a] for some results of an investigation of the likely magnitude of demand side or "timeless" option value.

to the individual such that state-dependent payments are not possible. If there are actuarially fair opportunities for insuring against risk either through contingent claim markets or alternative payment plans, then option price is an underestimate of the ex ante welfare measure. And, in any case, none of these measures based on use data reflects any form of nonuse value.

6.4 CONCLUSIONS

In this section we draw out some of the implications of the preceding analysis for efforts to estimate the ecological and intrinsic benefits stemming from hazardous waste regulation. In a world of uncertainty, individuals can be placed in one of three categories with respect to their possible use of the ecological resource. First, there are those who are certain to use the resource if it is available. Second, there are those who are uncertain of their use of the resource. They are potential or possible users. And third, there are those whose probability of using the resource is effectively zero--i.e., they are nonusers. The first and second categories of individuals can have both use and existence values for the resource. The third category of individuals can have only existence values. Of course, the boundary between the second and third categories may be indistinct in practice. If we ask individuals to identify themselves as either potential users or nonusers, some people with low but nonzero probabilities of future use may identify themselves as nonusers. And statistical models for predicting probability of use may generate trivially small but nonzero probabilities for many individuals. As a practical matter, they should be treated as nonusers.

For the moment let us assume that the probability of the supply of the resource is one. Use values for actual users (drawn from both the first and second categories) can be estimated by existing indirect methods such as the travel cost model. But these methods are incapable of shedding any light on possible existence values.

One approach to estimating the total value for users is to ask them a contingent valuation question about their total willingness to pay for the resource. If respondents understand that this value is to encompass both use and existence values, then their answers are all that is needed for policy purposes. However, to test hypotheses about the magnitude of and determinants of existence value, it would be useful to have the total value broken down into its two components. Some researchers have simply asked people to allocate their total willingness to pay into use and existence categories. One difficulty with this approach is that it asks people to place themselves in a hypothetical situation, which may be difficult for them to imagine. That is, it asks them to imagine that they are nonusers without specifying for them the reason that they no longer use the resource. A recommended principle in the design of contingent valuation instruments is that questions should correspond as closely as possible to respondents' actual situations.* Another approach is to compare the contingent value responses with estimates of use values derived from indirect techniques. In principle, the difference between the two measures is existence value. However, in practice, at least part of the difference may be due to measurement errors in either or both measures.

For the second category of users, one approach is to estimate expected consumer surplus from data on actual users and to use assumptions about the structure of demand uncertainty and preferences to compute option price. But this gives an estimate of the increase in expected utility associated only with use. Again, the only way to get at existence values is to ask a contingent valuation question about total willingness to pay. And, finally, for nonusers, contingent valuation questions are the only basis for drawing inferences about existence values.†

In the case of uncertainty in supply and programs to increase the probability of availability, consumer surpluses of actual users may provide a basis for estimating increases in expected use values. But, as in the case of only demand uncertainty, contingent valuation questions are required to obtain total values that include existence values.

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*For a more complete evaluation of the reference operating conditions that include this requirement, see the Cummings, Brookshire, and Schulze [1984] definition.

†See Brookshire, Eubanks, and Randall [1983] for an example in which certain nonusers in the sample were identified. Their responses were interpreted as pure existence values.

PART II

RESEARCH DESIGN, QUESTIONNAIRE DEVELOPMENT, AND THE SURVEY

Part II of this draft interim report describes how we implemented the conceptual framework developed in Part I through designing and completing a contingent valuation survey to measure the benefits expected to accompany hazardous waste regulations. Part II comprises the following four chapters:

Chapter 7 - Research Design: The Transition from Theory to Practice

Chapter 8 - Survey Questionnaire Development

Chapter 9 - Sampling Plan and Survey Procedures

Chapter 10 - Profile: The Survey Area and Its Population

As suggested by their titles, the first three chapters describe the evolution and development of the survey questionnaire, the experimental design, and our survey administration and sampling procedures. The last chapter in this part briefly describes the survey area, the information on hazardous wastes available to survey respondents, and the attitude and character of survey respondents.

In the process of conducting and reporting on a fairly long, complex research effort, the specific details of the tasks involved in the research, both important and tangential, can obscure the reader's overall perception of the research objectives. For this project it is important to remember that the primary objective was to value changes in the risk of exposure to hazardous wastes. In particular, in contrast to the strategy adopted by the Cummings, Brookshire, et al. [1983] study that sought to value regulations, our premise is that the hazardous waste regulations provide a reduction in the risk of exposure to these wastes. In effect, the regulations deliver a risk change--and a change in a very specific kind of risk at that: the risk of <u>exposure</u> to hazardous waste. Thus, to measure the benefits of a regulatory policy, it is necessary to value this change in risk. This implies that it is necessary to know how individuals value changes in risk and to obtain empirical estimates of those values. We have argued in the conceptual analysis that not all risks are the same. Therefore, it is also important to know how the empirical estimates of these values are influenced by the specific features of the risk (e.g., the attributes of hazardous waste risks are likely to differ from occupational risks), the circumstances of what is at risk, and the characteristics of the individuals who are asked to envision themselves as experiencing the changes in risk. These observations are not new. Indeed, the literature on people's ability to process risk information--both from experts and ordinary individuals--suggests that all of these elements will be important to interpreting the results of any effort to value risk changes.

The experimental economics and psychology literature on individuals' behavior under uncertainty provide valuable insights that influenced several dimensions of our research design for valuing changes in hazardous waste risk. For example, work by Schoemaker [1982], Hershey, Kunreuther, and Schoemaker [1982], Tversky and Kahneman [1981], and Slovic and Lichtenstein [1984] points out the need to consider various features of the risk itself. That is, hazardous waste risks may have certain attributes or characteristics that will affect people's values for reductions in these risks. The importance of the context of the risk also clearly emerges from this literature. Context implies that the circumstances through which the individual experiences the risk (whether real or hypothetical) may affect his valuation of a risk change. One of its central elements in any description of risk is the implicit property rights surrounding the risk change.

Some elements of the research also stem from another closely related set of research--the recent findings of the state-of-the-art assessment of the contingent valuation method (see Cummings, Brookshire, and Schulze [1984]). Chapter 7 begins this section by discussing how the conceptual framework influenced the structure of the questionnaire and its implementation in the survey design.

Of course, it is also important to note that the nature of the research design was significantly influenced by the focus groups conducted in the early stages of developing methods for discussing hazardous waste and risk with individuals. These activities are described in some detail in Chapter 8 (and in greater detail in Desvousges et al. [1984a,b]).

The sampling and survey design, described in Chapter 9, highlight the target population, the sampling procedures used to obtain a representative sample of the target population, and the survey procedures that implemented the sampling, and in fact, the research design. Chief among these are the detailed quality controls for the monitoring of interviewing process.

Chapter 10 provides a brief overview of the survey area, the target population, and how our respondents compare with that population. In addition, it also includes a brief description of several hazardous waste contamination incidents that have occurred in the survey area and types, amounts, and sources of the information concerning them. Finally, the chapter profiles certain key features of the survey respondents including their knowledge and perception of hazardous wastes.

CHAPTER 7

RESEARCH DESIGN: THE TRANSITION FROM THEORY TO PRACTICE

7.1 INTRODUCTION

This chapter describes the research design that underpins our contingent valuation survey for measuring an individual's values for reductions in the risk of exposure to hazardous wastes. It has a difficult but important task because it translates theoretical concepts and findings into their empirical counterparts. The research design links the conceptual analysis, developed in Part I of this report with the questionnaire development effort and the survey sampling and administration procedures described in this part. Equally important, it also provides some of the rationale for the analyses of the survey data that are described in Part III. In essence, then, the research design explains the reasons behind the structure of the empirical research and outlines in general terms hypotheses to be tested in the empirical analysis.

With valuing changes in hazardous waste risk as its focal point, our design tries to determine the most salient features of risk as a commodity. In performing this task, the design considers the sources of value (for both use and intrinsic values), the attributes or characteristics of risk, the assignment of property rights, and the basic elements of the risk change itself--initial values, endpoints, and outcomes at risk. To organize these efforts, the chapter examines how the risk-related concepts affect the main objectives of our research. It also draws on our conceptual analysis from Part I for most of the guideposts of our organization.

The scope and complexity of concepts relating to valuing changes in risk suggest that developing an effective research design will be difficult. For example, the concepts ignore neatly drawn disciplinary boundaries by involving changing mixtures of economic, psychological, and sociological phenomena that researchers from each of the disciplines have considered. With this diversity of disciplines, the research design presented in the chapter follows from our primary objectives of estimating the use and intrinsic benefits associated with reductions in the risk of exposure to hazardous wastes. However, it also tries to blend together those elements from various disciplines that seemed most important for how people perceive and process the information on, and ultimately value the changes in, the risk of exposure to hazardous wastes. The final blend follows from our review of the literature, our experiences in the focus group discussion sessions, and suggestions received from many outside reviewers. Consequently, this chapter describes how each of the research issues affects our objectives, considers their importance for valuing reductions in the risk of exposure to hazardous wastes and for the comparison of different approaches for valuing risk changes, and pinpoints how they are reflected in the overall design.

7.2 GUIDE TO THE CHAPTER

Section 7.3 of this chapter provides an overview of the project leading up to the development of the research design. Section 7.4 describes the types of values--use and intrinsic--that are addressed in the research design. Section 7.5 addresses the importance of different initial levels of risk and sizes of risk reductions on individuals' values of reductions in risk. Section 7.6 provides the rationale for and treatment of the assignments of the property rights of risk changes in the design. Section 7.7 highlights the two types of risk included in the research: risks of exposure to hazardous wastes and occupational risks. It also discusses risk attributes and their inclusion in the research design. Section 7.8 considers the context of hazardous waste risks and how it affects the research design. Section 7.9 describes risk outcomes and endpoints. Section 7.10 examines three issues from the contingent valuation literature that were important to the research design: the role of the question formats used to elicit risk values, the information provided to respondents, and the perceptions of the contingent commodity. Section 7.11 discusses the features of the design that allow for a comparison of its values with those measured using indirect approaches for benefits measurement. Section 7.12 explains the interconnections in the research design. Finally, Section 7.13 considers the implications of the various issues discussed in this chapter for the research design.

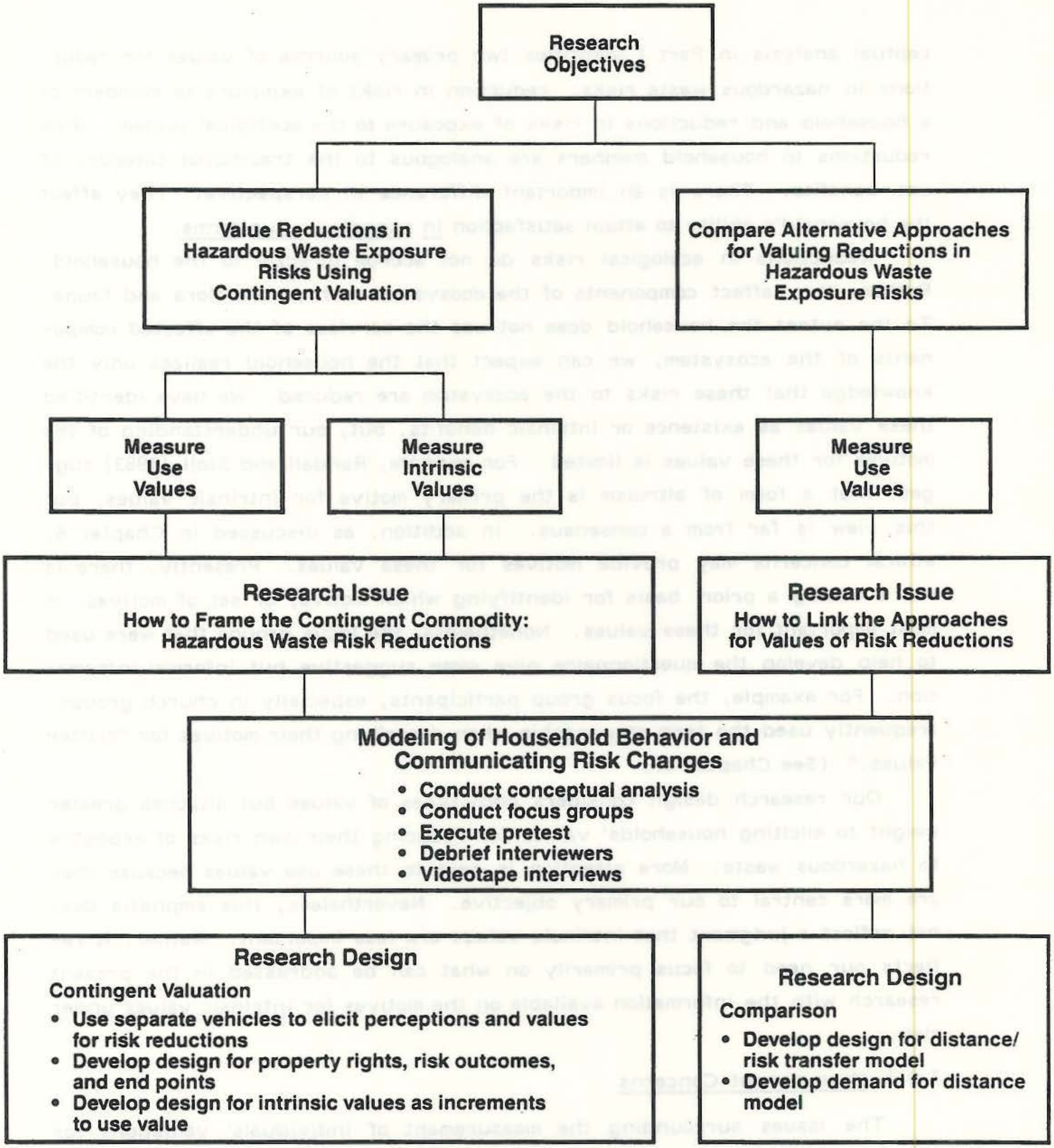

Figure 7-1. Overview of the origins of the research design for valuing reductions in hazardous waste risks.

ceptual analysis in Part I identifies two primary sources of values for reductions in hazardous waste risks: reduction in risks of exposure to members of a household and reductions in risks of exposure to the ecological system. Risk reductions to household members are analogous to the traditional category of use benefits. There is an important difference in perspective. They affect the household's ability to attain satisfaction in expected value terms.

Reductions in ecological risks do not accrue directly to the household. Rather, they affect components of the ecosystem such as the flora and fauna. To the extent the household does not use the services of the affected components of the ecosystem, we can expect that the household realizes only the knowledge that these risks to the ecosystem are reduced. We have identified these values as existence or intrinsic benefits, but, our understanding of the motives for these values is limited. For example, Randall and Stoll [1983] suggest that a form of altruism is the primary motive for intrinsic values, but this view is far from a consensus. In addition, as discussed in Chapter 6, ethical concerns may provide motives for these values. Presently, there is not a strong a priori basis for identifying which motive, or set of motives, is most important for these values. Nonetheless, the focus groups that were used to help develop the questionnaire give some suggestive but informal information. For example, the focus group participants, especially in church groups, frequently used the term stewardship when describing their motives for "critter values." (See Chapter 8.)

Our research design considers both types of values but attaches greater weight to eliciting households' values for reducing their own risks of exposure to hazardous waste. More attention is paid to these use values because they are more central to our primary objective. Nevertheless, this emphasis does not reflect a judgment that intrinsic values are less important. Rather, it reflects our need to focus primarily on what can be addressed in the present research with the information available on the motives for intrinsic values under risk.

7.4.1 Measurement Concerns

The issues surrounding the measurement of individuals' valuations for risk reductions are especially complex. Consequently, estimates for them are likely to be the most controversial. For example, Kahneman's [1984] comments on the use of contingent valuation methods to estimate the value of some amenity resources do not offer much encouragement for trying to measure these values. His comments imply that these benefits may be value-laden with ideological overtones.* Specifically, he argues that, where there has not been experience in purchasing a commodity (and, presumably, this experience could be direct, as with market goods, or indirect, as would be the case with commodities requiring the individual to incur costs to experience the service), the expression of preferences may lead to nonsensical estimates of value and be a "symbolic demand." Under this view, the use of contingent valuation for measuring the values of goods or services having no indirect basis for valuation would be questionable. He summarized his concerns by noting that

> In particular, I question the existence of a coherent preference order at the individual level which is waiting to be revealed by market behavior. I am not sure that I have a "true" dollar value for the trees that I can see out of my window. . . [Kahneman, 1984, p. 233]

Given this view--which might be regarded as an indirect implication of Cummings, Brookshire, and Schulze's [1984] reference operating conditions--how does one proceed to try to measure the values of risk changes, especially when contingent valuation offers the only approach presently available? Our research design addresses the measurement of these values in several very specific ways. First, it recognizes that individuals may have different capacities to envision the proposed risk changes and to value them. It is difficult to disagree with the Kahneman position or even the position suggested by Freeman [1984b] that people are being asked to perform very difficult tasks for which they have little prior experience in that particular range of their preference structure. The research design reflects this position by eliciting values for two different risk changes from <u>each</u> individual. This allows the empirical analysis to address the effects of differences among individuals in their ability

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*The relationship between a change in utility and dollar measures of that change have been controversial since Alfred Marshall first introduced the concept of consumer surplus. For the most part, the literature on developing these valuation measures has accepted a Hicksian framework and focused on valuing price and quantity changes (see Morey [1984]). The development of dollar measures for the utility changes associated with quality changes is not as clearcut. For an illustration of these issues, see Desvousges and Smith [1984].

to research their preferences. For example, the models discussed in Chapter 13 recognize that values will differ depending on differences in income, education, and knowledge of hazardous wastes across individuals. Moreover, they attempt to adjust for the differential performance of the model itself in explaining valuations across individuals.

The focus group and videotape sessions also played an important role in designing a set of questions that attempted to reflect the Kahneman concerns about measuring values for commodities that are not routinely a part of purchase and consumption decisions. These sessions asked people about how they thought about these values, their motives, and the sources of their values. In effect, these sessions explored ways that might make it easier for people to search these new areas of their preferences. Based on the focus group sessions, it appeared that the more specific the situation in which the risks to individuals (and to the ecosystem) was framed in the hypothetical questions, the easier it was for people to appraise their valuations for these risks. This finding is consistent with Wallsten and Budescu's [1983] evaluation of approaches to encoding probabilistic information from experts on particular phenomena. They suggest that the analyst has to carefully specify the class of events in question, the sources of information to be considered, and the causes of unreliability in the information. Thus, presurvey attempts to understand how people formed their preferences substantially affected the research design for eliciting and measuring the valuation of risk reductions.

7.4.2 Sequence Effects and Intrinsic Values

The conceptual framework developed in Part I of this report described the rationale for measuring individuals' values for risk reductions in an ex ante framework for both use and intrinsic values for changes in risk. Yet there may be differences in how risks affect these values. That is, in describing a risk change to a household, to elicit what is described as an ex ante use value, the risk change must be experienced by the household. In contrast, the intrinsic values are associated with changes in risks to the ecosystem (and not the household). The description and character of each is distinct. However, in some ways, this is an easier separation to explain than with the services associated with many other environmental policies. For example, to elicit the existence value of a water quality change in a specific lake or river, circumstances must be described to an individual to preclude use of the improved resource by him or his household members. As we acknowledged in Chapter 6, this hypothetical situation may be so implausible that it becomes completely unrealistic. By contrast, with a risk change, it is possible that disposal practices might reduce the risks experienced by one group (e.g., households) but not those of another (i.e., nonhuman species that constitute the ecosystem) or vice versa.

Past research on the process of eliciting these values suggests that the order or sequence of the valuation requests in a questionnaire may influence the authenticity of the values provided. Because of this plausible separation in the mechanism delivering the risk reduction, it appears that the sequencing issue may be less important for estimating different types of values for risk reductions. Nonetheless, it is important to discuss the sequence used in the research design and the potential relationship it might have for the valuation estimates. Mitchell and Carson [1984], Randall, Hoehn, and Tolley [1981], and Cummings, Brookshire, and Schulze [1984] all have expressed concern over the potential importance of the sequence in which a value is elicited. For example, Randall, Hoehn, and Tolley [1981] found that the question sequence eliciting the value people placed on visibility improvements in the Grand Canyon affected the value. Our research does not explicitly provide a test for the effect of question sequences. Instead, the intrinsic value question was asked after the use values, always as an incremental amount.

All of the questionnaire types in our survey maintained this incremental format--i.e., eliciting intrinsic values as an <u>additional</u> amount. This is in contrast to the Mitchell and Carson [1984] procedure that elicited a "total" value for water quality that reflected both use and intrinsic values. One reason for our use of a different procedure was to avoid mixing the very different characters of the two risks when they were presented to people. For example, the events at risk are fundamentally different. The use value is a reduction in risk of exposure (and potentially death, depending on the conditional risk) to the household, while the intrinsic value is a reduction in risks only for species in the natural environment. Our explanations also implied that the character of the risks would differ in terms of their respective endpoints. The endpoints for the household risks were always at some specific level of risk (or zero for those in the ranking version). The endpoint for species in the ecosystem was the unspecified risk level that these creatures face in their natural habitat.

The design does provide for two different sets of questions to precede the intrinsic value question, depending on the question format used to elicit the use values. For example, respondents receiving the direct question version (discussed in more detail later in this chapter) were asked to reveal amounts that they were willing to pay to obtain two successively lower levels of risk that varied within the design. However, the direct question version of the questionnaire did inform people <u>in advance</u> that the valuation exercise would elicit the two changes in the household's risk of exposure and an <u>additional</u> amount for critters. This advance notification was one element used in the structure of the questionnaire that attempted to reduce the potential sequencing effect in the direct question version.

In addition, the design elicited an intrinsic value from survey respondents, who gave zero bids for reducing their own household risks. Therefore, all respondents had the opportunity to express a value for intrinsic benefits. This approach contrasts with that used in Desvousges, Smith, and McGivney [1983], where values were elicited only from respondents who had given a positive dollar value to earlier use value questions. In the present survey, the individuals also differ in the initial levels of risk described for the intrinsic value question. Zero bidders, who chose not to "purchase" household risk reductions, had higher initial risk levels posed in the critter question than the people who purchased one or more reductions in household risk. Thus, the present design allows for a somewhat fuller treatment of intrinsic values. The importance of this alteration is an empirical question that is addressed in Chapter 11.

Although the design used the same question to elicit the intrinsic value questions for respondents who received contingent ranking version (also discussed later in this chapter), the procedure differed from the direct question version. The individual receiving the ranking version was asked to rank-order four pairs of exposure risks and payments. Following the ranking, a contingent valuation question was posed to elicit the willingness to pay to reduce household risks to zero was posed. This process provides another initial level of risk depending on whether or not the person purchased the household risk reduction. (The zero risk question was designed to address another issue hypothesized to have an important effect on behavior under uncertainty--the so-called "certainty effect," which is discussed later in this chapter.) In addition, in the ranking questionnaires, the individual was not told that an intrinsic value would be elicited after the value for reducing the household risk to zero. While this notification was inadvertently omitted and not a planned part of the design, it may provide a basis for evaluating some aspects of the sequencing problem. Thus, the research design placed the intrinsic value questions in very specific positions depending on the version of the questionnaire administered. The amount of information provided to people and the initial risk level was designed to permit differences in the starting risk level across versions of the questionnaire.

7.5 THE EFFECT OF RISK LEVELS AND CHANGES

This section highlights three dimensions of the risk information used in the research design that has been found in past research to be important to individuals' behavior under uncertainty: the level of the risk, the size of the risk change, and the specific set of probabilities (i.e., exposure and conditional) leading to these outcomes.

7.5.1 Risk Levels

Past research, both theoretical and empirical, has suggested that the level of the risk that confronts the individual when an increment (reduction or increase) is proposed can affect his marginal valuation. One rationale for including the level of risk as a feature of the design is that it was found to be important to the marginal valuation of risk (see, for example, Chapter 5).

A second reason may explain differences in the valuations for risk reductions from very low initial levels. This explanation works in the opposite direction to that used in most of the economics literature discussed in Chapter 5. That is, people may have higher values for risk reductions starting at very low levels because they may perceive that there is less technical knowledge or experience about these risk levels. For example, if a disease is known to be fatal in one out of every five cases, the individual may value a reduction in risk quite differently than if the fatality of the disease was one out of a million cases. In the second case, because the disease is rare, the individual may well regard the information provided on low-probability events as less accurate. That is, the individual is perceiving a different second-order probability distribution for the risks of death in the first case, where death is a more frequent occurrence, than in the latter case. Thus, the increased marginal values for reductions may reflect the greater perceived second-order uncertainty in the information on the risk.

The importance of assessing the effect of different initial levels of risk for valuing changes in hazardous waste risks is heightened by the uncertain nature of the technical information about the initial levels of risk. Three features complicate the technical estimation of the risks from hazardous wastes. One, research on exposure pathways, waste toxicity, and even the volume of the waste is in fairly early stages. For example, the Conservation Foundation [1984] and Office of Technology Assessment [1983] both point out the need for more and better technical information. Two, it seems possible that, even with better technical estimates of the risks from hazardous wastes, there will be a substantial range of these risks depending on the characteristics of the specific site. Sharefkin, Schechter, and Kneese [1984] stress the importance of site specific features such as geohydrology. Three, differences in response among receptors of exposure--e.g., people or ecosystems--are not well understood. Thus, having a research design that allows for different initial levels of risk is important not only from the perspective of consistency with the conceptual analysis used to define valuation measures for risk changes, but also from a very practical point of view that the situations in which regulations for hazardous wastes are proposed may involve a rather wide range of risk levels.

Allowing for varying initial levels of risks in the research design is also important because these levels may affect how individuals process information about risks. In effect, the kinds of thought processes that individuals can bring to bear on a question involving risk will be important to the valuation task that is central to contingent valuation. These thought processes may differ for different levels of risks. Wallsten and Budescu [1983] suggest that in its most general and far-reaching terms, the psychological considerations involve factors that influence memory and how people use information. Fischhoff, Slovic, and Lichtenstein [1980], Tversky and Kahneman [1974] and Kahneman and Tversky [1979] have documented the heuristics or judgment devices--e.g. anchoring,* representativeness, and availability--that may bias an individual's ability to judge situations involving risk. For example, if the individual felt that the high initial values of risks in the research design were not "representative" of hazardous wastes, then it may affect their ability, or willingness, to search their preferences and provide an estimate of value. One way the research design attempted to deal with the representativenesss heuristic was in the questionnaire design. The interviewers asked respondents to consider the hypothetical levels as if they were the actual levels but acknowledged that even experts did not know for sure the exact size of the initial values.† A second way was to use different initial levels for different individuals to try to assess the potential effect within the design itself.

The availability heurisitic suggests that people may assess the probability of an event by its familiarity. That is, the more information available to the individual (e.g., newspaper or television articles), the more likely he may be to "overestimate" the probability of an event occurring. The research design allows for an examination of the relationship between availability and the initial level of risk by asking in the questionnaire about the amount of information that respondents had available. In addition, it asked respondents whether they had attended town meetings about hazardous wastes.

All of the discussion of responses to risk levels, whether reflecting individuals' perceptions of the quality of the information provided or based on the heuristics suggested by some psychologists as the means used to process

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*The anchoring heuristic in which people's values might be affected by implied starting values or anchors especially is important for the format of the valuation question and is discussed in detail later in this chapter.

†The potential role of information on values is ubiquitous. For example, Cummings, Brookshire, and Schulze [1984] suggest that it maybe hard to pin down just exactly the effect of information. This seems to be the case with the availability heuristic. If individuals hear or read about heart disease or cancer or car accidents and then believe that they are more prevalent because of this information, then this seems consistent with the heuristic bias. However, if these same individuals read and or hear--and retain--factual information about the incidence of severity of causes of death, then it seems the bias does not exist. Thus, considerable caution will be required in trying to determine any relationships between the initial level of risk and the availability heuristic.

risk information, are important because they are alternative descriptions of the risk perception process. In short, when the questionnaire presents individuals with a risk level, do they believe it? How do they interpret it or adjust the value they are given when formulating a response to a proposed risk change? Clearly, the valuation responses will be related to what each individual perceives his risk level will be under the circumstances described in the contingent valuation questions. Control of the magnitude of the risk level and of the postulated change in risk that are posed to respondents does not in itself ensure the analyst will have control over the respondents' perceived risk level and the changes in it. This is the reason for attempting to understand the risk perception process and how the character of our contingent valuation questions would be interpreted within it.

7.5.2 The Size of the Risk Change and the Role of the Conditional Risk

Our discussion up to this point has focused exclusively on the importance of the initial levels of the exposure risk in our research design. However, there are two other closely related elements that are also addressed in the research design: the size of the change in risk and the role of the conditional probability of death given exposure to hazardous wastes. In the design, the changes in the levels of exposure risks were held constant--in percentages terms--across the varying initial levels of risk. For example, the percentage change in the initial exposure risk level (e.g., A) to the intermediate risk level (B) was the same in the four vectors of the design that relate to the levels of risk. However, the percentage change from the intermediate level (B) to the final level (C) was held constant at a different percentage change. In effect, each individual values two distinct risk changes--from Level A to Level B and from Level B to Level C. If we assume the values from the two different levels can be grouped together for statistical analysis, then it is possible to evaluate differences in individuals' understanding of the contingent valuation exercise in our marginal valuation models of risk changes (see Chapter 13). Finally, because of the findings of Kahneman and Tversky [1979] and others that individuals may respond more easily to percentage changes, the increments were held constant in percentage terms rather than using constant numerical increments.

The role of the conditional probability of a health effect (usually death) is the last numerical feature of risk addressed in the research design. Our approach to presenting probabilistic information about hazardous waste risks involved splitting the risk information into three risk circles that related to exposure, dying if exposed, and the combined risk of exposure and death. This format was derived as a direct result of the focus group sessions. Since it is important to our presentation of information on risk for the valuation task, the specific details behind its development are discussed in detail in Chapter 8. To examine the potential importance of the size of the conditional probability, which was assumed not to be affected by the hypothetical regulations in the scenario, the design allows for a full factorial design for three groups of exposure risks and two levels of conditional risks and an additional (1 × 2) design using lower exposure risk probabilities and two conditional probabilities. These lower probabilities were one-tenth the size of the other design points.

In summary, the specific dimensions of the risk information--the size of the initial level of risk, the change in risk, and the conditional risks--are treated in an experimental design. The specific features of the experimental design are explained in Section 7.9.

7.6 PROPERTY RIGHTS AND RISK VALUATION

An important dimension of the design is the examination of the influence of property rights on individuals' values for changes in risk. Property rights involve the set of legal entitlements, either implied or expressed, to a particular good or service. Mitchell and Carson [1984] stress the importance of property rights in a contingent valuation survey. Even for a fairly well understood public good like water quality, they find that the property rights can have an influence on valuation responses. In the case of hazardous wastes, where we have assumed the property right applies to the household having "the right" to some level of exposure to hazardous wastes, the issues are even more complex. This research did not attempt to deal with all of the issues that can be involved. Rather, we have offered a few reasons for their potential importance and then incorporated one simple means for considering their implications in the research design.

The importance of property rights for valuing changes in hazardous waste risks derives from three sources: their role in the economics literature, their role in the psychology literature, and their prominence in the focus group sessions. In the economics literature, particularly in the contingent valuation subset, property rights discussions have focused on the willingness-to-pay/willingness-to-accept issues. The literature has numerous examples of the difficulties of asking willingness-to-accept questions, with Knetsch and Sinden [1984] as the most recent example. In our research design for valuing hazardous waste risk changes, we have followed the recommendation of the Cummings, Brookshire, and Schulze [1984] reference operating conditions and used the willingness-to-pay format. Nonetheless, a willingness-to-accept approach is used in a different context within our research design: in eliciting the wage increment necessary for accepting higher risks from a new job. The rationable for using it in this context is that the acceptance structure was more plausible than the payment structure for this problem.

Property rights issues also appear to have been important within the psychology literature. For example, Kahneman and Tversky [1979] have argued that, contrary to the expected utility hypothesis, people have very different preferences for gains relative to losses. One interpretation of their arguments is that the gain versus loss phenomena may be a reflection of differences in the property rights that individuals perceive. Hershey, Kunreuther, and Schoemaker [1982] also discuss property rights in their evaluation of the implications of the assignment of risk for experimental evaluations of the expected utility framework. If respondents feel that they have some existing low level of exposure risk to hazardous wastes and are now faced with a possible increase in the risk (e.g., due to the siting of a hazardous waste landfill or a commercial waste processing facility), they might feel that a property right--the lower risk level--would be taken away from them. Their value for the risk change could be markedly affected by the implicit assignment of these rights.

The focus groups provided another reason for considering property rights within the design. Participants in these sessions frequently expressed views that were equivalent to a suggestion that how the property rights were handled in the hypothetical situations influenced their responses. For example, their comments and reactions differed depending on types of government actions involving risk. To organize these discussions, we deliberately chose actions that implied one assignment of property rights and then asked whether an alternative assignment made a difference. As a consequence of our experiences with these groups we developed ways to include property rights in the design.

In the design, one examination of "property rights" effects is accommodated by comparing individuals' valuations of a given risk change for a reduction in a specified level of risk with an equal increase. That is, the proposed and starting endpoints are simply reversed for the two changes in risk so that it is only the assignment of rights (and with it the direction of change in risk) that is different across the questions. Since payment for the risk reduction yields the endpoint and avoids it for the increase, the actual endpoints are the same.

The design also included a second feature in the property right issue. The focus group research suggested that individuals responded differently to the property rights issue depending on how they perceived the action was taking place. In effect, was it imposed on them or was the case described as if there had been an opportunity to affect the decision? This issue was reflected in our research design as a component of the hypothetical scenario for avoiding the risk increase. It was also varied independently from the changes in the risks across design points so that it would be possible to evaluate the implications of the degree of control available to individuals when changes in rights were taking place. To accomplish this task, the sample was divided in half with one group having the risk increase scenario that indicated the town council had voted to approve the change, while the other was told that the Federal government had decided to allow the change.

7.7 TYPES OF RISKS AND RISK ATTRIBUTES

This section addresses the influence of different types of risks on individuals' values for reductions in risk. Recent research--e.g., see Schoemaker [1982]; Hershey, Kunreuther, and Schoemaker [1982]; and Slovic [1984]--has stressed the importance of the different types of risk in influencing individuals' perceptions and their values of risk changes. One way of attempting to formalize the modeling of reasons for differences in individuals' responses to different types of risk is to assume that risks have attributes. Therefore, to understand the differences in responses to these risks, we must model how these attributes of risk affect individual utility and, in turn, their behavior in the presence of risk. The exact boundary between types of risk and risk attributes is poorly marked. The main distinction that we draw is that the types of risks may embody more than one attribute. This section considers discussions of risk types and then the use of a framework that tries to identify a set of attributes of risk which would describe the types separately. It then describes how both sets of research have influenced the research design.

7.7.1 Types of Risks

Two of the most important of the types of risks influencing an individual's willingness-to-pay response for changing exposure to hazardous waste risks are the "dread risk" and the "known risk" (Slovic [1984]). The first involves the notion that an event is dreaded because it is potentially catastrophic, involving many people. The second type relates to both perceptions about the individual's knowledge of the risk and whether the events at risk are delayed in time. The research of Slovic and his associates suggests that these factors influence how individuals respond to uncertainty. Other recent work by Von Winterfeldt and Edwards [1984] also stresses the importance of types of risks for assessing policy conflicts over technologies. For our analysis, this would imply that individuals may value incremental reductions in the risk of death from different sources quite differently. That is, individuals may value changes in hazardous waste risks quite differently than an equivalent risk change for another type of risk where it is known and not dreaded.

The character of the hazardous waste risks has other important implications for interpreting the values of the posed reductions in risk. For example, the hypothetical situation states that the outcome (i.e., premature death) of the exposure risk and the corresponding conditional risk will not be known to the household for 30 years. This long time horizon, although probably consistent with at least some hazardous wastes, may substantially affect how people process the information about the risks. For example, Bjorkman [1984] suggests that people make riskier decisions the further in future their consequences are experienced. In addition, the time dimension may affect the importance of the event itself. Lundberg et al. [1975] have found that events 10 years in the future are considered one-third as important as present events. While their research did not relate explicitly to a risk of death, their general implication seems relevant. Finally, Svensen [1984] has shown that the time character of the risks can affect people's perceptions of the risks. He found that people over estimated short-term high risks in relation to long-term small risks. However, he also notes that his exposure interval never exceeded 1 year which differs from our situation.

7.7.2 Risk Attributes

As noted earlier, in attempting to understand why individuals respond differently to different risks, researchers have stressed the importance of particular characteristics or attributes that a risk embodies. The ability to control risks and the extent to which risks are voluntary are two of the attributes most frequently identified as important. In addition, the focus group participants frequently mentioned these attributes as important to their perceptions of hazardous waste risks. In particular, they suggested that the extent to which they had a say in a decision involving risk significantly affected how they felt about the risk.*

Raiffa, Schwartz, and Weinstein [1977] suggest identifiability as an important attribute of risk. Identifiability is the extent to which individual lives are associated with decisions involving risk. They further differentiate between ex ante identifiability--individuals' identities are known prior to the decision--and ex post identifiability--individuals' deaths can be attributed only after the decision. For example, they suggest that decisions involving risks faced by trapped coal miners are identifiable both ex ante and ex post. On the other hand, the individual workers who die from exposure to asbestos or vinyl chloride can be identified only after the fact. Individuals, and collectively society, have a higher willingness to pay for a change in risk the larger the extent to which the risk is identifiable.

Our conceptual framework suggests that identifiability may not be a risk attribute. Instead, it is a reflection of the difference between ex ante and ex post analytical perspectives. That is, identifiability pertains to values when the outcome at risk is known. To draw from their example, it is no longer

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*This is clearly consistent with findings observed in studies of the siting of nuclear facilties. See for example Carnes et al. [1982], Carnes and Copenhaver [1983], and Carnes et al. [1983]. It is also consistent with the program of research recently described by Kunreuther and Kleindorfer [1984].

the risk of the coal miners being trapped underground that is valued but the outcome of the risk. This ex post perspective is inconsistent for valuing welfare changes from regulatory policies for reducing hazardous waste risks because the policy decisions are made prior to the outcome being known.

Weinstein and Quinn [1982] suggest that anxiety may be an important attribute of risk that could influence people's willingness to pay for reductions in risk. Anxiety causes people to have disutility from experiencing the risk. Weinstein and Quinn cite evidence to suggest that people may be willing to pay for risky diagnostic tests even when their overall prospects for survival are poor. They suggest that the additional expenditures may enable people to make better plans for either their death or survival. The focus group participants indicated some consideration of anxiety as an attribute of hazardous wastes in developing their valuation responses. Some suggested that the anxiety stemmed from the highly uncertain state of information about the effects--and extent--of exposure to hazardous wastes. Finally, some participants mentioned the possible anxiety from the potentially long latency periods that were discussed earlier. Clearly, anxiety and the other attributes of hazardous waste risks will be important for interpreting research findings.

7.7.3 The Role of Differences in the Types of Risk for the Research Design

To develop some information relevant to the potential effects of risk attributes and types of risk, the research design elicits values from individuals for changes in two types of risk--exposures to hazardous wastes and fatal accidents on the job. However, we do not have complete information on the valuation of both types of risk for all respondents. The job risk questions were asked only of those respondents who were working for pay--either on a full-time or part-time basis--at the time of the survey. Also noted earlier, the job risk valuations are posed in terms of the wage premium needed to accept the higher risks rather than willingness to pay. The job risks also were elicited using a different vehicle to express the risk change. Employed individuals were asked to place their perceived risk of dying from an accident on the job this year on a risk ladder (see Chapter 8). The questions then posed 50 percent and 100 percent increments in risk and elicit the wage change need to accept new jobs with these higher levels of risk. The reason for using the risk ladder for the job valuations is that this vehicle provided the easiest means of dealing with the differences expected in individuals' perceptions of their actual risks on the job. Nonetheless, any direct comparison of the values from the two different types of risk will be difficult and is beyond the scope of the research associated with Phase I of this project. Nevertheless, the value for changes in occupational risks elicited in the questionnaire can be compared with estimates from hedonic wage models (see Viscusi [1984] and Smith [1983]) as a rough gauge of the plausibility of the sampled individuals' responses.*

7.8 CONTEXT OF RISK

The context of a change in risk is another important element to consider when interpreting elicited values. The exact definition of context is difficult to pin down because different researchers, often from different disciplines, have used the term differently. For example, Mitchell and Carson [1984] discuss context as a type of misspecification bias in contingent valuation. In their terminology, context includes not only the setting of the contingent valuation interview but also what might be termed the mental setting created by the material in the questionnaire itself. On the other hand, Schoemaker [1980] uses the term to refer to what happens when respondents evaluate exactly the same information differently when it is in a different context. For example, his research showed respondents evaluating the same gambles differently in the context of a lottery rather than insurance.

Not only is context a difficult concept to define, but it is also difficult to distinguish from some of what we and others have designated as the attributes of the risk itself. For example, a context effect might occur because the way a risk is presented may imply--at least implicitly--a different set of attributes. Because several previous sections have described the general char-

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*The "property rights" effects can also be examined in part through the job risk questions. However, in this case, the questions use the individual's existing job as the basis for describing the risk changes. Thus, the level of this risk was not controlled as part of the experimental design. Moreover, since the sample was designed to be a representative sample of households in suburban Boston (with oversampling of Acton), there are good reasons to expect that it will not provide a representative sample of the occupation related risks experienced by individuals.

acter of hazardous waste risks, there will be no further discussion of this potential dimension of context.

Context effects also may imply that how a risk is explained to an individual may influence his response to it (see Schoemaker [1982], pp. 547-48, for further discussion). Instead of suggesting some form of irrational behavior, context effects also might suggest that analysts have done a poor job of communicating their questions to survey respondents. Consequently, one of the most important aspects of this research design has been the use of focus groups in the development of the wording of the questionnaire, the format of the vehicles used to explain risk, and in the pretesting and revision of the questionnaire. Since the specific steps in this process are described in Chapter 8, here we simply acknowledge their role in adjusting the structure of the empirical component of this research to reflect what has been learned from the varied sources of research on decisionmaking under uncertainty. The relevant sections of the questionnaire that describe the mental setting view of context are highlighted in Chapter 11.

7.9 RISK OUTCOMES AND ENDPOINTS

Two other considerations of risk are important in our research design: the events or outcomes at risk and the use of certainty as an endpoint. Our discussion of hazardous waste risks has focused almost exclusively on mortality as a potential consequence of exposure to hazardous wastes. This limitation was due primarily to deciding what was feasible to consider in one research effort. However, although it does not imply that morbidity effects are unimportant, the almost exclusive use of death as the health outcome has important implications. In their discussion of behavior under uncertainty, Weinstein and Quinn [1982] suggest that a risk situation (or gamble in their terms) that includes death can affect how people consider the situation. Not only might death be important, but how one dies--the quality of the death--may also be important.

The research design addresses death as an outcome in several ways. One, in the process of eliciting individuals' values for reductions in the risk of exposure to hazardous wastes, no specific cause of death is mentioned. People are then asked if they had a cause of death in mind when giving their values to provide some information on whether the perceived cause of death influenced their bids. In addition, after the individuals' values for reductions in the risk of exposure to hazardous wastes are elicited, two variations were used to change the information about possible health consequences. Specifically, a change in the health end state (e.g., whether the cause of death was due to damage to the body's immune system or whether the risk was associated with birth defects severe enough to cause lifetime mental or physical handicaps) was posed to the respondents to see if these would alter their value of the risk change.

The second aspect considered in the research design is the effect of certainty as a risk endpoint on individuals' values for reduction in risk. Tversky and Kahneman [1981] suggest that people will value a protective action that reduces the probability of a harm from 1 percent to zero more highly than an action that reduces the probability of the same harm from 2 percent to 1 percent. They attribute this phenomenon to the shape of their value function.

Our research design addresses the certainty effect by eliciting values for reducing the risk of exposure to hazardous wastes to zero. It is important to note that these values were elicited only from a subset of our sample--those respondents who received the contingent ranking version. In effect, they had completed a task in which they ranked different combinations of monthly payments and exposure risk levels prior to answering the certainty question based on the same hypothetical situation used in the direct question format. However, the certainty question posed a different hypothetical situation and then used a direct question to elicit their value for reducing hazardous waste exposure risks to zero.

In summary, the research plan addresses two dimensions of risk context--health outcomes of the risk and the certainty effect. In the former case, individuals are asked if they want to revise their previous bid in response to different outcomes. In the latter case, values are elicited from a subset of the sample for reducing the risk of exposure to zero.

7.10 CONTINGENT VALUATION AND ELICITING VALUES OF RISKS

An important set of issues considered in our research design stems from the literature on contingent valuation. Rather than exhaustively evaluating these issues, this section considers the three that are most relevant to our design: the question format used to elicit the values for reduced risk (i.e., our contingent commodity), the treatment of perceptions of the contingent commodity, and the role of information. Other aspects of the contingent valuation literature--e.g., Mitchell and Carson's [1984] context bias and related concerns--are discussed prior to the empirical results in Chapter 11.

7.10.1 Question Format

One of the key features of the research design is the use of two different formats--contingent ranking and direct question--to elicit values for reductions in hazardous waste risks. In the direct question format, the interviewer directly asks the respondents to give his maximum valuations of the risk change. These are option prices. By contrast, the contingent ranking format requires that the respondent rank a set of cards showing alternative combinations of payment amounts and risk levels. The alternatives are structured to prevent one choice from dominating and to require tradeoffs between increased payments and lower risks.

The importance of the influence of question format on valuations of risk reductions stems from several sources. Desvousges, Smith, and Fisher [1984] found that willingness-to-pay amounts are influenced by the format used to elicit values in contingent valuation. While this research focused on bidding games and payment card alternatives compared to the direct question format, it does suggest the possible influence of question format. In related research, Desvousges, Smith, and McGivney [1983] and Rae [1981a,b] found the contingent ranking format to be a promising alternative, but their findings were not conclusive. For example, in none of the evaluations had contingent ranking been composed on a completely independent basis. In previous applications, both the direct question, or some other alternative question format, has been administered to the same respondent along with contingent ranking. By allowing the contingent ranking format to be independently administered, our design is capable of addressing this issue. It is important to note that the independence of the ranking format refers only to the format being used to elicit willingness to pay. The ranking versions were completely consistent with respect to risk levels used in developing the alternatives to be ranked and the other key elements of the research design that are discussed later in this chapter.

There is a final rationale for using the contingent ranking format that draws from the psychological literature. Fischhoff and Cox [1984] have noted that the ordinal information processing task, like the one required in contingent ranking, is an easier one for respondents to perform. He has noted this advantage as especially important for tasks involving probabilistic information or the type of value information required in contingent valuation. In the case of our research, both of these elements are present, making a strong case for including the ranking format. In effect, contingent ranking requires respondents to perform only an ordinal task but, in the analysis stage, with explicit assumptions concerning the nature of individuals' preferences, can yield estimates of individuals' valuations for reductions in the risks of exposure to hazardous wastes.

Some explanation is also necessary for our decision to use the direct question format. One primary consideration in using this format is that it minimizes the chance of the respondent's "anchoring" on some artificial reference point in the interview, a possibility noted by Tversky and Kahneman [1981] in their analysis of individuals' decisions under uncertainty. For example, the starting point used in the bidding game format provides people with exactly such an anchor. It suggests to people a frame of reference for making their decision. For example, is the interviewer expecting a value of $20 or $200? Recent evaluations by Desvousges, Smith, and Fisher [1984], Mitchell and Carson [1984], and Boyle and Bishop [1984] all point to this troubling aspect of the iterative bidding format for contingent valuation questions.

Table 7-1 provides a summary of the available results on the existence and extent of starting point bias. Despite the promise of bidding games in the earlier work by Thayer [1981] and Brookshire, Randall, and Stoll [1980], recent studies by Mitchell and Carson [1984] and Boyle and Bishop [1984] have provided strong evidence of starting point bias. Boyle and Bishop's results, based on a sample of 176 recreationists, are probably the most telling evidence to date. Indeed, they are led to conclude that bidding games may not be worth the increased complexity. This conclusion also is supported by Cummings, Brookshire, and Schulze [1984].

> In our view, iterative bidding does result in substantially higher bids. . . . Mitchell and Carson as well as Bishop and Heberlein are obviously correct in pointing to the lack of evidence that would

TABLE 7-1. STARTING POINT BIAS: THE RESULTS

Study	Contingent commodity	Starting points used	Type of test	Sampling procedure	Sample size	Conclusion	Remarks
Rowe, d'Arge, and Brookshire [1980]	Visibility in Four Corners	$1,$5,$10	Regression	Random sampling of household in Farmington, NM, and Navajo Recreation Area	a) 93 respondents bidding in 3 scenarios b) 31 respondents bidding in 3 scenarios	Starting point bias evident in regression of equivalent surplus bids. Not evident in smaller sample of compensating surplus (CS) bids	Sampling and survey procedures were not standard; ambitious questionnaire also tried to address several other bases; authors noted order of magnitude differences between CS bids and starting points. Small sample size also limited effectiveness in CS case.
Brookshire, d'Arge, Schulze, and Thayer [1979]	Visibility in Los Angeles	$1,$10, $50	Means	Paired census tracts in Los Angeles area	12 communities with sample sizes ranging from 2 to 16	Reject null hypothesis of no starting point bias in 6 of 36 means tests; fail to reject in 30 of 36	Small sample sizes limit power of statistical tests. No adjustments made for other issues tested in survey design.
Thayer [1981]	Substitution of a recreation site	$1,$10	Means and regression	Random interviews with recreationists in Jemez Mountains	106	No difference between average bids at 10% level of significance; nonsignificant coefficient for starting bid	Well-defined commodity familiar to respondents--somewhat limited range of starting values--larger sample sizes than in many previous studies
Mitchell and Carson [1983], interpretation of Greenley, Walsh, and Young [1983]	Option price of water quality in Platte River Basin	--	Regression	Random sampling of households in Denver and Fort Collins	161 (water bill) 177 (sewer tax)	Mitchell and Carson show different implied starting values by the alternative payment vehicles	Some disagreement about exact commodity measured--see Chapter 5 of Desvousges, Smith, and McGivney [1983] and Mitchell and Carson [1984]
Boyle and Bishop [1984][a]	Scenic beauty on lower Wisconsin River	$10 to $120 Randomly chosen	Regression	Random sampling of recreationists onsite	176	Found statistically significant and positive relationship between starting bid and willingness to pay	Commodity is somewhat abstract; detailed examination of starting points with ample sample size and wide range of starting values
Brookshire et al. [1980]	The right to hunt elk for one annual season at various levels of hunting amenities, e.g., terrain and frequency of encounter with elk	$25,$75, $200	Regression and test of mean bids	Unspecified	108 licensed elk hunters	Authors reject hypothesis that starting points influenced final values at the 0.05 level of significance	Utility bill and hunting license fee used as payment vehicles; hypothesis that final bids affected by payment vehicle rejected at .01 level.
Desvousges, Smith, and McGivney [1983]	Option price for water quality and improvement	$25,$125	Regression	Stratified random sample of households in 5 county area of Monongahela River basin	150	Some evidence of starting point bias especially in comparison results; high starting point corresponded with 19 of 30 outlying bids making statistical results suggestive but not conclusive	Most detailed sampling and survey plan; trained professional interviewers; ample sample size and wide range of starting bias

[a]Boyle and Bishop cited results of other related research (Boyle, Bishop, and Welsh [forthcoming] that also suggested starting point problems. This study was unavailable to the authors at the time of this report.

> support the attribution of such effects to the preference research process,. . . . Moreover, we must acknowledge. . .that the parallel between the iterative bidding process and the iterative valuation trials used in laboratory experiments. . .is without obvious substance. . . . Thus, all that can be said at this point in time is that iterative bidding rather consistently results in higher CVM valuations, but we are unable to explain such differences. [pp. 267-268].

However, this conclusion may be too pessimistic with respect to our understanding of the processes involved with iterative bidding questions in contingent valuation. One study that provides the basis for their conclusion that iterative bidding leads to higher willingness-to-pay responses is their experience reported in Cummings, Brookshire, et al. [1983]. In these experiments, the respondent first provided a value using a payment card and then was "iterated" toward a maximum valuing by informing him that the commodity would not be provided based on their first bid. This process is not an iteration toward a maximum value but, instead, is a value provided under different conditions of provision. That is, they have changed the terms of exchange in the market. Rather than obtaining a maximum bid, it is hard to interpret the exact nature of their final value. Mitchell and Carson [1984] used an analogous procedure in their survey but are reluctant to interpret this bid as a maximum bid because of the circumstances under which it was elicited.

In addition, the influence of starting points need not always be in a positive direction. For example, Figure 7-2 shows the distribution of bids from two bidding games conducted in Desvousges, Smith, and McGivney [1983]. In the case of the $125, the iterations primarily are downward but the $25 starting points have a substantial number of upward iterations. In this case it is unclear that bidding games lead to an upward bias. As noted by Mitchell and Carson [1984], there are a substantial number of bids that are "anchored" at the starting value, which is consistent with the Tversky and Kahneman [1981] position. Also noteworthy are the large number of zeros with the $125 starting point. Mitchell and Carson [1984] suggest that these respondents also may have been affected by the "too-high" starting bid. As we indicated in Desvousges, Smith, and McGivney [1983], this bidding game also had 19 out of 32 respondents that we determined as outlying bids based on our regression diagnostics.

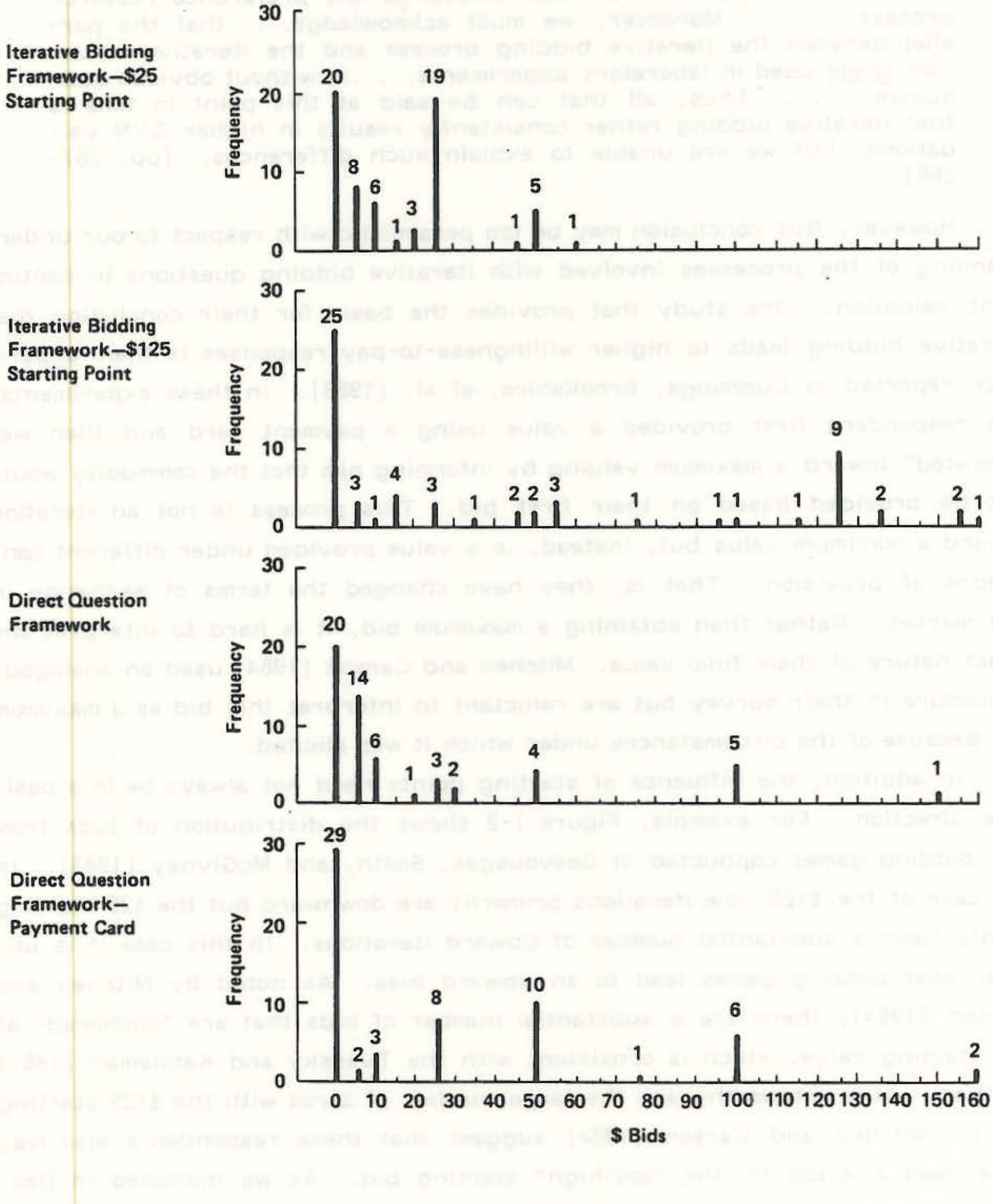

Figure 7-2. Effects of instrument—distribution of option price for a change in water quality from boatable to fishable, protest bids excluded.

In summary, the iterative bidding format has little to recommend it at this stage. Not only does this format seem to experience problems with starting point bias, it may also increase the likelihood of a rejection of the terms of the contingent market. As Mitchell and Carson [1984] suggest, the process of iteration upwards and downwards in these games may also be even more complicated than that assumed by the empirical models.

The other two formats considered were the anchored and unachored payment card. The anchored payment card, developed by Mitchell and Carson [1981,1984], gives respondents a card with dollar amounts and anchors at various amounts for other public goods like national defense and fire protection. Despite Mitchell and Carson's [1984] experience, this format was not used because of the concern over a respondent relying exclusively on the anchors in determining their valuation responses.

To illustrate what appears to be potential "anchoring" with the use of payment cards, Table 7-2 provides summary statistics from Mitchell and Carson's [1984] contingent valuation survey to measure the benefits of national water quality improvements that used a payment card with reference amounts.* Some individuals seem to have relied exclusively on the amounts provided on the card in forming their valuation responses. This seems especially the case for the lower income groups with the large majority of the individuals selecting amounts from the card and relatively few giving a response not shown on the card. However, it is not possible to conclude that this information clearly implies anchoring has been a problem with their approach, since the amounts on the card are also commonly used bids, such as $50 or $100 a year.

Another potential problem with the Mitchell-Carson payment card is individuals keying on the reference or anchor amount on their card. The third column in Table 7-2 shows the number and percentage of bidders who gave a bid within plus or minus one increment from the reference amounts on the card. While the data do not suggest that this is a serious problem in Mitchell and Carson's study, it does seem to indicate that it may be occurring to some degree. For example, 160 out of 452 nonzero bids, or about 35 percent, were

*These comparisons are only possible because of the detailed information provided in all of the Mitchell-Carson survey reports.

TABLE 7-2. WILLINGNESS TO PAY FOR BOATABLE WATER QUALITY[a]

Income	Number of respondents choosing value on card	Total number of respondents	Number of nonzero respondents with ± 1 increment of anchor	Total nonzero respondents
Less than 10,000	123 (98)	125	37 (41)	90
10,000 - 19,999	144 (94)	154	54 (42)	130
20,000 - 29,999	113 (87)	130	39 (35)	111
30,000 - 49,999	43 (44)	97	21 (25)	84
50,000 +	30 (73)	41	9 (24)	37
Total	453 (83)	547	160 (35)	452

Source: Mitchell and Carson [1984], Table 4.

[a]Numbers in parentheses are percentages.

within plus or minus one increment of the anchors on their payment card. Again the occurrence is more frequent at the two lower income levels, which had 91 out of 220 nonzero bids or 41 percent.

Based on two pretests of their questionnaire, Mitchell and Carson [1984] did not find any systematic bias from the anchored payment card. However, they acknowledge that the sample was relatively small in one pretest and that the range of the test--anchors that differed by 25 percent--may have been two narrow. By contrast, Boyle and Bishop [1984] experienced mixed performance when using it. Consequently, it seems prudent to conclude that we need to know more about it before any definitive conclusions can be reached.

The unanchored payment card consists of a card with dollar amounts arrayed from small to large. In this card, no anchors are used. The format proved reasonably effective in several previous studies--Brookshire, Cummings, et al. [1983] and Desvousges, Smith, and McGivney [1983]--and was used in the focus groups as an alternative to the direct question. After using the card with several focus groups, the participants suggested that the card was of little value in helping them determine their willingness-to-pay amounts. Based on these comments, and, perhaps more importantly, on the number of issues that needed to be addressed in this research design, the research design did not attempt to compare the direct question and payment card formats.

7.10.2 Perceptions

People's perceptions of the contingent commodity is the second contingent valuation issue that is relevant to our research design. Cummings, Brookshire, and Schulze [1984] consider people's perceptions of the commodity--i.e. the mental picture they envision--as one of the basic issues that affect the "accuracy" of contingent valuation as an approach for measuring the benefits of changes in environmental quality. They suggest that four aspects of perceptions will affect the "accuracy" of contingent valuation:

- Perceptions of hypothetical environment changes are consonant with real effects.
- All subjects are valuing the same commodity.
- Perceptions of the commodity are invariant over time.
- Perceptions of the commodity are independent of the quality and quantity of information provided.

Cummings, Brookshire, and Schulze [1984] concluded, based on the earlier Burness et al. [1983] study, that it would not be possible to specify risk effects of alternative policies related to the regulation of hazardous waste disposal because contingent valuation has no real world or "practical anchor" for accuracy. Clearly, their conclusion suggests that perception issues will be crucial to our research design.*

Consequently, several aspects of our research design address the Cummings, Brookshire, and Schulze [1984] concerns about perceptions. In fact, one purpose of the focus groups and videotaped interviews--which allowed the use of different vehicles in presenting risk changes and evaluating their performance--was to aid in understanding people's perceptions. Based on this experience, the questionnaire was structured to introduce risk and elicit individuals' perceptions with respect to a variety of different types of risks before asking the valuation questions. For example, we used a risk ladder to elicit people's perceived risk of dying from hazardous waste. (The exact details of this development are reported in Chapter 8.) This occurred prior to the framing of the contingent commodity to provide an independent evaluation of people's perceived risk of dying from hazardous waste. We also questioned people about the relative importance of specific pathways that they might perceive as being important for exposure to hazardous wastes. Thus, information on perceptions was elicited separately to provide some insights into the potential role of perceptions on individuals' values of changes in hazardous waste risks.

We framed the contingent commodity as a change in the risk of being exposed to hazardous wastes. This risk change was presented using an entirely different vehicle than the risk ladder. The risk circles were used for each of two components of the risk facing an individual. The first circle identified

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*Some of the Cummings, Brookshire, and Schulze [1984] accuracy conditions for perceptions are somewhat puzzling. It is unclear that this would not also be the case for market revealed values. For example, the perceptions of a person with perfect pitch of the quality of sound from a stereo speaker might account for his having a higher willingness to pay for that speaker than someone who is deaf to the full range of sounds from the speaker. Conventional demand theory allows that differences in characteristics of individuals may affect their demand for a commodity. Thus, a person's perception of a commodity--contingent or otherwise--would seem important in influencing willingness to pay.

a risk of exposure and the second the conditional risk of dying if exposed. The decision to use the two circles resulted from the focus group participants' comments that it was easier to understand the commodity--the risk change--that the regulation was supposed to provide. Detailed explanations and visual aids also were used in explaining risk to the respondent. These explanations were followed by a specific hypothetical situation--expressed in concrete terms--that finished the framing of the commodity prior to the elicitation of the values. Finally, the respondent was given information about the baseline level risk and asked to consider these as if they were the actual risks from the hypothetical situation.

In summary, our efforts to recognize risk perceptions play an important role in our final research design. Chief among these were the focus group and videotape sessions that led to the separate treatment--indeed separate elicitation vehicles--perceived risks and the contingent commodity.

7.10.3 The Role of Information

The final contingent valuation issue is the role of information and its effect on the design. The job risk part of the design included our attempt to address the effect of information on individuals' values for reducing hazardous waste risks. Specifically, after eliciting the values for the two changes in risk, the interviewer then provided the individuals with information about their actual risks of a fatal accident on the job. They were then allowed to revise their amounts based on the new information if they wanted to do so. The importance of this procedure is that it provides a gauge of how the individual responds to new information, an issue highlighted in the Cummings, Brookshire, and Schulze [1984] overview of the contingent valuation literature. If we assume that these individuals act the same way in response to new information about hazardous waste risks, then it may be possible to use their responses from the job risk section in the analysis of the values for reductions in hazardous waste risks. However, this must be treated as a maintained assumption. Specific analysis of these responses was not undertaken as part of the Phase I research but will play an important part in further research with the survey results.

7.11 THE DESIGN FOR COMPARISON WITH INDIRECT METHODS

Since one objective of this research was to undertake a comparative analysis of the valuation estimates for a risk change implied by a hedonic property value model with contingent valuation estimates, another factor influencing the research design was related to the approach for developing consistent information between the two methods. In this case, our approach accepted the distance of the housing unit from the hazardous waste site (see Harrison [1983]) as a proxy for the risk of exposure to these wastes. We attempted, first, to determine whether distance served as a good proxy for individual's perceived risk and, then, to develop information that would permit the estimation of the demand for distance (as a mechanism for reducing risk). The specific details of these steps are outlined in Chapter 15. What is important for our present purposes is the independence in the design of this component of the questionnaire from the other features and the assumptions implicit in our structure. Our approach poses a constant marginal price for distance to respondents and then asks for their desired distance (for locating their homes) from a specified hazardous waste site. The experimental design varied the marginal price across individuals.

7.12 RESEARCH DESIGN: ITS INTEGRATION

The previous sections have highlighted some of the influences to our research design for the contingent valuation survey. The design reflects both one of the primary objectives of the research--to value changes in hazardous waste risks and recognize important issues identified in past studies of behavior under uncertainty--e.g., attributes of risks, context effects, the assignment of property rights, and question formats. It also incorporates several of the conclusions implied by our conceptual analysis--the importance of the initial levels of risk for valuation and the role of intrinsic values. Finally, it addresses the second objective of the research--to compare our survey results with those from a hedonic property value study. This section explains how these various goals are tied together to form our final research plan. To meet these objectives, the research plan was designed, recognizing that

- Different questions can be asked of each respondent
- Different questions can be asked of different respondents--i.e., as part of an experimental design.

To illustrate these two paths, Figure 7-3 provides a block diagram of the major issues addressed in the research design. The first level shows our first objective--to measure the benefits of reducing hazardous waste risks. The next level shows the two types of values--i.e. use or household, values and intrinsic values--elicited from each individual in the sample. The design for the research ends with the intrinsic values elicited as an increment to the household values. Moreover, only the direct question format is used to elicit the intrinsic values.

The remainder of the research design shown in Figure 7-3 pertains exclusively to issues related to measuring the household or user values for reducing hazardous waste risks. The third level of Figure 7-3 shows that each respondent provided three different values for reducing hazardous waste risks: two values for two distinct reductions in risk and a value to avoid an increase in risk. The reduction in risk pertains directly to our first objective and the risk avoidance value examines the effect of property rights on values. In addition, to meet the needs of the comparative evaluation of different approaches to benefit estimation, the design uses a direct question format to elicit individuals' desired distances from hazardous waste disposal sites, given that increased distance will increase the price of the home. These responses provide the information needed for one of the approaches for comparing contingent valuation with hedonic models. The final level shows that two different question formats were used to elicit the value for reduction in risks and that two different levels of government were specified as actions for the risk avoidance questions.

In the last level of Figure 7-3, the second path of our research plan, the experimental design becomes more prominent. For example, values for risk reductions are elicited using the direct questions from approximately 60 percent of our sample, while 40 percent are elicited using the contingent ranking format. To illustrate the full design, Figure 7-4 shows the 24 separate versions of the questionnaire allocated across the sample households. As shown in this figure, key features of the design include the following:

- Dividing the sample between the direct question (D) and the contingent ranking (R) question formats to elicit the willingness to pay for reductions in risk (Part A of Figure 7-4).

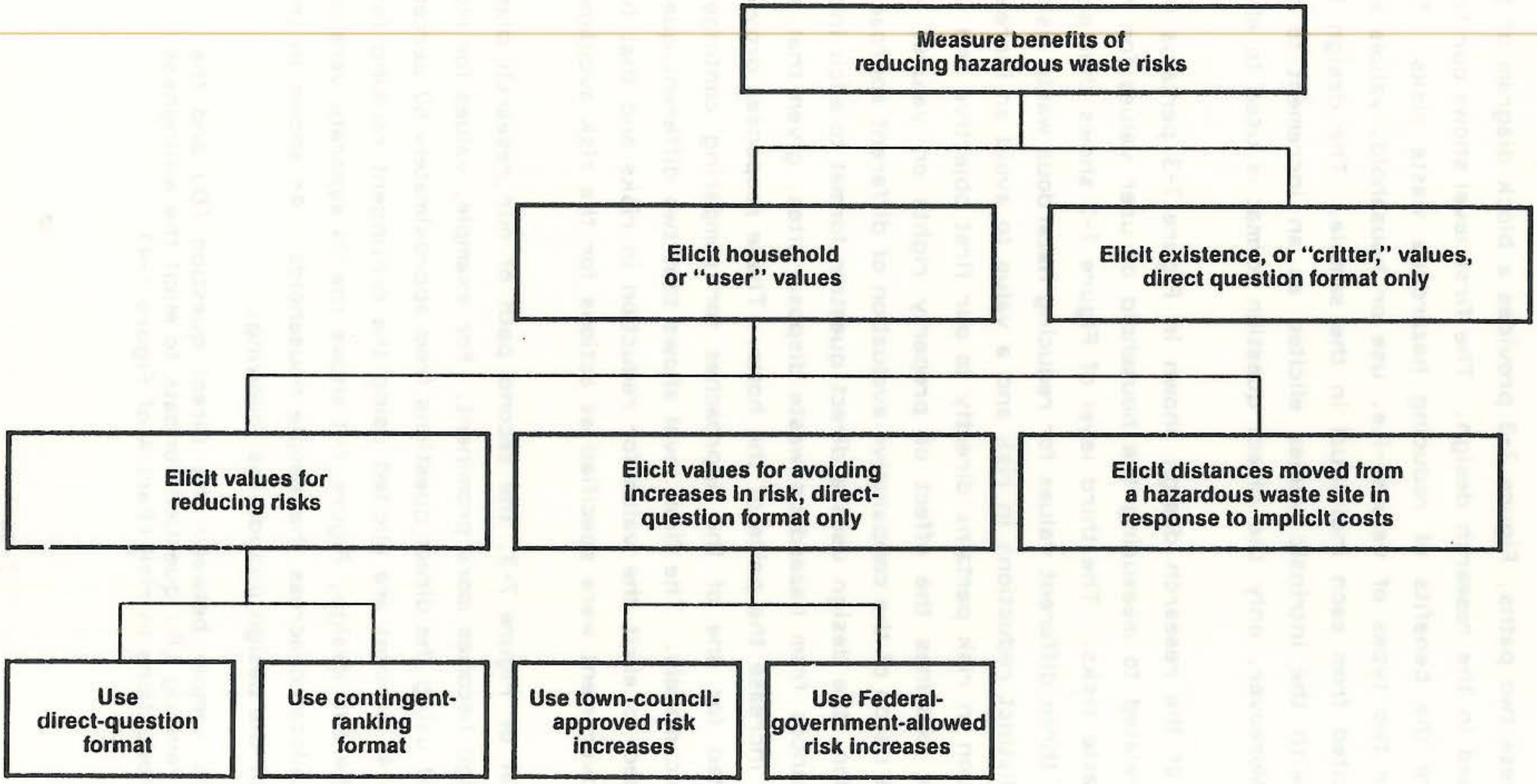

Figure 7-3. Block diagram of experimental design.

Part A. Questionnaire Versions for Valuing Reductions In Risk

Direct Question Format (D)						
Reductions in risk of exposure			Risk of death, if exposed			
Vector	From	To	1/10	1/20	1/100	1/200
I	1/5 1/10	1/10 1/25	D3	D4	—	—
II	1/10 1/20	1/20 1/50	D1	D2	—	—
III	1/30 1/60	1/60 1/150	D5	D6	—	—
IV	1/300 1/600	1/600 1/1500	—	—	D7	D8

Contingent Ranking Question Format (R)				
Levels of risk			Amount of monthly payment	
			Vector A	Vector B
Vector	Risk of exposure	Risk of death, if exposed	$0 $20 $55 $150	$-20 $5 $40 $80
I	1/10 1/20 1/50 1/100	1/10	R1	R2
II	1/20 1/30 1/60 1/150	1/10	R3	R4

Part B. Questionnaire Versions for Valuing Avoided Increases in Risk—Direct Question Format Only (D)[a]

Town Council-Approved Risk Increases						Federal Government-Allowed Risk Increases					
Reductions in risk of exposure		Risk of death, if exposed				Increases in risk of exposure		Risk of death, if exposed			
To	From	1/10	1/20	1/100	1/200	To	From	1/10	1/20	1/100	1/200
1/25	1/5	D31	D41	—	—	1/25	1/5	D32	D42	—	—
1/50	1/10	D11 R11[b] R21[b]	D21	—		1/50	1/10	D12 R12[b] R22[b]	D22	—	—
1/60	1/20	R31 R41	—	—	—	1/60	1/20	R32 R42	—	—	—
1/150	1/30	D51	D61	—	—	1/150	1/30	D52	D62		
1/1500	1/300	—	—	D71	D81	1/1500	1/300	—	—	D72	D82

[a] Although this part of the design used only the direct question format, both the ranking and direct question versions that correspond to the Part A design are identified to reflect the interrelationship between both parts of the design.
[b] There are two observations for this design point because of overlaps in the probability levels in the Part A design.

Part C. Questionnaire Versions for Valuing Moving Away from a Hazardous Waste Site—Direct Question Only

Version	($/Mile)
1	250
2	600
3	1,000
4	1,300

Figure 7-4. Overview of questionnaire versions by experimental design component and question format.

- Dividing the direct question versions to evaluate the influence of different levels of exposure risk and conditional risk (direct question format versions D1 through D8).

- Dividing the contingent ranking versions to evaluate the influence of different combinations of exposure risk and payment amounts (versions R1 through R4).

- Matching the exposure and conditional risks used for the value of avoiding risk increases (Part B of Figure 7-4) with the risk levels used in Section F for valuing risk decreases.

- Dividing the versions for avoiding risk increases to reflect differences in the hypothetical scenario if the town council had approved the risk increases (versions D11 through D81; R11 through R41) or if the Federal government had decided to allow the increase (versions D12 through D82; R12 through R42). Keeping this part of the design independent of the probability levels resulted in 24 separate versions of the questionnaire.

As shown in Part A of Figure 7-4, the direct question versions focused on the potential importance of exposure risks and the conditional risk of dying (prematurely) from hazardous wastes if exposed. The groupings of the risk levels in this part of the design into four vectors implies that each household--or sample point--will provide values for two risk reductions. For example, households receiving Version D3 in Vector I provided values for risk reductions from 1/5 to 1/10 and 1/10 to 1/25 with the conditional probability held constant at 1/10. The values for the same two exposure risk changes were elicited from households receiving Version D4 except that they were given a conditional probability of 1/20. Overall, Vectors I, II, and III comprise a 3 × 2 factorial design for the initial levels of exposure risk and conditional risks; and Vector IV is a 1 × 2 design for the lower probability cases.

Finally, the risk increments were developed in a very specific way to account for how people respond to risk changes. Specifically, the percentage change from the initial risk level to the intermediate level was held constant across the exposure risk vectors as was the percentage change from the intermediate level to the final level. However, the percentage changes were not the same. As noted earlier, with the two different sets of percentage changes, it may be possible to pool the responses to examine the effect of different percentage changes. In addition, the size of the risk change in attaining the lower level was held constant in all elements of this part of the design at 1.67

times the size of the initial risk change. For example, in questionnaire version D1, the decrease in exposure risk went from 1 over 5 to 1 over 10 for the first level, while in the second level it decreased from 1 over 10 to 1 over 25.

Part A in Figure 7-4 also shows the survey sample divided between the direct question and contingent ranking versions to evaluate the effect of question format. Within the contingent ranking portion of the design, a 2 × 2 factorial design was developed to evaluate the influence of different paired combinations of exposure risks and payment amounts (Vectors I and II within the R design). The specific combinations of exposure risks and payment amounts used in the factorial design are also shown in Figure 7-4. The payments amounts are structured to provide respondents with the central tradeoffs between lower exposure risks and larger monthly payments in higher prices and taxes. For example, one set of payments, used in the R1 and R3 versions of the questionnaire, provided one choice of zero payments for a baseline level of risk, while the other set, used in the R2 and R4 versions of the questionnaire, provided one choice that would allow the respondent to reduce his present payments by $20 but only with an increased risk of exposure. It is also important to note that the payments and risk levels were given to the respondent as ordered pairs.

The related aspects of the contingent ranking design focused exclusively on different levels of exposure risks. As shown in Figure 7-4, the levels of exposure risks in the contingent ranking portion of the design overlap those used in the direct question portion. However, there are some important differences between the direct question and contingent ranking designs. For example, the exposure risks used in versions R1 and R2 include an exposure risk level of 1 over 100 that is not employed in the direct question design. In addition, the ranking design holds the conditional risk of dying if exposed constant throughout the design. The rationale for this decision stemmed from the difficult tradeoff involving the cost of additional design points and the potential information to be gained. Although the conditional risks are potentially important for this part of the design, we considered examining the influence of different combinations of exposure risk levels and payment amounts more important for the ranking design. Earlier research (Desvousges, Smith, and McGivney [1983]) suggested the need to have a test for the influence of different payment amounts, as well as the independent comparison of question formats provided in the present design.

Part B of Figure 7-4 provides the details of the design for eliciting individuals' values of avoiding increases in risk. There are several distinguishing features of this part of the design. First, only the direct question format was used to elicit these values. Second, these values were elicited from all sample households but the endpoints of the risk change were linked to the risk changes used in the risk reduction part of the design. For example, the risk endpoints for Version D31 in Part B, the risk increase portion, were 1/25 and 1/5 the same endpoints for Version D3 in Part A for risk reductions. Not only were the endpoints the same but the conditional risks were also the same to avoid mixing the effects of the risk avoidance and the conditional probability.

The third important feature of Part B accounts for the need to have the 24 separate versions of the questionnaire instead of 12. This feature is the role of government that was specified in the hypothetical situation for the value to avoid a risk increase. To allow the town council approved vs. Federal government allowed revisions to be independent of the risk changes, it was necessary to have a separate version for each risk change. In continuing the above example, there is a Version D32 that differs from D31 only in the type of government actions specified in Part B.

The last feature of this part of the design is that the overlap in the risk levels in contingent ranking and direct question versions in Part A results in three sets of observations in four cells of Part B of the design. For example, this accounts for both D11 and R11 in value to avoid a risk increase to 1/50 from 1/10. This feature enables us to evaluate, at least for a subsample, whether the question format in the prior design for risk reductions affected values in the risk increase section that followed. However, there were also several intervening questions (e.g. critter values and certainty effect) between these major sections. This would be expected to reduce the effect of the format of the prior risk questions.

Finally, Part C of Figure 7-4 shows the design elements that related risk reduction to distance. In this part of the design, the individual was offered the hypothetical choice between purchasing two homes that were identical except for their respective distance from a manufacturing plant with landfill on site that contained hazardous wastes. Using the average price of a home in the neighborhood, the individual was asked how many miles he would want to have the house away from the plant if it cost "$x/mile" in higher housing prices. In effect, the individual was given a constant marginal price for reducing risk by moving but the price varied across individuals. The design specified four different prices per mile--$250, $600, $1,000, and $1,300. This part of the design was considered independently of the other two parts of the design, which implied that the versions in Part C would be assigned without considering the other features in the overall design. Had this not been the case, 96 separate versions of the questionnaire would have been necessary.

7.13 IMPLICATIONS

Using the main objectives of our research as guideposts, this chapter has described how we have integrated some of the many facets of risk into a research design for eliciting individuals' valuation for reductions in the risk of exposure to hazardous wastes. Additionally, the chapter has highlighted the underlying reasons for the different parts of the design. In this process we have explained our reasons including or excluding certain facets of risk, or some methodological concerns about contingent valuation, as part of the design. Ultimately, our final design is somewhat eclectic but this chapter suggests that its composite nature can be viewed as consistent with our main objectives.

The final design suggests an important, and perhaps sometimes unappreciated attribute of contingent valuation as an approach for benefits measurement. That is, contingent valuation provides a very flexible framework for developing tests for basic economic hypotheses. For example, in our final design, we have used this flexibility to examine the importance of question format, initial levels of risk, and different assignments of property rights by formulating different versions and assigning them to different parts of our sample. Although not controlled to the extent that is possible in a laboratory, it does allow for some degree of control. Moreover, the subjects respond in the same environment in which they make many economic decisions.

Finally, our design reflects the importance of the focus group sessions and other questionnaire development experiences to our final design. They proved essential in evaluating both different ways of approaching a question and the format for asking that question. Additionally, they suggested unanticipated hypothesis that are included in the design. A last consideration is that these activities were very compatible with the format and structure of contingent valuation survey that ultimately, would be implemented.

CHAPTER 8

SURVEY QUESTIONNAIRE DEVELOPMENT

8.1 INTRODUCTION

Developing a contingent valuation survey questionnaire that could effectively measure the benefits of hazardous waste management regulations by eliciting individuals' valuations of risk reductions was a difficult problem. Experimental psychological and economics research suggested that individuals' responses to questions involving decisions under uncertainty could be influenced by a number of factors, including the respondent's previous experience, the explanation of the situation, and the characterization of the uncertainty. In addition, earlier research suggested several compelling reasons to expect particular difficulties with situations involving the risks associated with hazardous wastes (Cummings, Brookshire, and Schulze [1984]).

Thus, the questionnaire development effort for this research faced two basic problems. First, we had to develop a set of procedures for the questionnaire that could effectively explain both the choices to be made under the uncertainty associated with hazardous wastes and, equally important, the changes that could occur in the uncertainty itself. Past psychological and economics research offered some valuable insights here, of course, but much of it is based on laboratory experiments whose results did not seem clearly transferable to a general population survey at the outset of this research effort. Second, and especially important to the objectives of this research, we had to develop an accurate description of the features of the risks associated with hazardous wastes and the ways in which regulatory actions might affect those features.

In view of these problems, therefore, we spent a great deal of time and effort during the questionnaire development and testing effort to try and understand accurately how people feel, think, and talk about risks, hazardous wastes, and other related topics. Appendix B contains two versions of our

survey questionnaire--one for the direct question format and one for the contingent ranking format. Concentrating primarily on the use of the focus group discussion technique and the efforts to pretest the questionnaire and to videotape its administration, this chapter briefly outlines the evolution of the questionnaire and its basic logic. In particular, after offering a short chronological overview of the entire questionnaire development process, the following sections describe the focus groups, how and why they were used, and what we learned from them and the other questionnaire development and testing activities. Specifically, Section 8.1 highlights the questionnaire development process, including the focus group, pretest, and videotaping activities; Section 8.2 describes what focus groups are and how they work; and Section 8.3 explains their role in contingent valuation. Section 8.4 describes how the focus groups were organized. Section 8.5 profiles the participants, concentrating on their knowledge and awareness of the hazardous waste problem; and Section 8.6 offers a brief summary and overview of what the project team learned from the focus groups. Section 8.7 describes the significant pretest activities conducted during the post-focus-group effort to further refine and test the survey questionnaire; Section 8.8 provides the same information for the videotaped interviews; and Section 8.9 concludes the chapter by highlighting some suggestions for enhancing the overall questionnaire development process.

8.2 OVERVIEW: A BRIEF CHRONOLOGY

As a first step in the survey questionnaire development process, a series of informal discussions--focus group sessions--were conducted with small groups of citizens in North Carolina and Massachusetts during April, May, June, and September 1983. The purpose of these sessions was to learn how best to communicate risk information to individuals and to understand how they think about hazardous wastes. Together, these sessions yielded substantial information--primarily on what individuals feel, think, and say about the risks associated with hazardous wastes--that was invaluable in the questionnaire development process. In particular, because the contingent valuation survey approach requires a questionnaire that creates a hypothetical--or simulated--market for goods not usually bought and sold (in this case, reductions in the levels of risk associated with hazardous wastes), the focus groups proved invaluable in collecting information on attitudes, perceptions, and language that helped frame the questionnaire's hypothetical market in terms that were both credible and understandable to survey respondents.

Following the last series of focus groups, the survey questionnaire was judged to have the appropriate structure. The sequence of questions, the amount and types of information they contained, and their general structure and format seemed to be "working" reasonably well. Despite having an appropriate structure, however, the questionnaire was clearly not ready for actual data collection because it had not been fully tested one-on-one under actual field conditions with a respondent. For example, the questionnaire had always been administered by a member of the project team--a situation that could not be duplicated in field work conducted with professional interviewers. In addition, the questionnaire had not been tried in the residence of a respondent, whose participation is always subject to varying interview conditions--televisions, children, telephones, etc. To minimize the chances of encountering unexpected problems in the field, therefore, the project team decided both to field test the survey questionnaire and to videotape ten one-on-one interviews with selected respondents. These activities resulted in changes to the questionnaire that substantially improved its ability to frame--i.e., explain--the hypothetical market for risk reductions in such a way that respondents could understand it and make willingness-to-pay decisions based on it.

8.3 FOCUS GROUPS: THE BASIC INGREDIENTS

Focus groups are informal discussion sessions in which a skilled moderator leads a group of individuals through an in-depth discussion of specific topics to discover their attitudes and opinions. Neither the participants nor the moderator is necessarily an expert on the topics. A concept that grew out of the psychiatric techniques of group therapy, the focus group assumes that individuals are more apt to talk about a problem in the security of a group environment than they are in a one-on-one interview. In the 1950s some researchers extended focus groups beyond their intial therapeutic purpose and used them to obtain qualitative information from consumers about product advertising and promotional efforts [Bellenger, Bernhardt, and Goldstucker, 1979].

Traditionally, focus groups have served as a tool in marketing research to acquire qualitative data on markets, prices, and the advantages of new products. In addition, focus groups have been used to

- Generate new hypotheses
- Provide background information on new product concepts, packaging, and advertising effectiveness
- Understand the consumer language associated with specific product categories or brands
- Stimulate new ideas about older products
- Structure and test questionnaires
- Interpret previously obtained quantitative results.

This project used focus groups in yet another way--to obtain and evaluate the information necessary to develop a contingent valuation survey questionnaire. Specifically, the focus groups provided an opportunity to listen as individuals discussed various aspects of hazardous wastes; to observe their responses to several tasks that would be used in the contingent valuation survey; and to try alternative methods for presenting information about the risks of hazardous waste contamination and other low-probability events.

8.4 FOCUS GROUPS: THEIR ROLE IN CONTINGENT VALUATION

In general, the focus groups were used in this research because they offered a cost-effective way of discovering how best to ask economic questions--especially those concerned with risk--of noneconomists. In particular, however, they were used to gather the kinds of information essential to the effective use of the contingent valuation survey approach to estimate the benefits of hazardous waste management regulations--information that could help explain the survey questionnaire's hypothetical market for risk reductions in terms the respondent's could easily understand. For example, contingent valuation requires the resolution of issues related to framing--i.e., the definition of the commodity in its hypothetical market and how the transaction would occur. Resolving these issues requires assessing whether responses are affected, for example, by the information given, by the way in which the valuation question is asked, or by the actual sequence of the questions on the questionnaire. Because they demonstrated in specific terms how respondents may react to varying types of information, varying types of questions, and varying question sequences, the focus groups helped assess these framing issues as the questionnaire was developed.

In addition, using contingent valuation to estimate the benefits of hazardous waste management regulations also requires detailed information on how and the extent to which respondents understand risk (or probability) and how government regulatory actions might change it. In particular, it is essential to determine what respondents are likely to know about these concepts before they are given information necessary to help them form notions of willingness to pay. Focus groups helped resolve this issue, particularly in discovering whether respondents think of risk in two separate stages--risk of exposure to hazardous wastes and risk of some resulting detrimental effect--and they helped identify language that would effectively communicate hazardous waste concepts.

Finally, the focus groups also proved an excellent way to test alternative methods of elicitng individuals' willingness to pay; to compare the workability of direct questions to elicit willingness to pay values with that for contingent ranking, which requires respondents to rank outcomes stated in terms of probabilities and wllingness-to-pay amounts; and to ensure the development of a clearly worded, comprehensible survey instrument. The focus groups were particularly helpful in the latter effort since the participants were able to point out fuzzy language and muddy or inadequately described concepts before the instrument was administered to the general target population.

8.5 FOCUS GROUPS: THEIR ORGANIZATION

The contingent valuation survey questionnaire evolved during a series of activities that spanned six rounds of focus groups, involved conducting 19 sessions in a variety of geographic areas, and required the participation of 198 men and women from a variety of economic, social, and educational backgrounds. Table 8-1 summarizes focus group session attendance. Round 1 consisted of general discussions centered around five major topics: risks in general, environmental attitudes, hazardous waste knowledge, hazardous waste risks, and attitudes toward paying for hazardous waste management. Figure 8-1 shows a sample of the questions used as guidelines for these discussions. How and the extent to which the focus group participants responded to these

TABLE 8-1. FOCUS GROUP SUMMARY

Round	Session	Participating organization	Location	Date	Number of participants	
					Per session	Per round
1	1	Duke Institute for Learning in Retirement	Durham, NC	April 6, 1983	14	
	2	White Rock Baptist Church	Durham, NC	April 11, 1983	7	50
	3	Vance County Heart Association	Henderson, NC	April 12, 1983	9	
	4	Triangle Presbyterian Church	Durham, NC	April 13, 1983	20	
2	1	INCO Sheltered Workshop	Henderson, NC	April 27, 1983	8	
	2	YWCA/Hobby Time Group	Durham, NC	April 28, 1983	11	27
	3	Methodist Retirement Home	Durham, NC	April 29, 1983	8	
3	1	Salem United Methodist Church, I	Haw River, NC	May 5, 1983	12	
	2	Salem United Methodist Church, II	Haw River, NC	May 24, 1983	7	35
	3	Ridgeroad Home Extension Club	Durham, NC	May 25, 1983	16	
4	1	Union Presbyterian Church	Carthage, NC	June 1, 1983	13	19
	2	Saint Catherine Catholic Church	Wake Forest, NC	June 2, 1983	6	
5	1	Presidents Crime Watch Council	Wadesboro, NC	June 21, 1983	22	
	2	Morven Presbyterian Church Women of the Church	Morven, NC	June 22, 1983	5	41
	3	Morven Presbyterian Church, Evening Group	Morven, NC	June 22, 1983	14	
6	1	Acton Congregational Church	Acton, MA	Sept. 13, 1983	7	
	2	Concord Council on Aging	Concord, MA	Sept. 14, 1983	7	26
	3	Acton League of Women Voters	Acton, MA	Sept. 14, 1983	6	
	4	Needham American Red Cross	Needham, MA	Sept. 15, 1983	6	
	Total 19				Total 198	

HAZARDOUS WASTES FOCUS GROUP QUESTIONS/TOPICS

1. In what ways do you think that you individually pay (monetarily) as a result of the "hazardous waste problem."

2. To whom do you pay? Where does the money go?

3. How is that money spent by the recipient(s) on hazardous waste management?

4. Have you personally or members of your immediate family actually experienced bodily harm or loss or injury to property due to hazardous wastes?

5. Do you believe in the possibility of personal loss or injury to yourselves as a result of hazardous wastes?

6. What do you think about the chances (probability) that you will actually experience personal loss or injury due to hazardous wastes?

7. What do you think about the chances that the environment will actually be damaged by hazardous wastes.

8. If you think that the chances are good that you will personally experience loss or injury from hazardous wastes, would you be willing to pay more than you now do to change the probabilities of loss or injury?

9. If you think that the chances are good that the environment will suffer damage, would you be willing to pay more than you now do to change the probabilities of loss or injury?

10. If you think that there is no chance that you or your immediate family will suffer loss or injury as a result of hazardous wastes, would you be willing to pay more than you now do to change the probabilities that others will suffer loss or injury?

11. If you think that there is no chance that you or your immediate family will suffer loss or injury as a result of hazardous wastes, would you be willing to pay more than you now do to change the probabilities that the environment will be damaged?

12. Whom do you hold responsible for proper hazardous waste management?

13. Whom do you hold responsible for the "hazardous waste problem?"

14. To what degree do you hold each of the following responsible for proper hazardous waste management:
    (1) yourselves
    (2) society
    (3) local government
    (4) State government
    (5) Federal Government
    (6) hazardous waste producers
    (7) companies that dispose of hazardous wastes

15. To what degree to you hold each of the following responsible for hazardous waste cleanup:
    (1) yourselves
    (2) society
    (3) local government
    (4) State government
    (5) Federal Government
    (6) hazardous waste producers
    (7) companies that dispose of hazardous wastes

Figure 8-1. Sample questions used in focus group discussions.

and other questions provided the information necessary to judge what kinds and amounts of information should be provided in the survey questionnaire so the respondent could form his notion of willingness to pay for risk reductions resulting from hazardous waste management regulations. As the focus group sessions were conducted during Rounds 2, 3, 4, and 5, the types and amounts of information given to the respondent--i.e., both the questions on the survey questionnaire and the supplemental materials used in the interviewer's presentation to the respondent--were substantially refined until, in Round 6, a first draft of the questionnaire was administered.

8.6 FOCUS GROUP PARTICIPANTS: THEIR AWARENESS OF THE HAZARDOUS WASTE PROBLEM

While the character of almost all the discussion sessions was largely the product of one or a mix of such important demographic variables as economic, social, and educational background, the factor with the greatest impact on the participant feelings and attitudes about hazardous wastes and the risks associated with them was personal awareness or experience--i.e., whether or not hazardous wastes and their risks had become a local issue for some reason. Table 8-2 lists the location of each of the focus group sessions and briefly indicates whether, to what extent, and how the participants in them became aware of the hazardous waste problem.

As shown in Table 8-2, participant awareness of hazardous wastes and their risks is particularly high in areas whose residents had experienced a hazardous-waste-related accident, as had the participants in the sessions held in Acton, Massachusetts, where the local water supply had recently been contaminated by chemicals leaking from a hazardous waste landfill site. Residents of areas that had recently faced a landfill siting decision were also highly aware of the hazardous waste problem and its potential risks, as illustrated by the participants in the Warren County and Anson County, North Carolina, sessions, whose communities, respectively, had unsuccessfully and successfully fought landfill siting decisions. In contrast, awareness of hazardous wastes and their associated risks was very low in areas whose residents had not experienced a local incident or fought a landfill siting. The responses of the participants in the Haw River, North Carolina, sessions, for example, show little awareness--indeed, little understanding--for what hazardous wastes are or the number and types of risks they might pose.

TABLE 8-2. FOCUS GROUP PROFILE: PARTICIPANT AWARENESS OF THE HAZARDOUS WASTE PROBLEM

Participating organization	Location of session: City	Location of session: State	Description and source of participant awareness[a]
Duke Institute for Learning in Retirement	Durham	North Carolina	The participants in this group had a heightened awareness and understanding of hazardous wastes due to several local incidents--e.g., PCB dumpings on North Carolina highways, the Warren County PCB landfill siting controversy, and a fire at a chemical waste recycling company in Durham.
White Rock Baptist Church	Durham	North Carolina	Most participants had a poor understanding of hazardous wastes, although they were able to site local incidents they had heard about in the media--e.g., the Warren County PCB landfill controversy.
Vance County Heart Association	Henderson	North Carolina	Most participants were aware of hazardous wastes and their risks due to the controversey surrounding the siting of a PCB landfill in adjacent Warren County against the strongly expressed protests of Warren County residents. Because of the proximity of their community to the Warren County landfill site, these participants had well-developed ideas on hazardous waste, particularly concerning possible compensation and its use in landfill siting decisions.
Triangle Presbyterian Church	Durham	North Carolina	Although this group had little personal experience with or awareness of the hazardous waste problem, some participants were aware of the Warren County landfill siting controversy, and a few people had detailed technical knowledge of the hazardous waste problem. Nevertheless, this group's understanding of hazardous wastes was not precise, and at least some participants expressed reservations about paying the costs of control.
Inco Sheltered Workshop (Warren County)	Henderson	North Carolina	Perhaps because their community is in such close proximity to the Warren County landfill site, these participants felt the hazardous waste problem was huge and perceived their probability of exposure as nearly 100 percent. They used the term <u>hopelessness</u> to describe the hazardous waste problem and were eager to express their opinions.
YMCA Hobby Time Group	Durham	North Carolina	A few of these participants cited local incidents--the Warren County PCB landfill and a chemical recycling plant fire in Durham--as sources of their awareness of the hazardous waste problem, but their understanding of what constitutes hazardous wastes was incomplete.
Methodist Retirement Home	Durham	North Carolina	These participants were very sensitive about how they were perceived by others and, consequently, were cryptic and defensive about their awareness of the hazardous waste problem. They seemed to understand that some substances are hazardous but not how they are related to manufacturing processes for consumer goods.

(continued)

TABLE 8-2 (continued)

Participating organization	Location of session: City	Location of session: State	Description and source of participant awareness[a]
Salem United Methodist Church, I	Haw River	North Carolina	These participants were poorly informed about hazardous wastes: One person asked what PCBs were, and another wondered if acid rain came from Agent Orange. Perhaps due to their lack of knowledge, these people were less afraid than most of the effects of hazardous waste exposure.
Salem United Methodist Church, II	Haw River	North Carolina	Though somewhat more informed than the participants in the previous discussion group, these individuals also had limited knowledge of the hazardous waste problem, particularly of effects or exposure. For example, they did not understand how leaving PCB-laced oil on the shoulders of North Carolina's highways could create an exposure problem.
Ridgeroad Home Extension Club	Durham	North Carolina	These participants indicated they knew about hazardous wastes through the media coverage of local events--e.g., the Warren County PCB landfill siting controversy--but they did not have a clear understanding of what constituted hazardous wastes and had difficulty giving specific examples: "Might have fumes associated with it."
Union Presbyterian Church	Carthage	North Carolina	These participants knew a great deal about the hazardous waste problem. They were aware of various exposure paths (particularly ingestion) and of the various products and manufacturing processes that produce hazardous waste byproducts. In addition, they followed not just local incidents (such as the Warren County landfill siting controversy) but also national ones--e.g., the Love Canal, New York, and Times Beach, Missouri, controversies.
St. Catherine Catholic Church	Wake Forest	North Carolina	In general, these participants were well educated and well informed about hazardous wastes, both at the national and at the local level. However, they had very set ideas on what hazardous wastes were and how large a problem they created. Their greatest fears were of the "unknowns" involved in cleaning up wastes and the implications of these unknowns for their children.
Anson County Crime Watch President's Council	Wadesboro	North Carolina	After overcoming their initial suspicion of the objectives of the focus group session, these participants indicated they were aware of the risks associated with exposure to hazardous wastes. This was due primarily to the fact that their county had successfully fought the siting of a commercial hazardous waste landfill. However, they did not fully understand what constituted hazardous wastes or that the manufacture of common consumer products created them.
Women of Morven Presbyterian Church	Morven	North Carolina	Probably because they lived in a County that had successfully fought a commercial landfill siting, these participants were very well educated about hazardous wastes. They were not surprised by the number and types of consumer products whose manufacture creates hazardous wastes, and they all indicated that they felt a high risk of exposure.

(continued)

TABLE 8-2 (continued)

Participating organization	Location of session: City	Location of session: State	Description and source of participant awareness[a]
Morven Presbyterian Church Members	Morven	North Carolina	Like the previous group, these participants lived in a community that had successfully fought a proposed hazardous waste landfill. They were very well informed about hazardous wastes, their risks, and the alternatives for waste cleanup.
Acton Congregational Church	Acton	Massachusetts	Probably because hazardous wastes from a leaking chemical landfill site had contaminated their water supply, these participants were well aware of the potential risks of hazardous waste exposure and effects. In general they felt they were very likely to be exposed to hazardous wastes, and, in particular, they felt exposure would most likely occur through their drinking water supply.
Concord Council on Aging	Concord	Massachusetts	The participants in this group were also very aware of the nature of the hazardous waste problem, probably because of the close proximity of their community to Acton, whose water supply had recently been contaminated. These participants were less sure about the levels of risk associated with exposure, however, and they had difficulty estimating cleanup costs.
Acton League of Women Voters	Acton	Massachusetts	Like the previous group held in Acton, this group was knowledgable about hazardous wastes due to a recent local incident in which their drinking water supply became contaminated by hazardous wastes. However, the large extent to which the participants identified with their own local incident prevented them from thinking about hazardous wastes in the hypothetical--i.e., they had difficulty describing what they would be willing to pay to reduce their risks in a hypothetical situation involving risks from hazardous wastes.
Needham American Red Cross	Needham	Massachusetts	Because Needham is further than Concord from Acton, whose drinking water recently became contaminated, these participants were somewhat less aware of the hazardous waste problem than were Concord participants. Unlike the Concord and Acton participants, for example, they perceived their own risks as zero, and they indicated they were less environmentally concerned than the other Boston-area participants.

[a] For a more precise account of focus group participant awareness of and experience with hazardous wastes and their risks, see Desvousges et al. [1984a].

8.7 FOCUS GROUPS AND QUESTIONNAIRE DEVELOPMENT: OVERVIEW AND SUMMARY FINDINGS

Experience with the focus group sessions suggested that they were a valuable tool in constructing the survey questionnaire, both in terms of learning how people think, feel, and talk about different issues and in terms of the mechanical aspects of organizing and writing individual questions and visual aids for the final survey instrument. The following discussion briefly summarizes these judgments, concentrating on the significant mechanical and perceptual issues of effectively presenting risk information to survey respondents. For further details, the interested reader can consult Desvousges et al. [1984a,b], which this section summarizes, for more detailed discussions of how the focus group sessions were organized, conducted, and analyzed.

8.7.1 Overview: Findings and Issues in Questionnaire Development

In almost every instance, the focus group participants provided important information for the survey questionnaire development process, including both substantive and editorial comments that resulted in substantial revisions to the survey instrument. Many of the suggestions could not have been anticipated a priori. For example, participants found simple examples of everyday risks useless for thinking about hazardous waste risks. In addition, while circles (or probability wheels) were the easiest vehicle for communicating hazardous waste risks, a risk ladder was more successful in eliciting responses about perceived risks. Also, the participants found the visual aid used to link the risk ladder and the probability wheels more confusing than helpful. Fortunately, the participants were willing to provide explicit, detailed criticisms of the visual aids and other survey materials.

The findings summarized below underscore the key element in the questionnaire development effort--the difficulty of presenting information about risk to the general population. This task was a central objective of the focus group research effort because it was the necessary first step to defining an adequate way to "frame" (i.e., discuss and put in context) the hypothetical commodity that ultimately would be valued in the contingent valuation survey. The commodity to be framed in the survey is a change in the risk of exposure to hazardous wastes and, corresponding to it, a change in the risk of a resultant effect, or death.* In effect, therefore, the questionnaire had to convey information about a commodity or event that might or might not happen.†

Communicating the commodity itself is only one element in framing the hypothetical commodity for a contingent valuation survey. It is also necessary to provide a specific context for the commodity--in this case, a context to explain how the exposure risk would arise, how it would be affected by government regulations, and how people would "pay" for reducing the risk of exposure (the "payment vehicle" in technical jargon). Once the respondent is given this information (i.e., the hypothetical commodity, the hypothetical context, and the hypothetical market), he is asked to complete the valuation task, during which he is asked to reveal his willingness to pay for the hypothetical commodity.

Researchers have used many different formats to elicit willingness to pay in the valuation task. They have tried asking the respondent directly (Desvousges, Smith, and McGivney [1983]) and have used iterative bidding games (Randall, Ives, and Eastman [1974]; Rowe, d'Arge, and Brookshire [1980]; Schulze, d'Arge, and Brookshire [1981]; and Desvousges, Smith, and McGivney [1983]). They have used cards with payment amounts and anchors based on average expenditures for other kinds of public goods (Mitchell and Carson [1981])--e.g. fire protection--and have tried rankings of specified payment levels matched with levels of the hypothetical commodity (Rae [1981a,b] and Desvousges, Smith, and McGivney [1983]).

Based on past experience, the direct question and the ranking formats were selected for evaluation in the focus groups because they represented two extremes in terms of the amount of information provided for the respondent: no information in the direct question format and a great deal of information (including specified payments) in the ranking format. Finally, these two formats also avoid the problems caused by choosing the various starting points

*Other nonlethal health effects are possible from hazardous waste exposure. For simplicity, the single effect of death was chosen because it is easier to define than a particular severity of a specific illness.

†Brookshire, Cummings, et al. [1982] found that their willingness-to-pay bids were quite sensitive to the changes in the framing of the hypothetical commodity.

necessary in the iterative bidding game format (see Mitchell and Carson [1981] and Desvousges, Smith, and McGivney [1983]).

8.7.2 Presentation of Probability

Introduction

The potential for difficulties in explaining the probabilistic nature of what can be expected from hazardous waste regulations was evident from the outset of the research. Previous research has identified many potential problem areas. Hershey, Kunreuther, and Schoemaker [1982] have found considerable variation in individual preferences for uncertain outcomes depending on how probability is presented. These findings are echoed by Tversky and Kahneman [1981] and Fischhoff, Slovic, and Lichtenstein [1982]. Unfortunately, the available research has not provided an unambiguous judgment on how best to present probabilities. Acton [1973] used bar charts to show alternative risk levels but did not evaluate the effectiveness of this vehicle. Jones-Lee [1976] and Frankel [1979] used fairly complex representations of probability distributions, and Loomes [1982] expressed probabilities in terms of deaths per 100,000 members of the population. He found significant differences in preferences with this measure depending on the equity implications implied in the presentation. Slovic, Fischhoff, and Lichtenstein [1978] used specific probabilities in numerical terms (percent measure of risk in some time period) in their research on accident probabilities and seat belt usage.

Selvidge's [1975] work suggests a number of areas for caution and offers some new insights. She cautions that "asking someone who has not worked a great deal with very small probabilities to make such distinctions is analogous to asking a member of a stone-age tribe to make judgments about lengths of time" [p. 200]. Her insights are that individuals can be acclimated to the task by working them through specific hypothetical situations, then asking for probability information or an evaluation in relative terms. She also suggests the use of visual aids to highlight probabilities. Specifically, she recommends an urn filled with balls of one color and one ball of a different color. (This is analogous to the visual aid used by Schoemaker [1982] in his research.) However, two important factors limit the applicability of Selvidge's research to the task of the present research. Selvidge was working with experts, requesting that they encode probabilities, and she was not conducting her experiments in a person's home (as is the case in the contingent valuation survey).* Therefore, the project team adapted the idea of using circles, or probability wheels, from risk assessment research, during which experts were asked to encode the probabilities for different risky situations. Wallsten [1983] was instrumental in explaining the workings of the vehicle and how it has been used in the past.

Overview

It was apparent from the focus groups in Round 1 that participants would have difficulty thinking of hazardous wastes as numerical risks or probabilities even though they frequently showed a good intuitive understanding of risks and hazardous wastes. It was also apparent there would be a wide range of understanding of the probability concept among participants. Some people appear to naturally think of risk in terms of probability while others do not. These different levels of understanding caused difficulty both in presenting probability to the focus groups and in explaining it within the questionnaire. To increase the understanding of probability among the focus group participants, examples of risky events that participants might face in their everyday lives were cited. Moreover, circles with shaded slices along with these examples were used to indicate the chance outcome for these risky events. Later, when participants were asked to perform the contingent ranking, circles were again used to convey the chances of exposure to and effects from hazardous wastes. It was hoped that participants would link what they learned in the general probability presentation to the contingent ranking task, where they were asked to make payment decisions based on the probabilities of reducing exposure risks.

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*The present experience with risk is an interesting contrast with their experiences with water quality (see Desvousges, Smith, and McGivney [1983]). When the water quality questionnaire was developed, Mitchell and Carson [1981] already had conducted a large-scale survey using a ladder to represent different water quality levels tied to recreational uses of water. Thus, the framing of the hypothetical commodity was a much easier task. The present research could not be based on the structure of the earlier contingent valuation study involving hazardous wastes because Brookshire, Cummings, et al. [1982] specified the commodity as a regulation and not as a risk.

In the early focus groups that included a presentation, probability was explained using two circles.* The first circle represented the risk of exposure, and the second, the combined risk of exposure and effect. Simple examples of risky events such as "rain," "IRS audit," "fishing," and "car accident" were listed beside the exposure circle, and the effects--"get wet," "pay more money," "catch a fish," and "get hurt," respectively--were listed beside the combined risk circles. Each circle had a different portion shaded to indicate the probability of the events' occurring.

In the ranking exercise, four cards (Cards A, B, C, and D) were used at first. The possible probabilities of exposure were 8/360, 6/360, 4/360, and 2/360. In the last two sessions of the first round, two additional cards (Cards E and F) with exposure probabilities of 1/360 and 25/360 were added. The risk of effect was always 4/360. In this round, a circle showing combined probability--the risk of exposure times the risk of effect--was not included. A sample of the cards used in the early focus groups have been included as Figure 8-2.

There were many problems with the presentation described above. First, participant comments indicated that the shaded circles did not do a good job of relaying the idea of chance. Adding spinners to the circles was suggested by many participants as a way to improve them as vehicles for relating chance.

Second, participants indicated they did not understand how the combined probability was formed. They were not perceiving either that the chance of exposure and the chance of effect were separate, or that the combined probability was the result of multiplying the exposure by the effect probability.† This was true in both the simple probability explanation and in the contingent ranking task, with different levels of understanding frequently appearing within all groups. After this round, it was hypothesized that participants would have an easier time determining willingness to pay for hazardous waste man-

---

*Focus groups conducted in Round 1 comprised only a general, spontaneous discussion of general topics related to risk and hazardous waste and, therefore, did not include a presentation using visual aids.

†This is consistent with some experimental research in psychology indicating that individuals have difficulty with multistage lotteries. See Schum [1980].

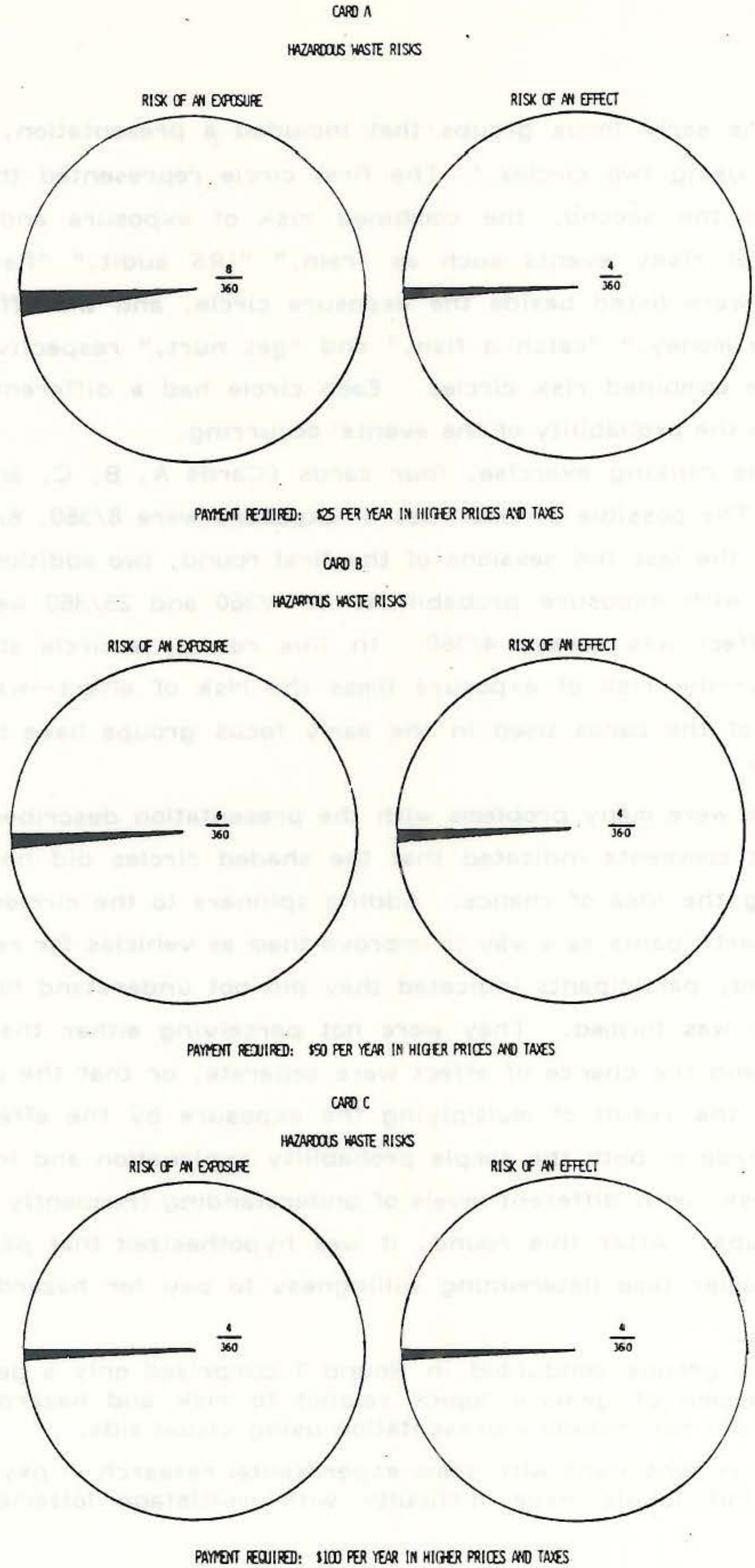


Figure 8-2. Probability circles with various combinations for risk of exposure and effect.

agement regulations if they were given very explicit information about probability. Participant comments in this round supported this hypothesis.

Third, with the exception of fishing, the simple examples (such as given in Figure 8-3) were easy for the participants to understand:

> The fishing didn't fit. Everything was a negative effect except for fishing. That was positive. The other examples all seemed like things you had control over.

However, participants did not find the simple examples of risk helpful in understanding the chances of exposure and effects from hazardous wastes. They indicated that the attributes of everyday chances were so different from those of hazardous wastes that one did not help explain the other:

> There were too many examples preceding the hazardous waste example.
>
> I understand the examples of the chance of rain, etc., but I don't understand the great relationship between your chance here and our deciding which is the best order to rank the cards in.
>
> In ranking the cards you go through a process of reasoning which is different from that of the simpler examples, like the chance of rain.

Finally, participants had trouble believing that the hazardous waste exposure probabilities were real. In general they felt they were too small:

> I wondered if what you were presenting was unbiased because of the extremely small chance of being exposed to hazardous wastes. I wondered if you were trying to program the results.

For later focus groups, the probability presentation was expanded to include three circles: an exposure circle, a conditional risk of an effect circle, and a combined risk of exposure and effect circle. This change was made to address the participant's need in the previous round for a better explanation of how the combined probability was formed. In addition, it was hoped this more explicit probability presentation would help participants understand both that the risk of exposure and the risk of effect were separate events and that the probability of an effect is conditional on a given level of exposure.

In this round, the research team added more descriptive titles to each of the three risk circle cards. Instead of just displaying the words <u>chance</u>, <u>probability</u>, and <u>risk</u>, the exposure card now included the title "What Will Hap-

Card 4
Examples of Risk

Event Outside Your Control	Your Circumstances When Event Happens	What It Means To You	How It Might Have Been Anticipated
It might rain	Walking from car to work (store, school, etc.)	Get wet	Bring an umbrella or raincoat
You might have a flat tire	On the interstate (versus in driveway)	Stranded on road (late)	Have a spare, change tires more frequently
You might be exposed to hazardous wastes	Physical makeup (hereditary background, resistance, diet, smoking)	Reduced life expectancy	Manage wastes properly, recycle wastes

Figure 8-3. Card in tabular form to present probability and explain simple risks.

pen?" and the effect card included the title "What it Means to You." Also, the example of fishing was excluded, but the examples of "rain," "IRS audit," and "car accident" were still used to illustrate effects. The card entitled "What it means to you" included the results "be outside," "make a mistake on return," and "glass breaks," respectively. The third circle included the combined risks--"that it will rain and you get wet," "IRS audit and pay more money," and "car accident and get hurt." It was hoped these changes would make it easier for each participant to relate to each circle. In addition, due to the suggestions of the first groups, spinners were added to the circles.

Finally, there were five cards (Cards A through E) in the contingent ranking exercise with exposure risks of 4/360, 6/360, 2/360, 1/360, and 25/360. The risk of effect was still 4/360 and the risks were not combined explicitly. These cards are included as Figure 8-4.

Participants still had difficulty understanding probability even after these changes. The spinners seemed to do little in helping them to understand chance:

> He was telling you that there's a certain amount of the stuff you're going to get irregardless.

> Without a dumpsite you are still going to get your share.

In addition, adding the third circle in the explanation section did not seem to help participants understand how the combined risk circle was derived; instead, they focused on the fact that the effect probability did not change in the ranking cards:

> No matter how much money you spend, the effect's the same.

> The effect is the same on all of them, so why should I pay $400 a year for something my risk of getting an effect from it is the same as if I pay nothing?

Moreover, participants' comments also indicated they still did not understand exposure and effect as separate events or effect as being contingent upon first being exposed:

> Question: Why do you think the risk of effect stays the same and the risk of exposure changes?

> I didn't notice.

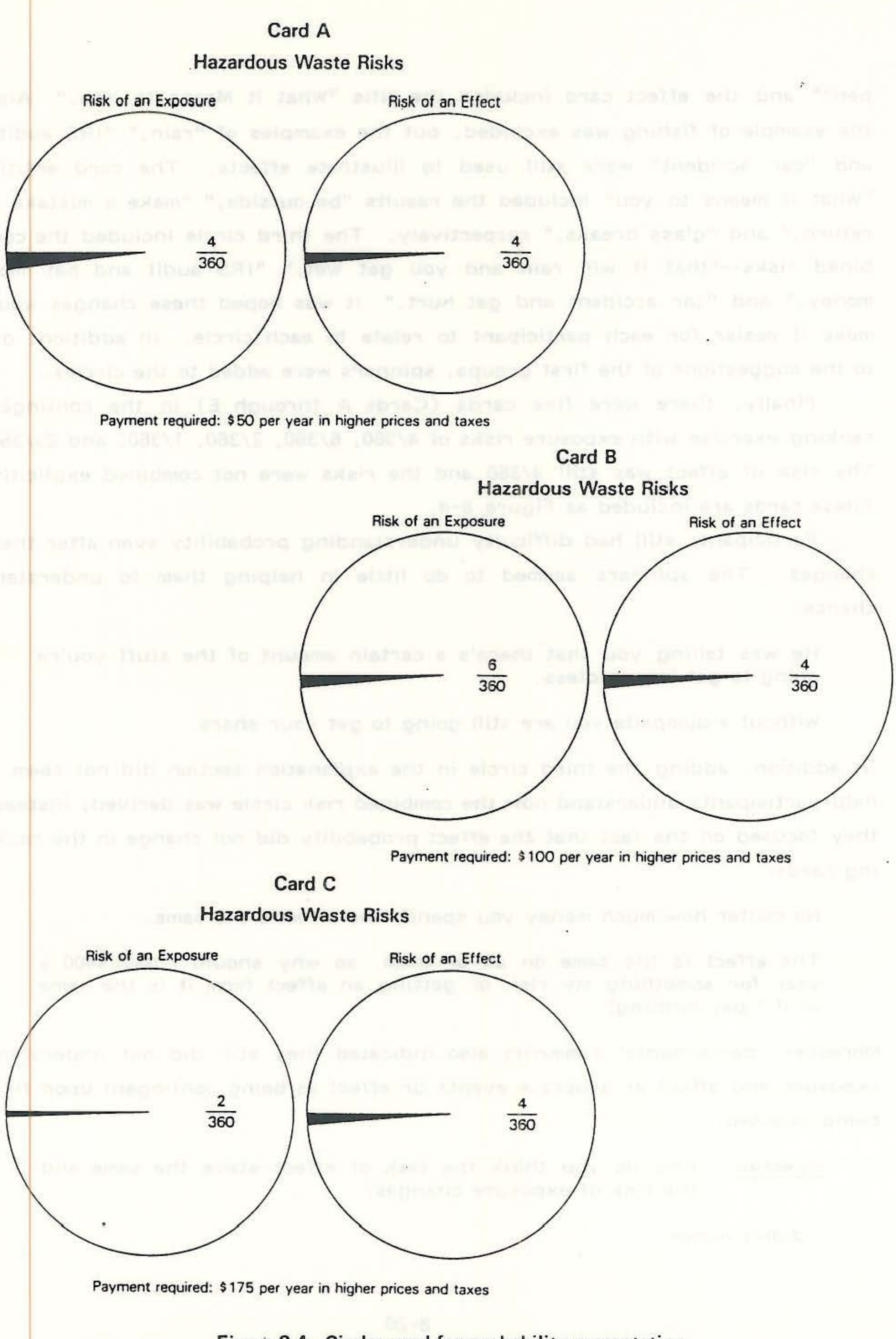


Figure 8-4. Circles used for probability presentation.

Obviously everyone exposed won't be harmed, some will, some won't, but here's one, one out of 360 exposures and 4 out of 360 the risk of effect, can't understand that, three of them got it that wasn't even exposed.

Finally, participants infrequently felt that the probabilities were too small. Rather, they indicated that they didn't perceive enough of a difference between them to affect their payment decisions:

Obviously we're going to look at how much it costs since there's not so much difference between the chances of exposure.

In the fourth and fifth rounds the circle cards and accompanying explanations were made even more explicit. The spinners were removed; the title on the exposure card was expanded to read "What Will Happen: Events Outside Your Control"; the effect card was changed to read "What It Means to You: Your Circumstance When It Happens"; and the combined risk card was changed to read "What It Means to You." The examples corresponding to these cards were changed to read, respectively, "rain tomorrow," "flat tire," "exposure to hazardous wastes"; "walking from the car," "on the interstate," "your hereditary background"; and "get wet," "flat tire," and "get cancer."

For the exposure to hazardous wastes example, the text on the cards described exactly the association participants were supposed to make--"exposure to hazardous wastes," "your heredity background," and "get cancer." Additionally, each circle card included the ratio of the part of the circle that was shaded and some explanation to help participants understand what was being conveyed on each card. The exposure card included the statement "probability = chance spinner will fall in the shaded part," and the combined probability card included the statement that "both of the earlier outcomes must occur."

Besides the circles and examples, an additional card was added to help participants make the association between the simple risk examples and the hazardous waste risks. This card, entitled "Hazardous Wastes as a Risk," included the same information displayed on the circle but in tabular form. Added to each example was a column entitiled "How it Might Have Been Anticipated." For "rain" this included "bring an umbrella"; for "flat tire" this included "have a spare"; and for "hazardous wastes" this included a question mark. It was hoped that using the hazardous waste example along with the simple risk examples would help participants link the two.

The ranking cards (Cards A through E) were also expanded in this round. Now, instead of each having two circles (risk of effect and the risk of exposure), they also included a third circle, combined risk. The risk of effect circle was also changed to read the "risk of effect if exposed." The risks of exposure were 1/90, 2/90, 5/90, 10/90, and 20/90. The risk of effect if exposed was 90/540. Combined risks were 1/540, 2/540, 5/540, 10/540, and 20/540. These cards are included as Figure 8-5. Round 5 cards were slightly different. Instead of being asked to rank cards, participants were asked to determine a willingness-to-pay amount. Therefore, only three cards were used, with risks of exposure of 1/90, 5/90, and 10/90.

Participant comments in these rounds indicated much greater understanding of probability. First, they appeared finally to have understood that the risk of effect is merely a multiplier:

> Question: What about that middle circle? Anybody have some feelings on the meaning or the use of that middle circle?
>
> At that point there's nothing you can do about it.
>
> It's just a multiplier.
>
> It's an arbitrary fact at that point.

They also seemed to be looking at exposure and effects from hazardous wastes as only being a chance occurrence:

> The thing that came across to me was that you were using the circles to point out that it could be controlled by just chance in the control of hazardous wastes and the effects on the people would just be a chance.

It is important to note, however, that the groups in Rounds 4 and 5 were well educated and/or very knowlegable about hazardous wastes.

In the final round of focus groups, where the first draft of the survey was administered, circles were no longer used in the probability explanation to explain simple risk. Instead, the card explaining risks in tabular form was made more explicit. It still included three examples, but each one was explained more clearly. Circles were still used on the ranking cards and were exactly the same as in Rounds 4 and 5.

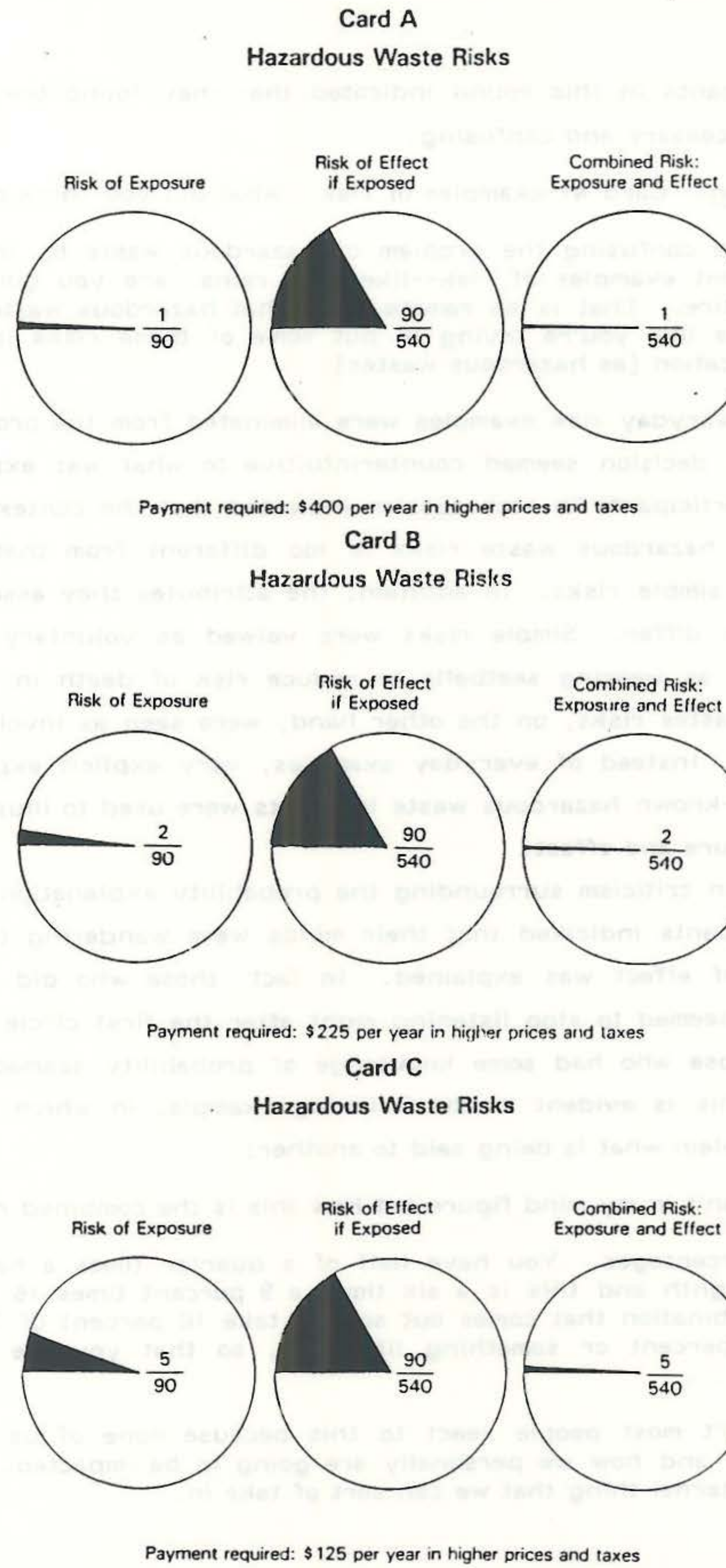


Figure 8-5. Sample cards (A through C) used for probability presentation.

Participants in this round indicated that they found the simple examples of risk unnecessary and confusing:

> Question: Card 4--examples of risk. What did you think of that?
>
> You are confusing the problem of hazardous waste by introducting irrelevent examples of risk--like if it rains, are you going to have a flat tire. That is so remote from what hazardous waste involves, it seems like you're trying to put some of these risks in the same classification [as hazardous wastes].

Thus, the everyday risk examples were eliminated from the probability explanation. This decision seemed counterintuitive to what was expected a priori. However, participants in each session indicated that the context in which they think about hazardous waste risks is too different from that in which they think about simple risks. In addition, the attributes they associate with each type of risk differ. Simple risks were veiwed as voluntary or controllable events such as wearing seatbelts to reduce risk of death in a car accident. Hazardous wastes risks, on the other hand, were seen as involuntary and uncontrollable. Instead of everyday examples, very explicit explanations using local or well-known hazardous waste incidents were used to illustrate probabilities of exposure and effect.

The main criticism surrounding the probability explanation was its length. Some participants indicated that their minds were wandering by the time the probability of effect was explained. In fact, those who did not understand the concept seemed to stop listening right after the first circle was described. However, those who had some knowledge of probability seemed to listen more intently. This is evident in the following example, in which one participant is able to explain what is being said to another:

> I still can't in my mind figure out how this is the combined risk.
>
> Two percentages. You have half of a quarter times a half is what is an eighth and this is a six times a 9 percent times 16 percent is the combination that comes out so you take 10 percent of 16 percent is 1.6 percent or something like that, so that you are getting it down . . .
>
> But don't most people react to this because none of us know our heredity and how we personally are going to be impacted. But this is an external thing that we can sort of take in.

You have been told that the middle is the average of all the population in that you are generally going to fit into that category.

Participants still had difficulty believing that the probabilities used on the cards were realistic:

Again I wondered where you came up with these. It looked as if it could be almost arbitrary.

Many helpful suggestions were made by the participants in clarifying the cards. Most of these surrounded the mathematical representation of probability. Using percentages was advocated by participants in all groups:

One of the things is the math that gets you down. Use a percentage figure or one out of thousand or hundred thousand, 10 over 90 and 10 over 540.

I would have used ratios. If you went from 1 in 54 to 1 in 10, I wouldn't use any circles.

They could be converted into percentage relationship. That I could read.

I kept wondering why you didn't put percentages here. 10/90 doesn't mean anything to me but 11 percent does.

Scientific notation, that we are going to lose most people. Put in terms of a one-over kind of number (i.e., 1/100,000) as opposed to ten-to-the-minus number.

Two out of 100,000 or something like that. . . .

One participant also suggested putting more description on the hazardous waste exposure risk cards:

Why not describe what it is [on the card], i.e., heredity, background, pathways.

These suggestions were all taken into account when the circle cards were designed for subsequent survey drafts. The final version of the circle cards includes three circles entitled "Risk of Exposure," "Risk of Death if Exposed," and "Combined Risk: Exposure and Death." Each circle's significance is further explained by a caption underneath. The exposure circle is captioned "Possible Pathways"; the effect circle, "Heredity and Health"; and the combined risk circle, "Personal Risk." Each circle has a portion that is shaded to signify chance or probability of risk. Both the percent and ratio of the shaded portion of the circle are on the circle card. The actual probabilities vary since there are several survey versions that will be administered to respondents. One version of these circle cards is included as Figure 8-6.

In addition, instead of giving payment amounts, some respondents will be asked to rank payment cards. These cards are identical except that each will have a title giving the payment amount. This title is also more explicit than in previous rounds. It includes both a monthly and yearly amount and states directly that this is in higher prices and taxes.

8.7.3 Perception of Exposure Risk

Requesting that individuals shade portions of empty circles was the first means used to elicit participants' perceived risks of exposure to hazardous wastes. However, participants indicated that the circle was not really the best way of doing this and that they often very arbitrarily selected the portion of the circle to shade. It became apparent that some kind of benchmark or anchor was needed to guide their responses.

Risk Ladder

A risk ladder was then used as a visual aid in determining participants' perceived risks of dying from hazardous waste exposure. In the early rounds, the risk of dying from exposure to three different kinds of hazardous wastes was placed on a ladder among the risks of death from other kinds of events. A copy of this risk ladder is included as Figure 8-7. In this first draft version of the ladder, three estimates of hazardous wastes risks from a risk assessment study were used in an attempt to determine how respondents would react to this (and other) information. The ladder was based roughly on the number of people who die annually from various causes or activities. Participants in general seemed comfortable with the ladder as a graphical representation:

> I think we're all used to seeing things represented in graphs like these and that it's easier than to start comparing circles.

They were, however, very sensitive to the other events on the ladder. For example, "eating peanut butter," one of these other events, was brought up for discussion in each group. Participants were also disturbed by the probabilities used in association with each event and in most cases were reluctant

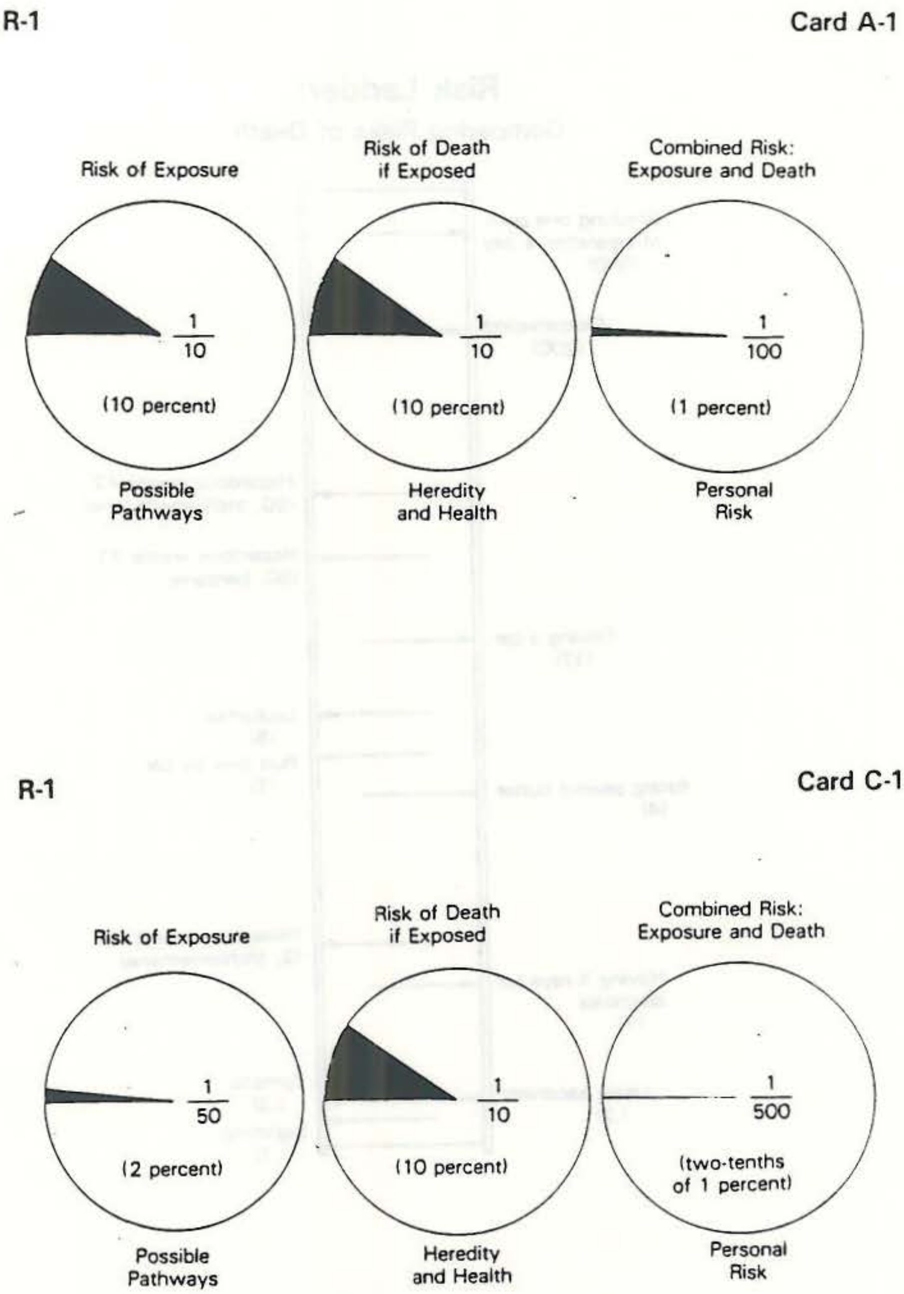


Figure 8-6. Two cards (A-1 and C-1) with final format.

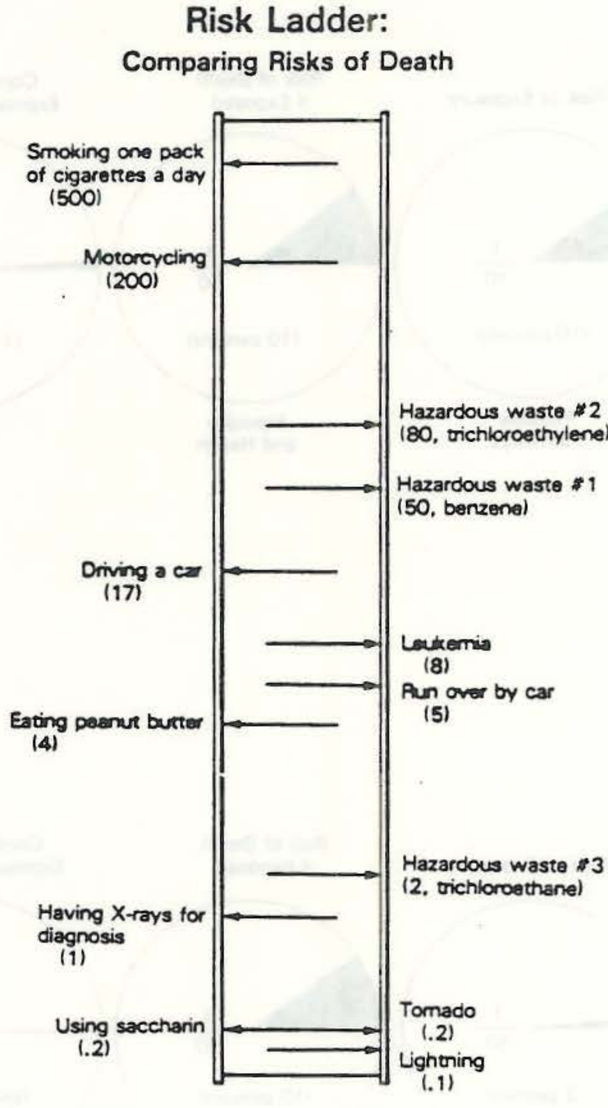


Figure 8-7. Initial risk ladder including exposure to three kinds of hazardous waste among risks from other events.

to believe they were accurate numbers. They indicated that if the team were going to try to use these numbers as true probability occurrences they ought to include at the least a source and some explanation of what they were based on:

> I never took it as an accurate measure of what the probabilities were. If I were to take it as an accurate number, I'd have to know what you meant by hazardous wastes # 2, where #1 set that exposure and what does that mean. I just took it as a general idea that we are exposed to a hazardous waste generates these possibilities rather than to graphically represent possibilities of it occurring.

Additionally, some participants felt the ladder was misleading because it wasn't drawn to scale:

> For true representation, don't you need to put a broken scale on it?

In the next round the same ladder was used, but this time the exposure risks to hazardous wastes were removed. Participants were asked to place their perceived risk of dying from hazardous waste exposure on the ladder. By and large, participants were able to perform this task, but their comments indicted they had the same misgivings with the ladder as in the previous rounds:

> This is a really misleading risk ladder. Your rates are not accurate. They're not age specific. The data is just not accurate. You're asking an individual for a certain age and this is just not accurate for an individual of that age. . . . The way you're trying to ask your questions, you can't extrapolate from death data for the whole population very accurately and then ask individuals where you put yourself on here.

In the final round, when a draft of the questionnaire was administered, the ladder was changed substantially. This ladder included occupational risks on one side and risks of dying from various events on the other. The probabilities were removed from each event, and each portion of the ladder was shaded differently. There was a break between each of these shaded portions on the ladder to give it the appearance of being more to scale. A copy of this ladder is included as Figure 8-8. In addition, a second card was included that attempted to tie the ladder to the risk circles that had been previously used to explain probability. This card had both a ladder and circles on it. The ladder had just three events on it of high, low, and medium death risks.

Card 5

Risk Ladder: Comparing Risks of Death

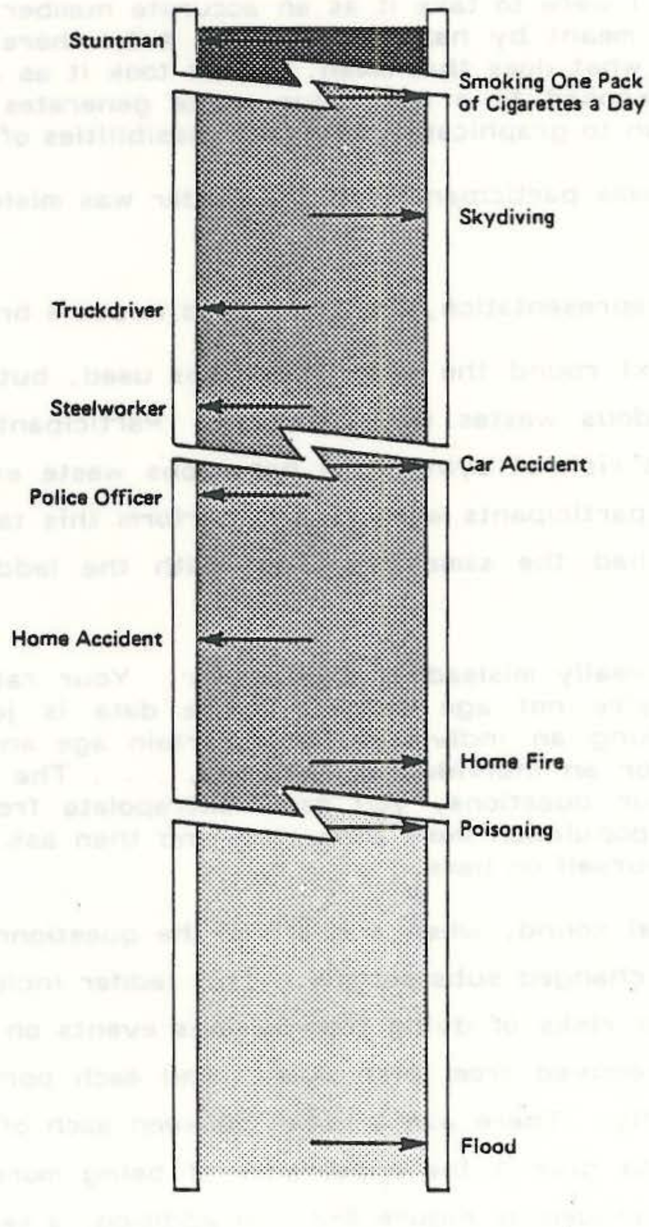


Figure 8-8. Revised risk ladder separating occupational risks from other events and introducing breaks in ladder.

Next to each event was a circle partially shaded to indicate probability of death from that event. This card (Card 6) is included as Figure 8-9. Participants in the first session in this round indicated this card was not helpful in making a transition between circles and the ladder. In fact, the card confused them:

> <u>Question</u>: Did card No. 6 help make a transition between the ladder and the circles?
>
> Pointless.
>
> If you can't keep it maintained to a 100 times for all three, it's meaningless.

This card was eliminated from subsequent sessions in this round.

Participants in this round had both graphical and conceptual suggestions for making the ladder and task clearer. The graphical comments revolved around shading and putting the events more to scale:

> <u>Question</u>: What did you think of the risk ladder? Was it helpful? Not helpful? What kind of impression did you get out of it?
>
> If you did the graph in a different format it might become a little clearer to more people. The gradation and shading are a little troublesome at first. There is not a great distinction between the gradation that one notices the distinction until you go back and study it. The arrows going in two directions rather than one.
>
> The breaks are not clear. If you're working with hard numbers, it's easier to see and to integrate it . . . to try to figure out how much space there is between steelworker and car accident, you're just left to your imagination. It could be a little or a lot; the person just has no idea.
>
> I had a question when you explained the ladder. The breaks in the ladder appear to indicate that this is a long ladder. Is there a big gap between smoking one pack a day and a stuntman or are they right on top of each other? That is something that isn't clear. I think it would help if you could somehow or other indicate that--maybe on a numerical scale--because then you wouldn't be constrained by the size of the page or whatever else.
>
> One of the difficulties is the way the break comes across. Cigarette smoking is at the top of the break and if there had been a wider break you would see it's not in the same class as stuntman.

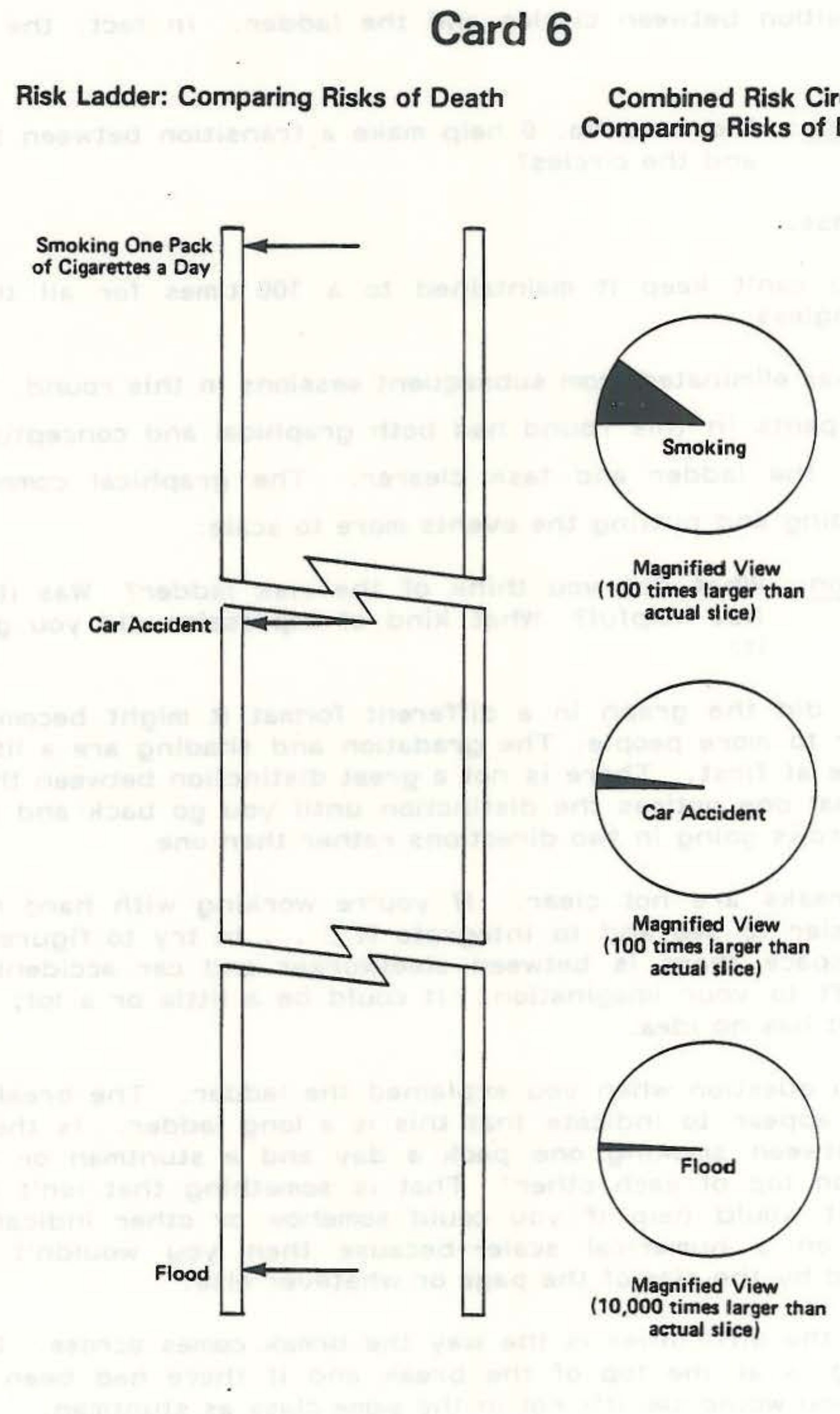


Figure 8-9. Card attempting to tie risk ladder to probability circles.

In addition, participant comments indicated that the examples made it difficult for them to assess where on the ladder they should place their perceived risks of death. For one participant, all the risks were accidental except smoking. Because participants did not see death from hazardous wastes as accidental, they tended to put their perceived death risks closer to smoking and thus higher on the ladder than they really felt was accurate:

> Do you mean the risk of premature death? Because all of these are by accident except for smoking. The rest are premature death due to some kind of accident.

> It's hard to relate the risk [of death] from hazardous waste [with the other examples of risks of death] because it's more like the cigarettes than all of these other things.

> Comparing [hazardous wastes] to all these accidental deaths made me keep pulling it up the ladder.

> You could compare it to smoking a pack of cigarettes a day. The problem is there is nothing else like that on here.

Other participants didn't feel there were enough examples on the bottom of the ladder:

> These seem to be all very high risk . . . at least from home fire up. I would have liked to have had something at the other end of the scale. In between flood and poisoning because everything else seemed too high up.

Many participants had difficulty in relating to the types of occupations used as examples:

> But the skydiving and stuntman are so remote from the average person's experiences, maybe you ought to have death of a heart attack at age 60, something that people relate to.

The women in particular thought there were too many male dominated occupations:

> The occupations are not ones I related to very easily. They tend to be more male occupations.

Most participants wanted to see some indication of the probability of dying from the events listed on the ladder:

> When I saw cigarettes way up there, I didn't think it very believable. I didn't believe it--it looked like someone just did it. Shouldn't it say based on insurance statistics or something?

> Everything else in the thing is done with numbers. You might very well, since all these are different levels, just put numbers along side of them. It might be easier.

In the group where the participants were asked to place their perceived occupational risks on the ladder, it became apparent that more examples that professionals could relate to were needed:

> I can't relate to your probabilities. I work in an office and the worst thing that is going to happen to me is hypertension and I have a heart attack.
>
> If they doubled the exposure from those CRT terminals. If it radiated more stuff, that's in an office.
>
> I couldn't even get on the first rung of the ladder. It's zero.
>
> I might have a problem getting to and from work; that's a problem.
>
> I did have a little difficulty identifying, say, with the sky diving, for example, or with drunk driving.

The older group of participants had the most difficulty understanding the exercise. They indicated more text around the ladder would clarify the task:

> Question: Does anyone have any reaction to the risk-ladder card? Did you find it helpful, confusing?
>
> Confusing.
>
> I just didn't understand it. A graph like that says nothing to me. You have to put it in words in a paragraph.

Finally, some participants suggested ways to reword the question to make it clearer. The comments indicated our question had to provide more specific details on the situation they were evaluating:

> It might have helped us if you said "premature" before "death."
>
> What about age. Some people might not care if it means they are going to live to 70-75.
>
> Whether it's an actual exposure to hazardous waste or what is your potential of being exposed to hazardous waste. If you have an actual chemical spill in your town, that's different than what you think your chances are of being exposed.

Participants' suggestions were taken into account to construct a ladder for the final version of the survey that is quite different from that used in the focus groups. Each segment of the ladder is a different color to show more clearly the breaks that signify changes from one probability level to another. The events are no longer listed on two sides of the ladder but down the middle. Risks of death from more common professional occupations are included, such as insurance agent, engineer, or banker. Probabilities of each event have been included, not in fraction form but as the number of persons out of 100,000 who will die every year. An uncolored copy (reduced in size) of the ladder is included as Figure 8-10.

In addition, the survey script explaining the ladder is much more explicit. It points out the breaks in the ladder and what they signify, documents the probabilities, and explains them--e.g., 11 out of every 100,000 people will die from home accidents each year. The development of the risk ladder clearly demonstrates the effectiveness of using focus groups to develop a contingent valuation questionnaire. Specific, immediate feedback enabled the research team to alter the ladder to resolve confusions.

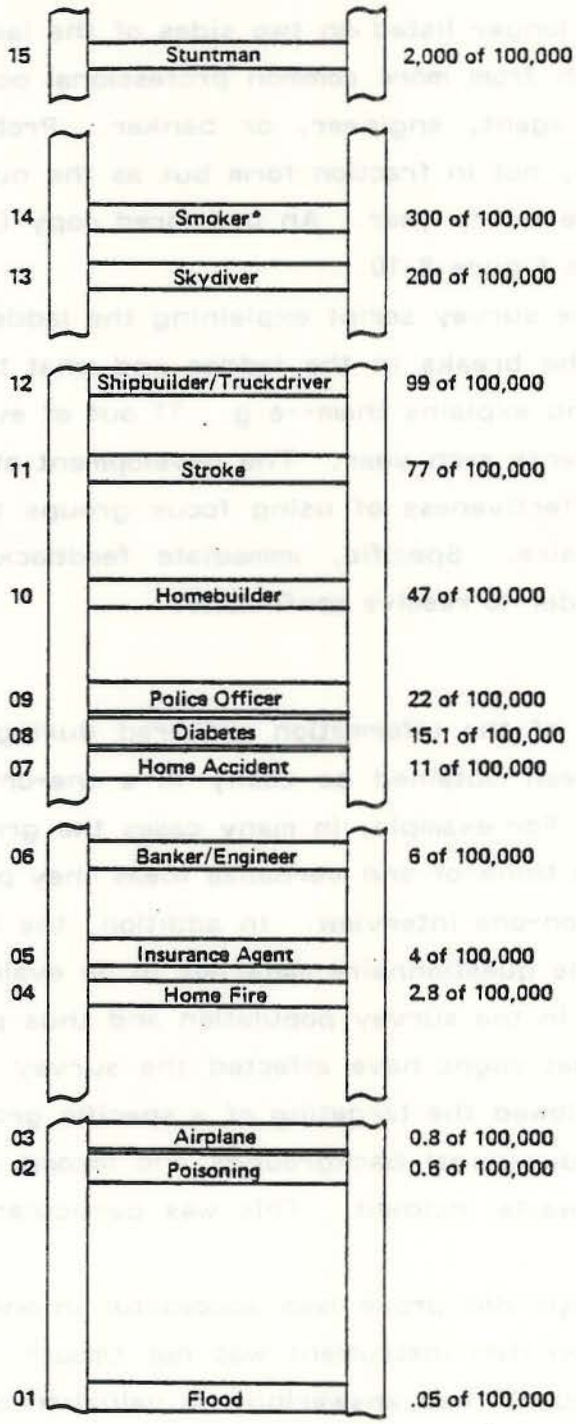
8.7.4 Summary

Although some of the information gathered during the focus group sessions could have been obtained as easily in a one-on-one pretest situation, not all of it could. For example, in many cases the group environment stimulated participants to think of and verbalize ideas they probably would not have expressed in a one-on-one interview. In addition, the focus groups conducted in Boston allowed the questionnaire materials to be evaluated using households comparable to those in the survey population and thus provided access to specific local details that might have affected the survey results. Furthermore, the focus groups allowed the targeting of a specific group composed of people from a variety of educational backgrounds and income levels that had experienced a hazardous waste incident. This was particularly crucial with such a complex topic.

The focus groups did prove less successful in one area. The transition from the oral to a written instrument was not smooth. This was apparent in the difficulty participants had answering the valuation question when the first draft of the survey was administered in the last round of focus groups. This difficulty occurred even though participants had little difficulty with the same question in the previous round of focus groups, where a less formal presenta-

Card 5

Risk Ladder: Comparing Annual Risks of Death



*At least one pack per day.

Figure 8-10. Final version of risk ladder incorporating suggestions from participants.

tion was used. Therefore, whereas focus groups are extremely valuable in the testing of ideas and techniques and in constructing a first draft of a survey questionnaire, they will not serve as a substitute for a pretest.

Finally, although the advantage of hindsight now suggests, perhaps, that some of the 19 sessions conducted during this research could have been eliminated by additional planning, the experimental nature of using focus groups in a major contingent valuation survey questionnaire development effort and the desire to learn as much as possible about how people feel, think, and talk about risks from hazardous wastes were compelling reasons to conduct a large--rather than an optimal (i.e., smaller)--number of sessions.

8.8 PRETEST OF CONTINGENT VALUATION SURVEY QUESTIONNAIRE

After a draft version of the survey questionnaire was administered during the final round of focus groups, the comments of the focus group participants--both on content and on presentation of information--were analyzed and then incorporated into a second draft. However, although it was judged to have the appropriate structure, sequencing, content, and presentation, this draft was not considered ready for data collection because it had not been administered under actual field conditions. To minimize the occurrence of unexpected problems during data collection, therefore, we elected to conduct a pretest of the questionnaire using trained interviewers and a number of pretest interviews.

To prepare for the fieldtest, or pretest, two interviewers were trained in a day-long session at the Research Triangle Institute (RTI) in Research Triangle Park, North Carolina. Subsequently, one of these interviewers, who later supervised the data collection on a day-to-day basis in the field, trained two professional interviewers in the Boston area to help collect the fieldtest data. For the pretest, a total of four interviewers completed 45 interviews in two locations: suburban Boston, Massachusetts, and the Research Triangle area of North Carolina. The latter area was chosen to take advantage of the services of an interviewer who had prior contingent valuation survey experience and who had demonstrated an uncanny knack for not only identifying trouble spots but also suggesting solutions. Nine of the interviews were completed in the Research Triangle area and 36 in suburban Boston. The interviews were divided about equally between the direct question and ranking versions. The interviewers used no specific criteria to select respondents, although the project team did request that they interview respondents from several socioeconomic groups.

To evaluate the effectiveness of the questionnaire, the project team conducted two half-day debriefing sessions with the interviewers at each location. The completed questionnaires also were analyzed for general consistency in responses. The outcome of these efforts was that the questionnaire generally was on the right track but that several trouble spots needed improvement. Generally, the interviewers were able to identify these areas and to indicate the kinds of problems either they or the respondents had experienced. Thus, the insights obtained from the pretest dealt almost exclusively with the workability of the questionnaire. The pretest samples were too small and nonrandom to yield any insights into the potential variances in willingness to pay amounts in the actual survey. In contrast, Mitchell and Carson [1984] found that their willingness-to-pay bids from a 100-interview pretest had variances almost identical to these in their full survey of 800. Information about variances is critical for judging the adequacy of the statistical power for the planned sample size but was beyond the capability of our pretest.

The pretest suggested that the main trouble spots in the questionnaire involved the overall language and the explanations at certain points. Specifically, the pretest questionnaire sounded too much like an interviewer reading and not enough like an interviewer talking. It simply was too formal and not conversational. To illustrate the value of the pretest in making this point, the following excerpts compare the pretest version with the final questionnaire. However, it should be noted that the final version reflects the efforts from other revisions, including those from the videotaped interviews and suggestions from outside reviewers:

> <u>Pretest version</u>
> Throughout life there are chances that people may die from many different causes. Every day of our lives there is a chance that we may die from some accident on the job, at home, or somewhere else. There is also the chance that we may die from some long-term illness or disease or we may die suddenly from some health problem. On the other hand, there is a chance that we may fully live out our lives and die of natural causes. Some common risks of death are shown on this risk ladder (see Figure 8-10).

Final version
Throughout our lives there are many different risks of dying. There is a risk or chance we may die from an accident or some long-term illness, or we may die suddenly from some health problem.

The pretest experiences also indicated several problems in the introduction to the risk ladder. Specifically, the example used to illustrate how the respondent was to use the ladder was misleading and the importance of the different sections was not emphasized:

Pretest version
The ladder will help you compare different risks of death. Notice that the ladder is divided into six sections to show that the differences in risk levels are quite large between sections. Each section shows the relative sizes of the risks of dying during any year of a person's lifetime based on national averages. Beside each cause of death there are figures that show the number of people who die each year from that cause. For example, the risks to stuntmen show that in any year 2,000 out of every 100,000 stuntmen will die from an accident on the job.

Final version
This ladder shows the different risks of dying associated with a variety of common activities, including accidents, habits, hobbies, illnesses, natural disasters, and job accidents. The numbers on the right show the risks for each of the activities listed. The ladder displays these risks from low to high so you can easily compare them. The two types of risks shown and those based on some of the people and those based on all of the people in the United States. For example, numbers shown for occupations, skydiver, and smoker are based only on people in these activities. This means, for instance, that during the next year 47 of every 100,000 homebuilders in the United States will die from an on-the-job accident. However, the numbers shown for the remaining risks are based on averages for all people in the United States. This means, for instance, that during the next year, 77 out of 100,000 people in this country will die from a stroke. Notice also that there are breaks between the five parts of the ladder to show that the difference in risk levels is quite large between each part.*

The explanation of the risk circles was the area most frequently recommended for major revisions. Interviewers found the explanation in the pretest version both redundant and confusing:

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*Another important change was also made in response to suggestions from A. L. Nichols and several other reviewers from the U.S. Environmental Protection Agency (EPA). They suggested that all risks, except for the occupational risks, be put on a consistent basis. The pretest version had some risks that applied only to people who presently experienced the health condition.

Pretest version

Another way of thinking about hazardous wastes as involving risk is with this card (HAND RESPONDENT HAZARDOUS WASTE RISKS CARD A, WITHOUT DOLLAR AMOUNT). It uses circles to stand for two types of hazardous waste risk that we want you to think about: the first circle, which shows the risk or chance that you (or a member of your household) would be exposed to hazardous wastes. By exposed, I mean touching, breathing, eating, or drinking a large enough amount of a hazardous waste over a period of time so that it could harm the health of whoever is exposed. Exposure through the pathways we have discussed could be a brief, one-time exposure, or it could be over months or years. The importance of the second circle is that even if a person is exposed, there is another and different risk or chance that he would develop a health problem and die. With many of the kinds of health problems that could be caused by hazardous wastes, it might be 10 to 30 years before a person would know that he was seriously ill and die. The third circle combines the two types of risks into risks to a person.

Final version

Another way to think about hazardous wastes and risk is with this card. It uses circles to stand for two different kinds of risks we face from hazardous waste.

Pretest version

The middle circle on Card A stands for the second type of hazardous waste risk--the chance of a harmful health effect after being exposed. This risk means that even if you are exposed, there is a chance, not a certainty, that you will be harmed. For example, if one person catches a cold at home or at work, everyone around will not get sick. Some people are healthier or have better resistance. The same idea is true for hazardous wastes. Whether or not you are actually harmed is based on your physical makeup--your heredity and your overall health. Looking at both of these circles, you can't be harmed by hazardous wastes if you are never exposed to them. You would never have to spin the pointer in the middle circle as long as the pointer on the first circle (POINT TO FIRST CIRCLE) never landed in the darkened area.

Final version

The importance of the middle circle is that it stands for the second, and different, type of hazardous waste risk--the chance of dying after being exposed. This means that even if you're exposed, there's a separate chance--not a certainty--that you would die. For example, some people are healthier or have better resistance. Whether or not you're actually harmed is based upon your physical makeup, heredity, and overall health. An important thing to remember about the first two circles is that you would never have to spin the pointer on the second circle as long as the pointer on the first circle never landed in the blackened area. In other words, there's no chance you would die from the effects of hazardous wastes if you're never exposed to them.

The interviewers also pointed out that respondents had trouble with the transition between hypothetical scenarios. It was necessary to repeat entire sections because the respondent was unclear about the ground rules. The transition at Section G of the questionnaire (willingness to pay to avoid an increase in risk) was especially troublesome because respondents frequently thought their bids in the previous question also applied to this one:

Pretest version
Now let's consider a completely different situation.

Final version
Now let's consider a completely different situation. That is, your dollar amounts and answers to previous questions are not carried over to this one.

The pretest also confirmed the effectiveness of the focus groups in evaluating the visual aids used in the interview. With one exception, the payment vehicle card, the interviewers felt like these visual aids worked well. The payment vehicle card subsequently was revised and the interviewers (in the final field survey) confirmed that the changes had remedied the problems with the payment vehicle card.

In summary, the pretest and the subsequent discussions with the interviewers provided valuable information on the workability of the questionnaire. These steps led to major revisions that clarified the exposition. They also clearly demonstrated the importance of how a questionnaire "sounds." To be effective, good exposition is not enough; the questionnaire also must sound appropriate when spoken.

In addition, the project team felt that there was little difference in the information obtained in the suburban Boston and Research Triangle area pretests. That was encouraging for three reasons: First, the local pretest was less expensive than the onsite pretest because there were no travel costs for training or debriefing. Second, with the interviewer working only in the local area, it was easier for the project team to communicate on a more frequent basis. Third, the lack of any significant differences also implied that the videotape interviews could be done in the local area at considerable cost savings with probably only minor losses in information.

Finally, caution is required in drawing a general conclusion from our experience that a local pretest can substitute for one conducted at the actual survey location. One difficulty is that although the context of our hazardous waste valuation scenario was for a specific site, the actual location could have applied to any town. The critical question to be answered is whether there are any reasons to expect that respondents in different areas would react differently to the framing of the questionnaire. This does not suggest that they would necessarily have the same willingness to pay. Indeed, we would expect differences based on income and other relevant explanatory variables. However, it does imply that the same behavioral model applied to two populations would fit each equally well. Even with hindsight, it would seem desirable to perform the onsite pretest because it provided relatively low cost insurance for avoiding major problems in the actual survey.

8.9 VIDEOTAPED INTERVIEWS

To supplement the field pretest, ten one-on-one videotaped interviews were also conducted with members of the RTI staff. As the final stage of the questionnaire development process, these videotaped interviews provided information necessary to evaluate additional aspects of the final questionnaire's workability. They were especially helpful in identifying the various verbal and visual cues that respondents used to develop their answers to specific questions.

In evaluating whether or not the questionnaire "worked," the videotaped interview sessions focused on five key elements:

- The respondent's perceptions of the questionnaire's framing--e.g., the hypothetical commodity and the payment vehicle.
- The usefulness of the visual materials as aids in the framing process.
- The effectiveness of the risk circles in communicating very small probabilities.
- The logical progression of the questionnaire.
- The sound of the questionnaire's language.

Ten separate interviews were videotaped with RTI employees in a conference room at the Institute. The employees included two maintenance workers, two data entry workers, a mid-level statistician, an electrician, a painter, a carpenter, and two secretaries. The interviews were divided equally between men and women. Respondents also were chosen to represent a wide range of ages and educational levels.

The videotape camera was placed in one location and operated automatically eliminating the need for a camera operator. One project team member observed the session while another conducted both the interview and the subsequent discussion. It was explained that the purpose of the session was to evaluate the questionnaire, that there were no right or wrong answers, and that participants were to respond the same as if they were in their own living rooms. No one-way mirrors were used to conceal the observer. However, the participants seemed unaffected by the presence of the observer or the camera after the initial explanation of the purposes of the session.

Although it is difficult to isolate the specific changes that resulted exclusively from the videotape sessions, several general conclusions can be highlighted from the videotapings based both on the observations of the interviews and on the discussions with respondents. For example, in their explanations of how they formed their willingness to pay bids, almost all respondents mentioned one key feature: their monthly income and their present expenses. The respondents clearly used this as their common anchoring point. Although the bids varied quite substantially, the first thing each person mentioned in describing his thought process was his budget constraint. It seemed that the use of monthly amounts rather than annual amounts made it easier for him to consider his budget constraint. If the budget constraint as the primary anchor were common to contingent valuation surveys, it may help to explain, at least in part, why respondents have shown considerable difficulty in developing their willingness to accept bids (see Knetsch and Sinden [1984], Meyer [1979], and Rowe, d'Arge, and Brookshire [1980]). In the willingness-to-accept case, they lose the common anchor on which they rely in the willingness-to-pay case. Of course, the difficulty may also in part be due to an unwillingness to be morally responsible for accepting a payment for degradation of the environment (see Kahneman [1984]).

The discussions in the videotape sessions also focused on the adequacy of the framing for the hypothetical commodity, reductions in the risk of exposure to hazardous wastes. In particular, the respondents were asked about how they used the circle cards in relation to the various hypothetical scenarios.

Some described using the visual relationships between circles, while others said that they felt more comfortable with the numerical expressions--a finding consistent with our focus group experience. They understood the link between the changes in the risks and the proposed regulations in the hypothetical scenario. Some focused on the exposure circles while others used changes in the combined circle in forming their bid. The majority indicated that the three separate circles communicated the relationships between exposure, their own heredity, and the risk of death. The videotape sessions reinforced the earlier judgment that how the respondents responded to the probability information will be one of the central questions to be evaluated in the empirical analysis.

Another important use of the videotape sessions was to evaluate the feasibility of using the risk circles to communicate the low probability parts of the experimental design. In response to suggestions from reviewers, the experimental design was expanded to include two additional direct question versions of the questionnaire. One new version had combined risks of exposure and death ranging from 1/30,000 to 1/150,000 and the other, risks ranged from 1/60,000 to 1/300,000. These probabilities were 100 times smaller than the risk levels that previously had been evaluated with the risk circles. About half of the total videotape sessions consisted of the lower probability cases. The general conclusion was that the respondents seemed to be able to use the risk circles equally well to see the reductions due to the regulations. In effect, the videotape sessions provided low-cost insurance that the additional design points were workable before more resources were committed to collect data from these additional designs.

The videotape sessions also indicated that the improved introduction to the risk ladder (noted in Section 8.6) made it easier for respondents to use the ladder in expressing their perceived risk of dying from various causes, including exposure to hazardous wastes. The respondent descriptions of how they used the ladder reinforced the focus group finding that some preferred the numerical expressions while others used the various anchors of other types of risk. Each of the different kinds of risks--job risks, health risks, risks from different activities, and risks from natural hazards--was mentioned by respondents in their descriptions of how they used the ladder.

The videotape sessions helped to evaluate another important aspect of a workable questionnaire--its logical progression. In the followup discussions, respondents indicated that they felt comfortable with the order of both information and questions. They pointed out the importance of the order of information on Card 1 that related hazardous wastes and common products. Almost every person cited some part of this information in their explanation of how the questionnaire oriented them in thinking about hazardous wastes. They also felt that the sequence of the risk discussion using the circle card, followed by the payment vehicle and then the hypothetical situation seemed straightforward. Several noted that the explanations were longer than they needed (e.g., the circle cards) but others felt that the additional information helped them.

Finally, the videotape sessions afforded the opportunity to listen to the questionnaire to evaluate its sound. After the pretest, the interviewers had stressed the importance of having the questionnaire sound like an interviewer talking and not simply reading. By observing and listening to the session it was easy to evaluate the sound of different questionnaire sections as they were administered. The videotape also enabled the team member conducting the interview to replay these same sections and elicit the respondent comments on what caused a puzzled expression or some other kind of response. In listening to the interview, some words or vagueness had a jarring effect and prompted the search for simple and/or more concrete words to replace technical or vague language. The repetition of interviews by a team member also led to improved interviewer instructions on how to use the visual aids to make the questionnaire more interactive.

8.10 THE QUESTIONNAIRE DEVELOPMENT PROCESS: REFLECTIONS AND SUGGESTIONS FOR IMPROVEMENT

While the actual process of developing the questionnaire evolved over a period of about 1 year and had to respond to other objectives besides the primary one, the passage of time, the advantages of hindsight, and some missteps have all yielded some useful impressions about the overall process. Generally, focus groups, field pretests, and the videotaped interviews should be viewed as complements rather than substitutes. Each seemed to offer some advantages relative to the other but there were also some disadvantages. The focus groups were especially effective in getting a general sense of people's knowledge and perceptions of hazardous wastes. This was especially useful for this application, since very little information was available in the literature on how to meaningfully present hazardous waste risks in a household survey.* On the other hand, the pretest was a better indicator of trouble spots in the questionnaire due to either logic or language. The pretest also focused attention on the administration of the questionnaire and the importance of the verbalized form or "sound" of each question. The videotape sessions proved very effective in evaluating whether or not revisions aided either "sound" or workability. Both the focus groups and videotape sessions were excellent for getting people to explain their thought processes and for determining the effectiveness of the visual materials in aiding the information processing. In addition, caution is required in using the pretest for the purpose of knowing what the respondent was thinking. This information came from experienced observers (the interviewers) rather than the respondent. This shortcoming can be minimized by encouraging the interviewers to seek out the respondent's reactions rather than relying exclusively on their impressions, but the possibility of inaccurate filtering still remains.

The complementary nature of focus groups, pretests, and videotaping implies that a blend of the three can be every effective tools in dealing with complex environmental commodities. However, better integration likely would enhance their complementarity. After the first two rounds of focus groups, additional time to prepare a written draft of the questionnaire likely would have permitted the more rapid development of a final questionnaire. Using an early draft questionnaire in several videotape sessions perhaps could have replaced at least one round of focus groups. This change would have shortened the time involved in planning and the logistics of focus group sessions and allowed more time for the team to work on the questionnaire itself. The videotape sessions, supplemented by simply reading the questionnaire into a tape recorder as revisions are attempted, likely would have enhanced the way the pretest version sounded.

Following the videotaping and subsequent revisions, a round of focus groups to administer the draft questionnaire to participants from the survey

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*Recall the earlier study (Burness et al. [1983]) treated the problem as one of valuing a regulation with general uncertainty as to the exact nature of hazardous waste risks.

area would provide valuable feedback on the respondents thought processes as well as the effectiveness of the questionnaire and visual aids. However, the cost differential between local and onsite pretesting could be kept relatively small by foregoing in-person training and debriefing. Both activities could be done by telephone supplemented with programmed training. These two substitutions could enable pretests both onsite and locally for about the same cost as one full-scale onsite effort with expensive personal training. However, the in-person training supplemented with practice interviews and intensive discussions proved critical to the success of our actual field survey, since the cost of mistakes could have been much higher.

In summary, the process of questionnaire development could have been enhanced by better integration of focus groups, pretests, and videotape interviews. Focus groups seem to diminish in effectiveness after two or three sessions. They are most useful with longer periods of time between sessions and a corresponding larger amount of time for better formalizing ideas. The sooner a written draft can be prepared the better. Speaking rather than reading even early versions makes a major difference in the way they sound. Videotaping is a fast, relatively inexpensive way to explore how the respondents are using different parts of the questionnaire. Finally, field pretests are still useful in simulating actual field conditions.

CHAPTER 9

SAMPLING PLAN AND SURVEY PROCEDURES

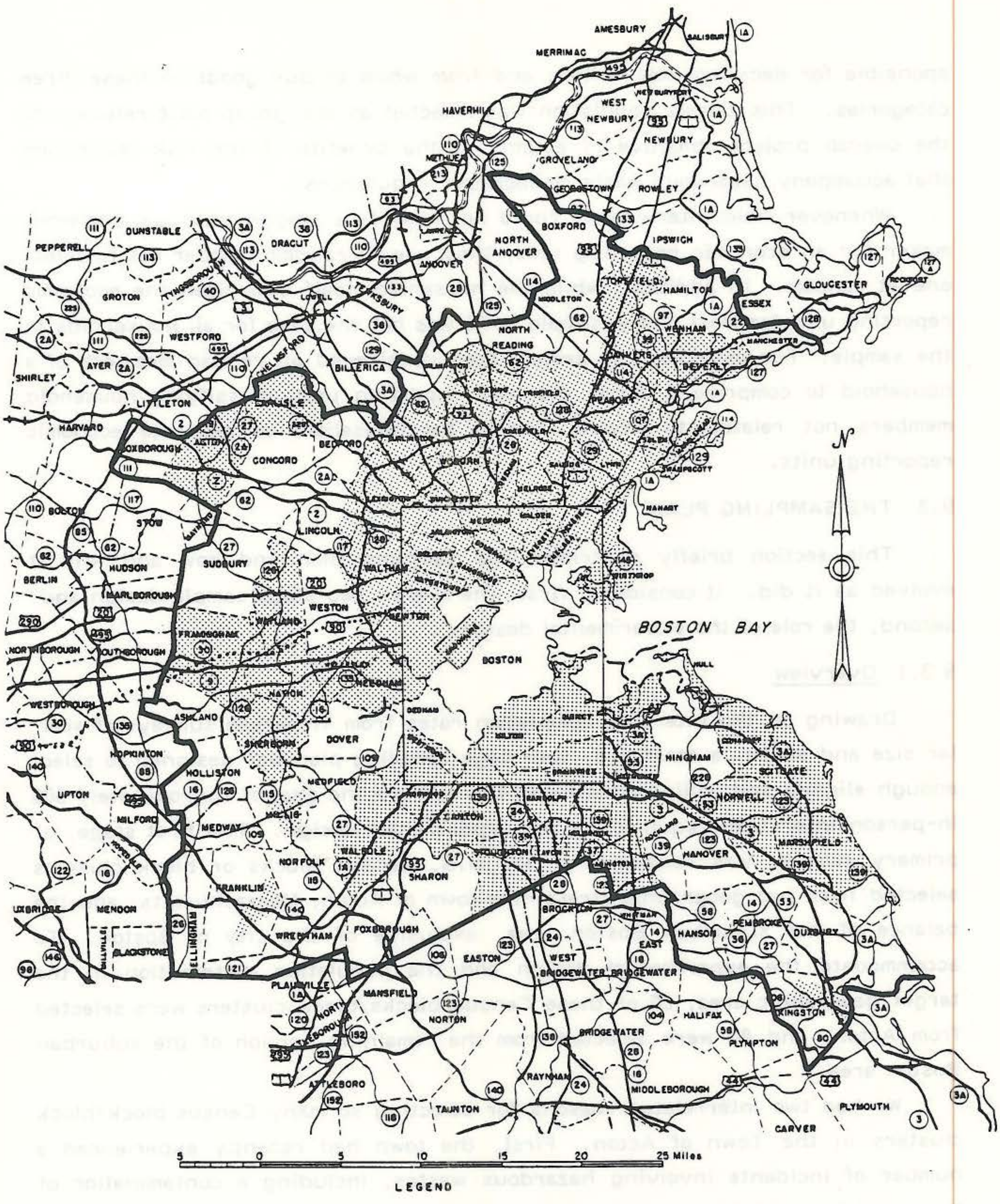
9.1 INTRODUCTION

This chapter summarizes the sampling plan and the survey procedures used to gather the information required by the experimental design. Specifically, Section 9.2 defines the target population, Section 9.3 gives a brief overview of the sampling plan and its relationship to the experimental design, and Section 9.4 describes how the survey questionnaire was administered to the target population, including discussions of interviewer training, quality control, data collection, and interviewer debriefing procedures. Section 9.5 concludes the chapter with a brief summary of its main points.

9.2 THE TARGET POPULATION

As noted in Chapter 6, the experimental design for the survey called for approximately 600 completed interviews with economic decisionmakers in households in suburban Boston--specifically, the Boston, Massachusetts, standard metropolitan statistical area (SMSA), exclusive of the City of Boston. Figure 9-1 shows this target geographic area and indicates, in the shaded portions, the location of the areas eventually selected for the survey interviews that composed the sample.

The experimental design required that all survey respondents be economic decisionmakers, not just a randomly selected member of the household. Therefore, the target population actually consisted only of persons who made primary economic decisions for groups of household members residing in the target geographic area. These groups of household members, called economic reporting units, consisted of the members of a household who act as a single economic entity to make expenditures in three categories--food, housing, and other expenses. Representing these groups of household members (or economic reporting units), the economic decisionmaker was the single individual most re-



Note: Shaded areas indicate locations selected for survey interviews.

Figure 9-1. Map of survey area.

sponsible for deciding how, when, and from whom to buy goods in these three categories. This target population was selected as the group most relevant to the overall project objective of estimating the benefits of the risk reductions that accompany hazardous waste management regulations.

Whenever field interviewers could not identify a single individual decision-maker for an economic reporting unit, they used a random number list to select one at random. In addition, while the household itself comprised the economic reporting unit for most of the sample, this was not the case for all households in the sample. For example, the project team considered all related members of a household to comprise a single economic reporting unit, classifying household members not related to anyone else in the household as separate economic reporting units.

9.3 THE SAMPLING PLAN

This section briefly describes this sampling plan and how and why it evolved as it did. It considers, first, the overall two-stage sample design and, second, the role of the experimental design.

9.3.1 Overview

Drawing on the interview completion rates from in-person surveys of similar size and scope, a stratified, two-stage sampling plan was designed to select enough eligible and willing respondents to achieve the goal of approximately 600 in-person interviews required by the experimental design. The first stage, or primary sample, was composed of 100 U.S. Census blocks or block clusters selected from two geographic strata--the town of Acton, Massachusetts, and the balance of the suburban Boston area, exclusive of the city of Boston. To accommodate the experimental design and the population distribution in the target geographic area, 20 of these Census blocks/block clusters were selected from Acton, and 80 were selected from the remaining portion of the suburban Boston area.

We had two interrelated reasons for selecting so many Census block/block clusters in the Town of Acton. First, the town had recently experienced a number of incidents involving hazardous wastes, including a contamination of two municipal drinking water wells, that resulted in a substantial amount of information about hazardous wastes being disseminated in the community. (See

Chapter 10 for a more detailed discussion of hazardous wastes and Acton.) Because this information could have an important impact on people's valuations of risk reductions, we oversampled the population in Acton so we could compare the valuations of Acton residents with those of the rest of the target population. Second, oversampling in Acton also helped us meet the objective of comparing the results of our study and those of Harrison [1984]. Specifically, because Harrison [1984] used a hedonic property value model (discussed in detail in Chapter 15) and two other methods (i.e., a risk assessment and an analysis of averting costs) to develop policy analyses of alternative regulations of the disposal of hazardous wastes, including estimates of the benefits for avoiding exposure to hazardous wastes for homeowners in the Town of Acton, our oversampling of Acton residents will allow us to compare our survey estimates with Harrison's.

The second stage, or secondary sample, was derived from the U.S. Census blocks/block clusters in the first-stage sample by first listing and then selecting specific housing units in the two target geographic strata. A total of 915 housing units were listed and selected for the second-stage sample--189 from the Acton stratum and 756 from the remaining portion of the surburban Boston area. Sample weighting procedures--equal weights within strata, different weights between strata--were also developed to help ensure accurate compilation of data from the surveyed population. Appendix C provides more information on the listing of housing units within the two strata, and Appendix D contains a more detailed discussion of the first- and second-stage sampling procedures.

9.3.2 Experimental Design Considerations

The experimental design raised three important questions for the sampling procedures used to sample the survey's target population:

- How would the design be allocated across the sample without confounding it?
- How many sample housing units would be required to achieve the planned number of observations for each cell in each part of the experimental design?
- How many sample housing units would be required to yield the desired number of completed interviews?

In answering the first question, the 24 versions of the questionnaire were randomly ordered across the entire sample, and this random ordering was replicated in units of 24 across the entire sample. This procedure assured that each interviewer and each sample housing unit had an equal probability of receiving any one of the 24 versions of the questionnaire. This randomization was selected in an attempt to reduce the potential confounding of the design with either the sampling procedures or the procedures used to assign sampling housing units to specific interviewers.

The answer to the second question involves a tradeoff between the expected cost of obtaining a completed interview and the number of sample housing units required to permit reasonably powerful tests of the hypotheses that were implied by our conceptual analysis, given the elements of the experimental design. This process also has implications for the precision of our estimates of option price functions. Trying to anticipate the necessary sample size for estimating the values associated with changes in hazardous waste risks is complicated by the lack of previous studies and the potential for nonlinearities in these tradeoffs. Given our uncertainty over the precise forms of some of the functional forms and final tests for the models we estimated, and given our desire to test a variety of hypotheses, to estimate payment (option price) functions, and to realize other estimation objectives simultaneously, we did not attempt to derive the sample design allocations through a constrained optimization problem (e.g., see Conlisk and Watts [1979] and Aigner [1979]. A flexible full-factorial design was selected for part of the direct-question design, with separate blocks to consider the effects of low probability scenarios, and an independent full factorial design was selected for the contingent ranking component of the design. We allocated a somewhat larger number of observations to the contingent ranking design points in an effort to permit (within the limits of the budget for the survey) separate indirect utility functions to be estimated for each design point. In all cases, however, the sample sizes exceed conventional rules of thumb for testing of hypothesis concerning means and are more than adequate (given the experimental design) for multivariate analysis.

Figure 9-2 is a matrix showing both the planned sample sizes and the number of observations obtained for each element of the experimental design, including direct question and contingent ranking question formats for valuing risk reductions and two versions of the direct question format for valuing the

Value of Reductions in Risk

Direct Question Format (D)

Vector	Reductions in risk of exposure: From	To	Risk of death, if exposed: 1/10 P	1/10 A	1/20 P	1/20 A	1/100 P	1/100 A	1/200 P	1/200 A
I	1/5	1/10	45	42	45	46	—		—	
	1/10	1/25	45	34	45	35				
II	1/10	1/20	45	47	45	46	—		—	
	1/20	1/50	45	31	45	33				
III	1/30	1/60	45	48	45	35	—		—	
	1/60	1/150	45	36	45	29				
IV	1/300	1/600	—		—		45	53	45	41
	1/600	1/1500					45	32	45	28

Contingent Ranking Question Format (R)

Vector	Levels of risk: Risk of exposure	Risk of death, if exposed	Amount of monthly payment: Vector A ($0 $20 $55 $150) P	Vector A A	Vector B ($−20 $5 $40 $80) P	Vector B A
I	1/10 1/20 1/50 1/100	1/10	60	57	60	59
II	1/20 1/30 1/60 1/150	1/10	60	56	60	55

Town Council-Approved Risk Increases

Reductions in risk of exposure: To	From	Risk of death, if exposed: 1/10 P	1/10 A	1/20 P	1/20 A	1/100 P	1/100 A	1/200 P	1/200 A
1/25	1/5	22	15	22	20	—		—	
1/50	1/10	83	66	22	22	—			
1/60	1/20	60	47	—		—		—	
1/150	1/30	22	21	22	18	—		—	
1/1500	1/300	—		—		22	21	22	18

Federal Government-Allowed Risk Increases

Increases in risk of exposure: To	From	Risk of death, if exposed: 1/10 P	1/10 A	1/20 P	1/20 A	1/100 P	1/100 A	1/200 P	1/200 A
1/25	1/5	23	20	23	21	—		—	
1/50	1/10	82	73	23	16	—		—	
1/60	1/20	60	44	—		—		—	
1/150	1/30	23	22	23	13				
1/1500	1/300	—		—		23	26	23	16

[a] Although this part of the design used only the direct question format, both the ranking and direct question versions that correspond to the Part A design are identified to reflect the interrelationship between both parts of the design.

[b] There are two observations for this design point because of overlaps in the probability levels in the Part A design.

P = Planned A = Actual

Figure 9-2. Matrix of planned and actual observations for each cell of the experimental design.

avoidance of risk increases. As shown in the figure, the experimental design generally called for 45 observations in each of the cells for the direct question versions and 60 observations in each of the cells for the contingent ranking versions. The final sample sizes exceeded the planned sizes for all but the direct question part of the design, which asked each respondent to provide values for two separate risk changes. Because some individuals declined to pay for the second increment, some of the direct question cells had fewer observations than were planned.

To answer the third question, i.e., to determine the number of sample housing units required to yield the 600 completed interviews, the results of previous surveys of similar size and scope were used to develop target interview completion rates. Specifically, a sample size larger than the desired number of completed interviews was selected because past experience indicated that interviews would probably not be obtained from every economic reporting unit included in the sample. For example, some units would be ineligible because they were vacant; in others, the respondent would refuse to be interviewed. In anticipation of not obtaining interviews for all units, therefore, the following anticipated completion rates were used to develop the sample size required to yield at least 600 completed interviews:

- 0.92 eligible occupied housing units per prelisted unit
- 0.92 enumerated housing units per eligible occupied housing unit
- 0.75 interviewed economic reporting units per selected economic reporting unit.

Table 9-1 shows the sample sizes developed for the two target strata using these interview completion rates.

TABLE 9-1. SAMPLE SIZES

Strata	Completed interviews required	Sample housing units[a]
Acton	120	189
Balance of suburban Boston	480	756
Total	600	945

[a]Computed as completed interviews/(0.92)(0.92)(0.75).

9.4 SURVEY ADMINISTRATION

Once the target population had been identified and an appropriate sample had been scientifically selected, a set of survey procedures was designed to fulfill the sampling protocol and to attempt to minimize problems stemming from the administration of the questionnaire. These procedures provided for the use of experienced professional interviewers, intensive in-person training of the interviewers, and close supervision of the entire data collection effort. In addition, to conclude the survey administration effort, the team also conducted an in-person session to debrief the interviewers about data collection. This section describes the training methods, highlights the quality control procedures, summarizes the outcome of the data collection, and concludes with a review of the information provided by the interviewers in the debriefing.

9.4.1 Interviewer Training

Because interviewer training had played such a critical role in earlier contingent valuation surveys (e.g., see Desvousges, Smith, and McGivney [1983]) and because of the complex nature of the hazardous waste questionnaire, the project team developed a detailed training agenda. This agenda consisted of preparing a comprehensive manual tailored to the questionnaire, a home study of the manual, a 2½-day training session, and four to six practice interviews accompanied by intensive debriefing. All five of these elements played an important part in helping the interviewers understand not only what they were supposed to do, but why they were doing it.

The interviewer training manual consisted of eight chapters. Topics included a description of the overall research objectives, the sampling protocol, procedures for securing the interview, general questionnaire administration, question-by-question specifications with detailed explanations and examples, and general administrative procedures. Interviewers studied the manual prior to the training session and referred to it throughout the data collection.

The in-person training session covered topics ranging from enumerating the household to using the visual aids to represent risk. Figure 9-3 presents the agenda for the training session. During the session, the project team stressed the importance of developing a thorough understanding of the logic of the questionnaire and, therefore, carefully explained the rationale for each

Contingent Valuation Survey to Estimate Benefits of Hazardous Waste Management Regulations

Field Interviewer Training Agenda March 19 - 21, 1984

Monday March 19, 1984		
8:30 a.m.	Introduction of Trainers, Trainees, and Observers	Kirk Pate
8:45 a.m.	Review of Training Agenda	Kirk Pate
9:00 a.m.	Background and Purpose of the Regulatory Benefits Survey	Bill Desvousges
9:45 a.m.	Break	
10:00 a.m.	The Benefits Questionnaire • Overview of major sections • Versions and variations • Visual aids	Kirk Pate
10:45 a.m.	Demonstration Interview (A simple simulated interview designed to illustrate administration of the direct question version D111)	Kirk Pate Bill Desvousges
12:00 p.m.	Lunch	
1:00 p.m.	Mock Interview #1 (The trainees will be divided into two groups to expedite interviewing through all sections of version D711)	Trainers Trainees
2:15 p.m.	Discussion of Mock Interview #1	Full Group Discussion
3:15 p.m.	Break	
3:30 p.m.	Mock interview #2 (The trainees will be divided into two groups to expedite round-robin interviewing of version D824)	Trainers Trainees
5:00 p.m.	Adjourn for the Day	
Tuesday March 20, 1984		
8:30 a.m.	Discussion of Mock Interview #2	Group Discussion
9:15 a.m.	Demonstration interview of the ranking version R111 (ranking section only)	Kirk Pate Bill Desvousges
10:00 a.m.	Break	
10:15 a.m.	Mock Interview #3 (The trainees will be divided into two groups for round-robin interviewing of the ranking section only of version R213)	Trainers Trainees

(continued)

Figure 9-3. Interviewer training agenda.

Contingent Valuation Survey to
Estimate Benefits of
Hazardous Waste Management Regulations (continued)

Field Interviewer Training Agenda
March 19 - 21, 1984

Tuesday
March 20, 1984 (continued)

11:00 a.m.	Discussion of Mock Interview #3	Group Discussion
12:00 noon	Lunch	
1:00 p.m.	Mock Interview #4 (ranking section only of version R424)	Bill Desvousges
1:30 p.m.	Discussion of Mock Interview #4	Group Discussion
1:45 p.m.	Locating Sample Segments and Housing Units	Annette Born
2:30 p.m.	Completing the Household Control Form • Record of contacts • Enumeration and reporting unit formation • Reporting unit selection • Eligibility rules for interview respondents • Sample individual selection	Kirk Pate Annette Born
3:00 p.m.	Break	
3:15 p.m.	Continue Topic	
4:30 p.m.	Quality Control Procedures • Field editing • Telephone review of first administration • Observations • Validations	Kirk Pate Annette Born
4:45 p.m.	Pass out Assignments	
5:00 p.m.	Adjourn for the Day	

Wednesday
March 21, 1984

9:00 a.m.	Administrative Procedures • Completion of Interviewer Production, Time and Expense Report • Preparation of assignments • Reassignment procedures • Visual aids and questionnaire supply and replacement • Disposition of completed questionnaire and household control forms • Disposition of administration forms • Scheduled weekly telephone reports	Kirk Pate Annette Born
10:15 a.m.	Break	
10:30 a.m.	Final Discussion, Clarification and Wrap-up	Kirk Pate Annette Born
1:00 p.m.	Adjourn	

Figure 9-3. Interviewer training agenda (continued).

element in the hypothetical market. Following this review, the project team divided the interviewers into small groups and conducted mock interviews with both the ranking and direct question versions of the questionnaire. The session continued with the interviewers administering the questionnaire at home and again with team members.

The final element in the training, full-scale practice interviews, proved very successful. The interviewers conducted four to six practice interviews with respondents. A member of the project team and the field supervisor observed the first practice interviews and reviewed them with the interviewers. These same project team members critiqued the final practice interviews on a question-by-question basis in telephone conversations with each interviewer. At the end of these sessions, the interviewers were familiar with both the logic and purpose of each section of the questionnaire.

9.4.2 Quality Control Procedures

The field supervisor monitored all field activities on a daily basis. The monitoring consisted of both telephone conversations and in-person review supervision. Interviewers discussed problem cases as they arose and reported the status of each case on a weekly basis to the field supervisor. The field supervisor transmitted an updated computer file to the project team each week for review.

During the data collection, two problems arose which required additional discussion. First, the interviewers experienced unexpected problems in obtaining an enumeration of respondents. These difficulties stemmed from the fact that a substantial number of the sample housing units were in limited access apartments and from the fact that many professional persons were not at home even after five attempts to interview them at various times of the day and night. Second, the sample contained at least 30 respondents who did not understand English. (The majority were Portuguese.) The language barrier problem proved impossible to solve without expensive (and of uncertain value) translations of the questionnaire. However, a certified mailing with a letter providing a strong appeal for cooperation signed by each interviewer proved a very cost-effective way of gaining access to difficult-to-reach respondents. Indeed, had the mailing been attempted sooner in the data collection period, it is likely that the interviewers could have reduced the number of "no respondent at home" because several of the interviewers had not mailed all their letters.

The final quality control measure consisted of telephone verification of a randomly selected sample of the interviews. These calls all indicated that the interviewer has completed the interviews with the respondent and that certain selected items were accurately recorded.

9.4.3 Data Collection Summary

The data collection yielded 609 completed interviews from a total sample of 953 sample housing units. The sample size increased over the earlier figure cited above because of the addition of eight housing units that were missed in the counting and listing activity. The household enumeration was the first element of the data collection. Enumeration consisted of listing the names and ages of the household members, determining the economic reporting units within the household, and randomly selecting an economic decisionmaker (as defined earlier) from the reporting unit. The interviewer attempted the initial contacts for enumeration in-person but left notification when the respondent was not home.

Table 9-2 summarizes the status of the household enumerations. Interviewers successfully enumerated the household for slightly more than 75 percent of the sample housing units. Respondents refused to be enumerated in 11 percent of the households, while no one was home in about 5 percent of the households. A sizable percentage of the refusals gave "illness" or "too elderly" as the reason they refused. The remaining nonenumerated households consisted of vacant units, nonhousing units, respondents with language barriers, respondents on vacation, and respondents with a physical or mental limitation. These latter 15 respondents did not refuse to be enumerated but were incapable of providing the information.

The final stage of the data collection consisted of the interview stage. Table 9-3 provides the summary of outcomes for this stage. Interviewers obtained fully completed interviews for 609 (84.58 percent) of the 720 successfully enumerated housing units. Only three interviews were not completed after initiation. This statistic is encouraging because it suggests that the interviewers were effective in communicating the material. It also suggests that few respondents found the interview (which lasted an average of 53 minutes)

TABLE 9-2. ENUMERATION RESULTS

Result code	Result at the household enumeration stage	Present study		Desvousges, Smith, and and McGivney [1983]	
		Number	Percentage of sample	Number	Percentage of of sample
1	Successfully enumerated	720	75.55	347	87.41
2	No enumeration eligible home	49	5.14	9	2.27
3	Household absent during study period	4	0.43	-	-
4	Enumeration respondent refused	105	11.02	17	4.28
5	Language barrier	23	2.41	-	-
6	Vacant housing unit	22	2.31	18	4.53
7	Not a housing unit	15	1.57	3	0.76
8	Mentally/physically incapable	15	1.57	3	0.76
	Number of sample housing units	953	100%	397	100.00[a]

[a]Total may not add to 100 percent due to rounding.

TABLE 9-3. INTERVIEW RESULTS

Result code	Result at the interview stage	Present study: Number	Present study: Percentage of enumerated housing units	Desvousges, Smith, and McGivney [1983]: Number	Desvousges, Smith, and McGivney [1983]: Percentage of enumerated housing units
20	Fully completed interviews	609	84.58	303	87.32
22	Partially completed interviews	3	0.42	2	0.58
23	Sample individual not at home	21	2.92	14	4.03
24	Sample individual refused	69	9.58	24	6.92
25	Language barrier	7	0.97	1	0.29
26	Mentally/physically incapable	11	1.53	3	0.86
	Enumerated housing units	720	100%	347	100.00

either too difficult or disconcerting that they failed to complete it. The refusal rate was a relatively modest 9.58 percent, which was also encouraging, indicating that respondents were not discouraged by the subject area. The remaining 39 cases consisted of incompletions because respondents were not at home or because the respondents had language barriers or physical or mental limitations.

The project team computed two different rates to express the results of the field data collection process: an enumeration rate and an interview rate. Each rate may be calculated in two ways, depending upon how eligibility for the survey is defined. In the strictest sense, ineligible housing units included only those that were occupied by persons who were temporarily absent for the study period, those that were vacant, or those that were discovered not to be housing units at all (for example, demolished or used as a business). In the less strict sense, ineligible housing units also included those that occupied by non-English-speaking persons or by persons who were physically or mentally incapable of providing meaningful responses.

In the strict sense, the enumeration rate was computed as follows: number of enumerated housing units divided by sample size minus result codes 3, 6, and 7:

$$\frac{720}{912} = 78.95 \text{ percent} .$$

In the strict sense, the interview rate among successfully enumerated housing units was computed as follows: number of completed interviews divided by number of enumerated housing units:

$$\frac{609}{720} = 84.5 \text{ percent} .$$

In the less strict sense, the enumeration rate was computed as follows: number of enumerated housing units divided by sample size minus result codes 3, 5, 6, 7 and 8:

$$\frac{720}{874} = 82.3 \text{ percent} .$$

In the less strict sense, the interview rate among successfully enumerated housing units was computed as follows: number of completed interviews divided by number of enumerated housing units minus result codes 25 and 26:

$$\frac{609}{702} = 86.75 \text{ percent} .$$

In summary, then, completed interviews were obtained from 66.78 percent of all eligible sampling housing units under the most conservative definitions. Under more generous but realistic assumptions, 71.46 percent of the sample housing units yielded completed interviews.

9.4.4 Comparison With Other Contingent Valuation Studies

This section compares the results of our fieldwork with those of two other contingent valuation studies--Desvousges, Smith, and McGivney [1983] and Mitchell and Carson [1984]. These studies were selected because they both elicited valuations of water quality changes, which we would expect to be an "easier" commodity for the respondent to understand, and because both provided sufficient documentation of the fieldwork--in their respective reports--to enable the comparison.

Table 9-2 summarizes the fieldwork results from the present study and from the Desvousges, Smith, and McGivney [1983] study. As shown in Table 9-2, the water quality study has substantially more (12 percent) successfully enumerated households than our study. The difference can be attributed to higher rates of "not at homes" and refusals in our present study. However, differences at the enumeration stage also likely reflect the difference in attitude toward household surveys in the two areas (Pittsburgh versus suburban Boston) or, more simply, the differences between the time periods--1981 versus 1984--during which the two studies were conducted. Finally, our interviewers did encounter more apartment buildings with limited access in the Boston area.*

For additional perspective on the final disposition of our sample, Table 9-4 gives the disposition of the national sample in the Mitchell-Carson [1984] survey of individuals' willingness to pay for improving the nation's water quality. In reaching their 1,042 eligible respondents, they encountered 409 indi-

*Conversations with interviewers also suggest that the Pittsburgh interviewers were very effective at using people's concern over water issues as a way of getting a foot in the door. Boston interviewers did not have any comparable comments about hazardous wastes. Alternatively, the suburban Boston residents had experienced several other surveys prior to our survey, including one on environmental issues. Area residents could simply have become weary with surveys.

TABLE 9-4. ENUMERATION RESULTS--MITCHELL-CARSON [1984]

Result at the household enumeration stage	Number	Percentage of sample
Successfully enumerated	1,042	51.20
No enumeration eligible home	454	22.31
Listing areas not assigned	33	1.62
Enumeration respondent refused[a]	383	18.82
Language barrier	26	1.28
Vacant housing unit	83	4.08
No information	14	0.69
Number of sample housing units	2,035	100.00%

Source: Mitchell and Carson [1984].

[a] Includes 27 respondents classified as too busy to give enumeration information.

viduals out of a total sample of 2,035 (20 percent) who either refused or were unable to complete the screening questions. In addition, 487 households were not contacted because no one was home when the interviewer called, and no information was obtained from 14 of the sample households due to administrative reasons. Summing these numbers gives a total of 993 households, or 48 percent of the total, that could not be screened for eligibility. By contrast, about 25 percent of our households did not provide enumeration information. Comparing refusals of enumerated households also shows that the field experience with the hazardous waste questionnaire was somewhat better. Specifically, Mitchell and Carson [1984] had a 16-percent refusal rate while this study experienced about a 10-percent refusal rate. However, differences in field procedures and in the survey designs account, at least in part, for these differences in field results. For example, in an attempt to improve our enumeration results, our procedures required a greater number of callbacks to complete the household numeration. In addition, while the Mitchell and Carson sample was drawn from households across the United States, our sample, as noted earlier, is taken from a much smaller geographic area. Finally, the limitations imposed on fieldwork procedures by the severe cost constraint in the Mitchell-Carson study should also be acknowledged.*

In summary, our field experiences with the hazardous waste questionnaire fare well when compared with those of two other recent contingent valuation studies. And, although the Desvousges, Smith, and McGivney water quality study did better in terms of enumerating households, our survey performed as well at the more critical interview stage. When compared to Mitchell and Carson's [1984] study, our present survey performed at least as well in both stages of the fieldwork.

Finally, the data on successfully enumerated households in Table 9-5 suggest several other illustrative comparisons. In particular, our survey compares very well with the earlier Desvousges, Smith, and McGivney study in both percentage of interviews completed and in the refusal rates. Both rates differed by less than 3 percent. Because the hazardous waste interview was

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*It should clearly be noted that these activities are costly. A budget constraint for survey activities often requires that enumeration rates be optimized subject to that constraint.

TABLE 9-5. INTERVIEW RESULTS--MITCHELL AND CARSON [1984]

Result at the interview stage	Number	Percentage of enumerated housing units
Fully completed interviews	813	78.02
Partially completed interviews	-	-
Sample individual not at home	33	3.17
Sample individual refused	171	16.41
Interviewed wrong respondent	11	1.06
Other	14	1.34
Enumerated housing units	1,042	100.00%

Source: Mitchell and Carson [1984].

longer and more complex, we would have expected larger differences in these two summary statistics if our respondents had experienced difficulty with the subject area.

9.4.5 Interviewer Debriefing

After the completion of the data collection,* the project team conducted a debriefing session with the field interviewers and the field supervisor. This session, which followed the precedent set in Desvousges, Smith, and McGivney [1983], proved informative. One of the most encouraging dimensions of the session was simply listening to the interviewers describe how they handled various questions that arose during their interviews. Without exception, the interviewers described solutions that were completely consistent with the goals and procedures for the survey. This was not self-serving behavior on their part because, frequently, the questions involved issues not explicitly covered in training. Their matter-of-fact delivery reinforced with concrete examples also suggested that their answers were rooted in experiences and not their imagination. This impression was shared by all members of the project team but was especially apparent to the team members who had not participated in the earlier training sessions.

In addition, the session yielded important information about the interviews, the questionnaire, and the training. This information ranged from general impressions to detailed suggestions for improvements. General impressions included the following:

- Even though it was not easy for some respondents, both versions of the questionnaire "worked." The interviewers expressed a slight preference for the ranking version as being easier to administer.

- The visual aids all contributed to the success of the interview. Respondents tended to use them extensively.

- Respondents frequently expressed genuine gratitude to the interviewers at the end of the interview, often indicating that they "had not thought about these things quite like that before."

- The interview needed more interaction with respondents.

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*Technically, about 1 week remained for collection activities.

- All the training activities were useful, but the practice interviews and the intensive debriefings really made a difference. (Interviewers were almost unaminous on this point.)

- Flipping through the visual aids in the job risk section was the most dreaded portion of the interview. The materials were too cumbersome. (This was noted in the pretest but the project team did not have time to make the extensive changes that would have been required to make it work easier.)

- The question asking for individuals to indicate a distance that would assure a risk reduction (#F4.b.) was probably the least reliable question.

Specific suggestions for improvement included the following:

- The colors on the risk ladder were a big plus. There were some questions about actual numbers, but most interviewers indicated that the ladder "usually worked" for purposes of this study.

- The introduction to the risk circles needed more pointing/interaction with respondents. Some respondents would have preferred shorter explanations, but many found the explanation helpful .

- A smaller cleanup slice was needed on first part of payment vehicle card. An additional reminder of product prices would also have been an improvement, though the card did help.

- The circumstances card helped respondents keep the hypothetical situation in mind.

- The presence of children in a family seemed to influence responses. (This was also noted with focus group participants.)

- There were not many bid revisions, and where revisions did take place they went both ways rather than one way or the other.

- In the ranking version of the questionnaire, people frequently mentioned having their budgets in mind. Respondents seemed to separate highest and lowest first and then pick between the other two.

- Respondents' values for the question on intrinsic values were in addition to their earlier bids.

- Some respondents disliked the property rights reversal in Section G of the questionnaire. Some may have had a hard time separating Section G from Section F.

- People genuinely liked the housing distance/risk reduction (Question H1.) Several respondents indicated that this was an "easier game to play."

- Respondents seemed to use metrics of 10 in answering distances question (H2). They felt the responses were more ordinal than cardinal.

- In the wage risk section, some respondents expressed fairly large dollar amounts that the interviewers thought were unrealistic.

- Card 1, which contained the list of common products and corresponding wastes, was the most effective card in the interview. (This was also noted in the review of videotape sessions and focus groups.)

9.5 SUMMARY

This chapter has highlighted the sampling procedures and the administration of the contingent valuation survey. The key points in the chapter can be summarized as follows:

- The sample design called for a two-stage, stratified, clustered sample of economic reporting units in the suburban area around Boston. The two primary geographic strata consisted of the town of Acton and the remainder of the suburban Boston area.

- The sample size of 953 housing units yielded 609 interviews--9 more than planned. The final sample was well distributed across the various versions of the questionnaire.

- The study rate, which includes enumeration and interview rates, was about 61 percent under conservative assumptions and about 71 percent under more realistic assumptions. The interview rate was very satisfactory, with almost 85 percent of enumerated housing units completing the 54-minute (average) questionnaire. Only three respondents broke off an interview after initiation.

- Certified mailing provided a cost-effective means of contacting difficult-to-reach respondents.

- Intensive interviewer training using in-person sessions, at home study, and practice interviews proved very successful. Interviewers strongly endorsed practice interviews supplemented by debriefing.

- The interviewer debriefing session yielded very encouraging information. Interviewers felt that the questionnaire worked and that the visual aids were effective. This session also provided pertinent suggestions for improving the questionnaire.

CHAPTER 10

PROFILE: THE SURVEY AREA AND ITS POPULATION

10.1 INTRODUCTION

While there has been a growing awareness among the general public of the potential environmental problems associated with the disposal of hazardous wastes, it is not clear what level of information on these problems has been acquired by the average household. Contamination incidents such as those that occurred in Love Canal, New York, in Times Beach, Missouri, and, most recently, in Bhopal, India, have clearly heightened the attention given both to the production processes involving hazardous substances and to the practices and procedures used for their disposal. However, from the perspective of the analysis of household behavior in these circumstances, it is fair to suggest that analysts do not have a full understanding of either the level of available information or the public's perception of the problem. Consequently, an important aspect of this chapter, which describes the features of the population in the area chosen for our contingent valuation study, is a discussion of the availability of information on hazardous wastes in the survey area and the perception of the risks of exposure to hazardous wastes in comparison to other risks faced by individual households in our sample. In addition to providing background for the results, this description also compares the features of our sample in relation to those of the overall population of the survey area.

Throughout our conceptual analysis to this point, hazardous waste disposal practices have been described as imposing both risks of exposure and risks of death, if exposure occurs. Regulating these disposal practices delivers a risk reduction to house. As a result, it is also important to understand the knowledge, perceptions, and attitudes toward risk. Therefore, this chapter also briefly highlights survey responses that are especially relevant to these issues.

10.2 GUIDE TO THE CHAPTER

Section 10.3 of this chapter provides a brief description of the geographic area for the survey, an explanation of how and why it was chosen, and a brief socioeconomic profile of the target and sample populations. To characterize the available information on hazardous wastes in general and the experiences of area households in particular, Section 10.4 briefly examines a series of incidents involving hazardous wastes in one survey-area town and reflects on the various reactions in the local population. Section 10.5 focuses on our sample and describes respondent knowledge, perceptions, attitudes, and personal actions concerning hazardous wastes. Finally, Section 10.6 concludes the chapter with a summary of its major points.

10.3 THE SURVEY AREA AND POPULATION

This section briefly describes the survey area and its population. In particular, after describing the geographic area--its character and its industrial development--the following subsections describe how and why the area was chosen and offers a brief socioeconomic profile of both the overall population in the survey area and our sample.

10.3.1 The Survey Area

The geographic area chosen for our contingent valuation survey was the greater Boston area--specifically, the Boston, Massachusetts, standard metropolitan statistical area (SMSA), exclusive of the City of Boston itself. As shown in Figure 10-1, this target geographical area consists of more than 100 smaller communities (i.e., towns) of varying distances from Boston and of varying population sizes. Many of these smaller communities have been absorbed by Boston as suburbs--i.e., they are without any recent major industrial, commercial, or residential development that is truly independent of the city, although many others are largely self-contained communities with their own industries. Irrespective of distinctions in the economic base, however, it should be acknowledged that many residents of these smaller communities commute to work in the Boston central business district.

Historically, New England, and especially Boston, have been noted for several traditional industries--fishing, merchant shipping, textiles, and the shoe industry. Due to a number of sociological and economic factors, however,

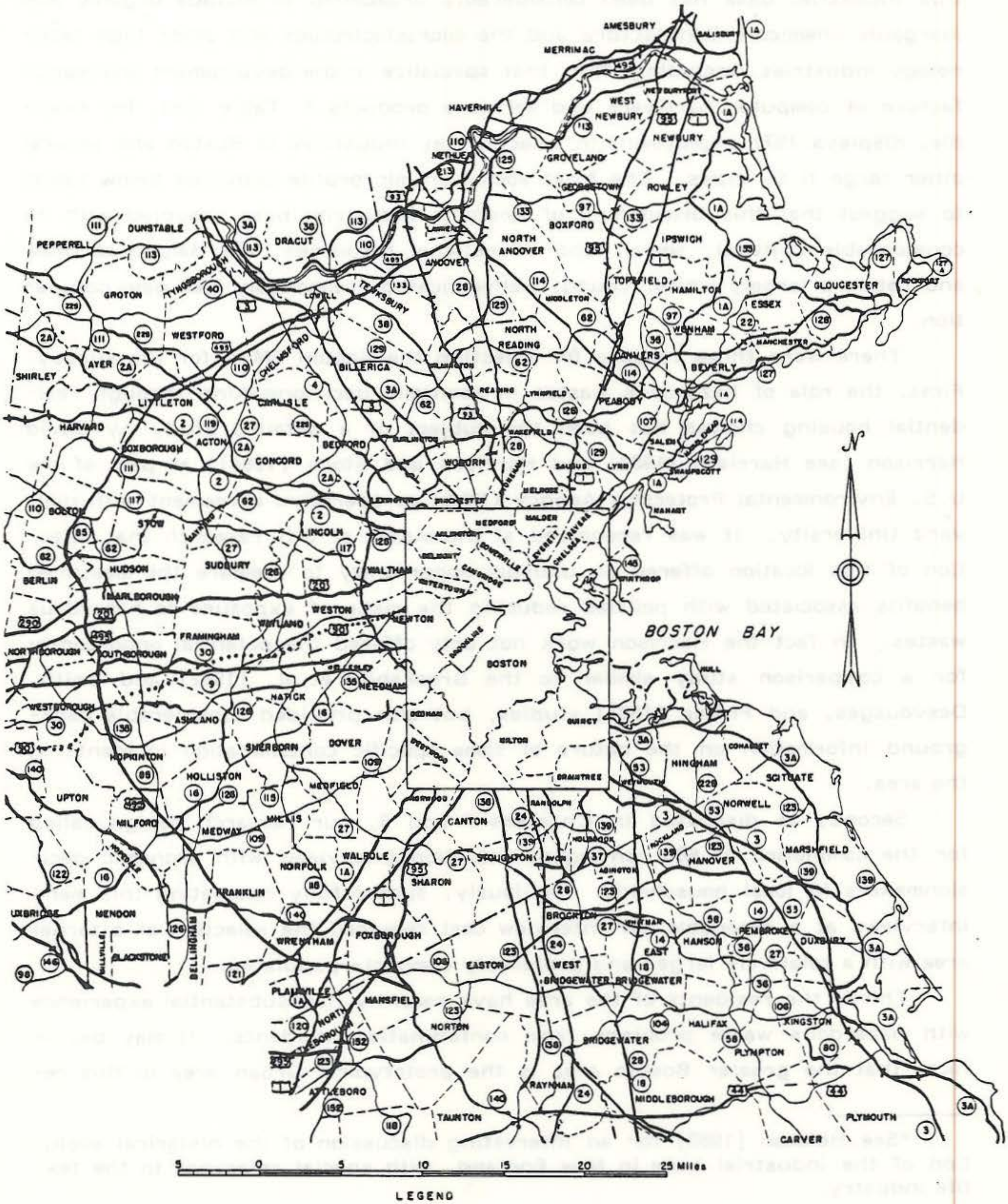

Figure 10-1. Survey area.

this industrial base has been considerably broadened to include organic and inorganic chemicals manufacture and the microelectronics and other high technology industries, including firms that specialize in the development and manufacture of computer hardware and software products.* Table 10-1, for example, displays 1977 employment in selected key industries in Boston and several other large U.S. cities. The brief socioeconomic profile provided below seems to suggest that this broadening of Boston's industrial base, coupled with its considerable cultural, social, and educational resources, has helped to draw and retain a largely white, young, well-educated, reasonably well paid population.

There were three reasons for selecting the Boston SMSA for the survey. First, the role of hazardous wastes in economic decisionmaking through residential housing choices has been the subject of a detailed study by David Harrison (see Harrison [1983] and Harrison and Stock [1984]) as part of the U.S. Environmental Protection Agency (EPA) co-operative agreement with Harvard University. It was recognized at the outset of this research that selection of this location offered an unusual opportunity to compare the measured benefits associated with policies reducing the risks of exposure to hazardous wastes. In fact the Harrison work not only offered the potential opportunity for a comparison study similar to the Brookshire et al. [1982] and Smith, Desvousges, and Fisher [1984] studies, but also provided considerable background information on the nature of some specific contamination incidents in the area.

Second, as discussed in Chapters 7 and 8, our research design called for the completion of 600 contingent valuation interviews with economic decisionmakers in local households. Obviously, successfully completing this many interviews at a resonable per-interview cost required the selection of a target area with a relatively large--and preferably compact--population.

Third, the residents of the area have recently had substantial experience with hazardous waste problems from contamination incidents. It may be, in fact, that the greater Boston area is the prototypical urban area in this re-

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*See Hekman [1980] for an interesting discussion of the historical evolution of the industrial base in New England, with special reference to the textile industry.

TABLE 10-1. COMPOSITION OF 1977 CIVILIAN LABOR FORCE FOR SELECTED U.S. CITIES

City	1977 Civilian labor force (percentage) Manufacturing	Wholesale and retail trade	Professional and related services
Atlanta	13.2	20.1	23.2
Boston	14.3	16.8	31.6
Chicago	26.6	18.6	20.1
Dallas	18.7	23.4	16.8
Los Angeles	23.0	19.9	20.1
New York	17.4	18.1	23.1
New Orleans	9.7	21.6	25.1
Philadelphia	20.9	19.2	24.5
San Francisco	10.3	19.9	23.0
Seattle	16.4	21.1	25.8
Washington, D.C.	4.5	11.7	27.8

Source: County and City Data Book, U.S. Department of Commerce, Washington, D.C., 1983.

spect. Its long and varied history of industrial development--particularly with manufacturing industries whose production processes generate hazardous waste byproducts--make it well suited for the study, especially since this long experience usually implies rather substantial and prolonged media coverage. Indeed, as indicated in Table 10-2, which summarizes news items taken from two Boston area newspapers, The Boston Globe and The Acton Beacon, several different communities in the greater Boston area have experienced major problems with hazardous waste management.

In summary, the greater Boston area was chosen as the location for this survey not only because it offered easy, cost-effective access to the numbers of respondents required by the experimental design, but also, and more importantly, because it offered the opportunity to develop a comparative analysis of alternative methods for measuring the values of hazardous waste policy and because it offered the chance to study an area whose residents have recently been forced to deal with the problems of hazardous wastes and who are therefore likely to be interested and well-informed on the problem. This last dimension is quite important to our study, since, as implied by the reference operating conditions proposed by Cummings, Brookshire, and Schulze [1984], familiarity and experience with the circumstances involved in contingent valuation experiments may well be quite important to the ability of the method to elicit reasonably accurate valuation estimates.*

10.3.2 Socioeconomic Profile

As noted earlier, the social, cultural, educational, industrial, and economic opportunities offered by Boston and its surrounding communities have attracted a fairly well paid, predominantly white, young, and fairly well-educated population. Based on the population information from the 1980 Census, Table 10-3 provides an economic and demographic comparison of the overall population and the sample we acquired. The two sets of descriptive statistics compare remarkably well because of the sample design. For example, based on 1984 dollars, the median income for the target population is $32,723; the medium income of the sample is only slightly lower, at $32,500. Similarly, the target

*This is especially important in our case because the commodity being valued is a risk change.

TABLE 10-2. NEWS SUMMARY: GREATER BOSTON AREA COMMUNITIES EXPERIENCING PROBLEMS WITH HAZARDOUS WASTES

Greater Boston community	Date	News item
Woburn	May 1979	State officials announce the discovery of 187 barrels of abandoned chemical wastes containing polyurethane resin.
East Woburn	May 1979	Two wells are shut down when tests reveal they have been contaminated with trichloroethylene.
Danvers	May 1979	Oil spill at Danvers State Hospital leaks 2,500 gallons of oil into brook.
Lowell	May 1979	Bankrupt owner of hazardous waste storage facility abandons 15,000 barrels containing several million gallons of chemicals. Fires and explosions ignite hundreds of barrels.
Kingston	March 1980	Several hundred barrels of abandoned toxic chemicals are discovered at rear of property by owner of trucking firm.
Sommerville	April 1980	Thousands of residents are affected by fumes from phosphorus trichloride spilled in a railway accident.
Salem	April 1980	State and local police raid a warehouse and confiscate 350 cardboard and steel drums containing illegally stored chemical wastes.
Canton	January 1981	State officials order removal of 40 barrels of polychlorinated biphenlys (PCBs) from farm site.
Lowell	February 1981	Based on complaints of fumes and noxious odors by residents, Federal, State, and local officials begin sampling wastes at a barrel and drum company.
Middleborough	July 1981	Junkyard owner found in contempt for failing to clean up 300 barrels of hazardous wastes buried on his property.
Woburn Ashland Tyngsborough	October 1981	Three Greater Boston communities appear on EPA list of 114 priority hazardous waste locations.
Acton Ashland Bridgewater Groveland Holbrook Lowell Plymouth Tyngsborough Westborough Woburn	December 1982	Ten greater Boston area communities appear on EPA list of the nation's most dangerous chemical dump sites.
Boxborough	May 1983	City officials seek source of Clapp well contamination, contemplating lawsuit.
Acton Boxborough Bedford	May 1983	State officials identify three communities whose drinking water supplies are susceptible to contamination from local hazardous wastes.

Source: The Boston Globe, Boston, Massachusetts, 1979-1983; The Acton Beacon, Acton, Massachusetts, 1979-1983.

TABLE 10-3. CHARACTERISTICS OF THE TARGET POPULATION AND THE SAMPLE

Characteristic	Target population[a]	Sample
Income		
Median	$32,723[b]	$32,500
Per capita	$11,447[b]	$12,185
Race		
Percent white	97.0	97.2
Age[c]		
Median years	39.4	42.5
Percent 65 years or over	12.0	17.2
Sex		
Percent male	46.6	39.2
Education[d]		
Median school year completed	12.9	14.0
Percent high school graduates	79.4	89.2
Percent college graduates	25.8	38.3
Family status		
Percent single[e]	32.6	35.9
Percent of households with children less than 18 years old	48.4	36.0
Persons per household	2.8	2.7
Mobility		
Percent living at the same address for the last 5 years	63.0	73.3
Labor force participation[e]		
Male	78.0	78.4
Female	54.2	63.3

Source: 1980 Census of Population and Housing, U.S. Department of Commerce, Bureau of the Census, Washington, D.C., 1982.

[a] The target population is defined as individuals within the Boston SMSA and outside the city of Boston. All values for the target population are derived from the 1980 Census of Population and Housing.

[b] These Census data values were converted from reported 1979 dollars to 1984 dollars using the GNP implicit price deflator.

[c] These populations include only those individuals more than 17 years old.

[d] These populations include only those individuals more than 25 years old.

[e] As the Census data uses include individuals more than 15 and the survey was administered to those 18 years or over, these populations are not identical.

and sample are primarily white and young: While the target population is 97 percent white, has a median age of 39.4 years, and is only 12 percent 65 years old and over, the sample is 97.2 percent white, has a slightly higher median age, 42.5 years, and is slightly more than 17 percent 65 years old and over. The largest discrepancy between the target and the sample arises in comparing sex composition. Both are less than 50 percent male, with the target population at 46.6 percent and the sample at 39.2 percent.

The target population and sample exhibit fairly high levels of education, though the sample is slightly more well educated. Specifically, while the target population has on average completed nearly 13 years of school and has graduated from high school more than 79 percent of the time and from college almost 26 percent of the time, the sample has on average completed 14 years of school and has graduated from high school almost 90 percent of the time and from college more than 38 percent of the time. The sample has slightly more single persons than the target population (35.9 versus 32.6 percent) and has fewer children less than 18 years old than the target population (36.0 versus 48.4 percent). Somewhat surprisingly in view of these other family status statistics, however, the sample and target population have virtually identical family sizes--2.7 and 2.8, respectively. Finally, the sample has been living at the same address longer than the target population (73.3 versus 63.0 percent, respectively) and has a greater number of female workers (63.3 versus 54.2 percent, respectively) in its labor force.

10.4 A SURVEY FOCUS: HAZARDOUS WASTES IN ACTON

The experimental design of our survey deliberately called for oversampling in a single community in the Boston SMSA--Acton, a small town of approximately 19,000 people about 45 minutes northwest of the City of Boston. The decision to oversample in Acton was made for several reasons. First, one component of the Harvard University study [Harrison, 1983; Harrison and Stock, 1984] mentioned earlier had already developed detailed analyses of the consequences of recent contamination incidents in Acton, including a risk assessment, an evaluation of household and community averting costs, and the application of an area-wide hedonic property value model. Thus, since an important objective of our study was to develop information that could enable a comparative analysis of estimates from a variety of benefits measurement approaches, we felt detailed contingent valuation estimates for Acton were necessary. Second, and equally important, the experience in Acton is itself quite interesting. As shown in Table 10-4, Acton has over a decade of experience with hazardous waste problems. It is therefore reasonable to expect that local households will have considerable familiarity with the issues encompassed by these kinds of problems. This prior knowledge should facilitate the process of communicating the contingent valuation questions. It has, as we have noted throughout the report, been argued to be an important factor in determining the plausibility of contingent valuation estimates in past studies (see Cummings, Brookshire, and Schulze [1984]).

Although Acton is in many respects primarily a bedroom community whose residents, predominantly professionals and skilled technicians, commute to work in Boston or in the high-technology companies that have sprung up in other larger communities around it, the town has experienced more serious environmental pollution and hazardous waste contamination incidents than most towns with considerably greater industrial development. In 1982, in fact, EPA listed Acton as the site of one of the nation's most dangerous chemical dump sites, and, in 1983, that dump was listed as one of 38 top priority sites eligible for cleanup under the "Superfund" Act.

Given Acton's small size and relatively modest industrial development, it is not surprising that its major environmental/hazardous wastes contamination problems are almost synonymous with those of its largest industrial resident--a large chemical firm that has operated a battery separator plant and variously manufactured organic chemicals, synthetic rubber, and plasticizers in Acton since 1945. Based on news items that appeared in the local newspaper, The Acton Beacon, Table 10-4 summarizes the history of major environmental and hazardous waste contamination incidents in Acton during the last 15 years.

As shown in Table 10-4, Acton experienced five major incidents involving hazardous and/or toxic substances during the past 15 years--all related directly or indirectly to operations at the chemicals plant.* The most important

*It should be noted that Acton has also experienced environmental pollution and hazardous waste contamination incidents that are not related to operations at the chemical plant. However, none of these had the impact of the five incidents listed in the table.

TABLE 10-4. SUMMARY OF MAJOR ENVIRONMENTAL POLLUTION AND HAZARDOUS WASTE CONTAMINATION EPISODES IN ACTON

Date	Contaminant	Description of incident(s)
1973 to 1978	Organic chemicals	Acton residents repeatedly complain of chemical odors, paint peeling from houses, and effects on vegetation. Local chemical plant institutes odor screening program in 1973 and extends it in 1974 and again in 1977. Company denies in 1978 that odors result from plant chemical emissions.
November-December 1978	Organic chemicals	Acton Water Supply District detects several organic chemicals in two municipal water supply wells and shuts them down immediately, decreasing the Acton municipal water supply by 35 to 40 percent.
August 1981	Styrene	Fumes leak from an underground storage tank at local chemical company, requiring an emergency evacuation of 100 Acton and 400 Concord residents.
August 1982	Oil	Oil (6,500 gallons) leaks from an underground storage tank at local chemical company, risking contamination of Sinking Pond Aquifer. Test wells show oil reaches depths of 14 to 40 feet.
January 1983	Hexane	Hexane (1,400 gallons) leak is discovered in an underground storage tank at local chemical company. Leak actually occurred in November 1982. Eventually, hexane dilutes oil spilled in earlier incident, further risking contamination of aquifer.

Source: The Acton Beacon, Acton, Massachusetts, 1973-1983.

of these incidents is the water supply contamination that occurred in November-December 1978, which involved the contamination of the water in two municipal wells that constituted 40 percent of Acton's water supply. A year-long hydrogeologic study in 1979 concluded that the aquifer supplying the two wells, the Sinking Pond Aquifer, had been contaminated by liquid wastes from two chemical company lagoons and a landfill located 2,500 to 3,000 feet north of the two municipal wells, Assabet No. 1 and No. 2. This study also identified a contamination plume with chlorinated hydrocarbon concentrations as high as 10,000 ppb within 1,000 feet of Assabet well No. 2.

While the loss of 40 percent of a municipal water supply is a serious disruption, the other long-term consequences of this major hazardous waste contamination incident may well prove to be more serious. Primary among these were the questions that quite naturally arose concerning the condition of the town's remaining water supply and its susceptibility to future contamination incidents. In addition, this incident raised questions as to the chemical company's ability to manage its operations--and its hazardous waste byproducts--in a manner that would ensure the health and safety of the citizens of Acton. Perhaps most important of all, the long-term implications of the potential health effects of exposure to the six contaminants identified in the two municipal wells are unclear. Table 10-5 lists these contaminants along with their potential health effects. Although no data have yet shown that any Acton resident has experienced any of these health effects as a direct result of the water supply contamination in 1978, the long latency periods associated especially with carcinogens leave the ultimate impact of the contamination incident an open question.

Several aspects of Acton's contamination incidents are especially relevant to the objectives of our research: (1) the sources and types of information provided on the first undertaking and three subsequent contamination episodes, (2) the nature and types of activities the citizens who responded to these incidents, and (3) the actions taken by local government in response to the problems posed by the incidents. It is difficult to reconstruct specific events that would answer all the questions related to these areas. However, in an effort to develop a better understanding of the events that surrounded these contamination episodes and how residents learned and responded, we undertook a

TABLE 10-5. CONTAMINANTS FOUND IN ACTON WATER SUPPLY AND THEIR POTENTIAL HEALTH EFFECTS

Contaminant	Potential health effect(s)
Trichloroethylene	Suspected carcinogen Neurological effects--dizziness, loss of appetite, loss of motor coordination Causes cell mutation and liver damage
Dichloroethane	Suspected carcinogen Central nervous system damage Liver damage Kidney damage
Dichloromethane	Central nervous system damage
Trichloromethane	Carcinogen Central nervous system damage Blood chemistry effects Kidney damage Liver damage Heart damage
Ethylbenzene	Suspected carcinogen
Benzene	Carcinogen Blood chemistry effects Fatigue Anorexia Central nervous system disorders

search of 6 years of news items reported in The Boston Globe and The Acton Beacon. Composed of summaries of these news items, Tables E-1 through E-3 in Appendix E present the results of our search by describing the chronology of events in three ways. Table E-1 describes the nature of the information available, specifically from October 1978 to May 1983; Table E-2 highlights this information as well as additional sources of the record of community responses to the incidents over the same approximate time span; and Table E-3 describes the actions taken by the local Acton town government. Because a substantial overlap among these three sets of information is almost inevitable, each dimension of these three interrelated issues is not discussed in detail. Rather, we summarize the most important elements that appear to characterize each.

Based on the summary information in Appendix E, it appears fair to conclude that the local news coverage was excellent. Indeed, the public had continual and immediate access to substantial amounts of political, technical, and other factual information concerning hazardous wastes in general and their water supply and other waste contamination problems in particular. In addition, the public had other important sources of public information, including the reports released after several hydrogeologic studies of the contaminated Sinking Pond Aquifer and the information assembled and dissiminated by various citizens groups, such as the Acton League of Women Voters (LWV). The availability of all these studies and other information sources was also reported in The Acton Beacon. The following summary lists the most important sources and types of public information available to Acton residents during the hazardous waste contamination controversy:

- Newspaper coverage--The Acton Beacon and The Boston Globe together covered the full range of events surrounding the contamination incidents in Acton as well as their implications for Acton and the larger greater Boston community. Particularly important is the appearance of a "water" column in The Acton Beacon to provide public information on water-related issues on a regular basis.

- Technical Reports--Several different studies by several different engineering consulting firms were commissioned by Acton, the chemical company, and others--all resulting it detailed technical information on the incidents and their implications.

- Public Meetings--Several different forums for public discussions existed during the incidents, including meetings of local concerned citizen groups and public meetings of the Acton Board of Selectmen (ABS) and others.

- Publications of Environmental Groups--Several different environmental groups--including the Audubon Society and the Sierra Club--published accounts of the incidents in Acton and their implications for the local citizenry and for hazardous waste management generally.

- Pamphlets--The Acton League of Women Voters published several pamphlets on the history of the incidents and on ways to cope with their effects.

Based, once again, on the new items summarized in Appendix E, the citizens of Acton reacted quickly to protect themselves and to monitor the actions being taken both by the chemical company and by the local government to address the problems posed by the contamination incidents. In particular, the Thoreau Group (a local Sierra Club chapter), the Acton Committee for Environmental Safety (ACES), the Metropolitan Area Planning Council (MAPC), the Acton League of Women Voters (LWV), the Water Land Management Advisory Committee (WLMAC), the Citizens Association for Preservation of the Environment (CAPE), the West Concord Citizens (WCC), the Concerned Citizens Coalition of Billerica (CCC), and numerous individual Acton citizens took the following specific actions:

- Speaking to each other and to town government officials (e.g., the ABS) about the planned chemicals company plant expansion and the contamination incidents.

- Submitting citizen petitions on contamination to the town government.

- Joining in on the suit filed against the chemical company by EPA and others.

- Gathering, organizing, and distributing information on contamination and mitigation strategies.

- Ensuring large turnouts at ABS meetings on contamination problems.

- Seeking reimbursement from chemical company of evacuation costs due to contamination.

- Questioning ABS on delays in chemical company actions to comply with the Consent Decree.
- Serving on the Technical Advisory Committee (TAC) appointed by ABS to review materials on contamination incidents.
- Supporting each other in position of mutual interest against the chemical company or ABS.
- Pressing for a "Hazardous Waste Day," during which hazardous household products could be collected.

Finally, also based on the news items summarized in Appendix E, the town government acted quickly and repeatedly to protect its citizenry and to address the problems posed by the contamination incidents. In particular, specific actions by the Acton Water Supply District (AWSD) and the Acton Board of Selectmen (ABS) include the following:

- Identifying the well contamination and its contaminants
- Closing the contaminated wells
- Demanding the chemical company fund a hydrogeologic study
- Controlling local water use through bans
- Investigating and reporting on mitigation strategies for the contamination
- Appropriating funds for technical studies by the town
- Filing suit against the chemical company
- Locating and tapping additional water supply sources from surrounding communities
- Inspecting the chemical company plant site and forcing it to comply with State and local requirements
- Meeting with and critiquing the action of Federal environmental protection personnel
- Meeting with and criticizing the actions of chemical company officials.

10.5 RESPONDENT KNOWLEDGE AND PERCEPTIONS OF HAZARDOUS WASTES AND THEIR RISKS

This section describes respondent knowledge, perceptions, and attitudes concerning hazardous wastes and the risk(s) associated with them. Specifically, it summarizes what respondents knew about hazardous wastes, how they had learned it, how serious they thought the problem was, how they perceived their risks from it in relation to other sources of environmental pollution, whether they had taken any action to try to mitigate that risk, and, finally, how effective they thought the government and other organizations were in dealing with the hazardous waste problem.

10.5.1 Respondent Knowledge

Tables 10-6, 10-7, and 10-8 describe how many respondents had recently read or heard about hazardous wastes in the media, the frequency with which they had read or heard about them, and the subject geographic area of the information they had read or heard about, respectively. As shown in Table 10-6, 551 respondents, 90.6 percent of the sample, had recently read or heard about hazardous wastes in the media, while only 57 respondents, or 9.4 percent, had not. In addition, although nearly 40 percent of the respondents did not know on how many occasions they had heard or read about hazardous wates, most did know. Table 10-7 summarizes these results, showing that 10 percent indicated a frequency of 1 time; 2 percent, 2 to 5 times; 29 percent, 6 to 10 times; and 20 percent, 11 times or more. As indicated in Table 10-8, most respondents, 74 percent, said that the geographical area associated with the hazardous waste information they had recently read or heard about was their own state; nearly 40 percent said it concerned their own town; and 67 percent said the information concerned the entire nation. Therefore, it appears that the survey respondents had almost invariably read or heard about hazardous wastes in the recent past; that most of the respondents had read or heard about them on 6 or more occasions; and that most of the respondents saw or heard about information concerning their own state or town.

10.5.2 Respondent Perceptions

This section summarizes how serious an environmental problem the survey respondents thought hazardous wastes were and how effective they thought various organizations--Federal, State, and local governments and other organizations--were in dealing with the problem. It should be noted that we elicited these ratings from the respondents by using a scale card that we explained should be used to provide a basis for scaling the issue addressed. Thus,

TABLE 10-6. NUMBER AND PERCENTAGE OF TOTAL RESPONDENTS WHO HAD RECENTLY READ OR HEARD ABOUT HAZARDOUS WASTES

Status	Respondents Number	Respondents Percent[a]
Had read or heard about hazardous wastes	551	90.6
Had not read or heard about hazardous wastes	57	9.4
"I don't know"[b]	4	-

[a]"Percent" column may not total 100 due to rounding.

[b]Respondents giving "I don't know" answers are excluded from the population from which percentages are calculated.

TABLE 10-7. FREQUENCY WITH WHICH RESPONDENTS HAD RECENTLY READ OR HEARD ABOUT HAZARDOUS WASTES

Frequency	Respondents Number	Respondents Percent[a]
1 time	57	9.6
2 to 5 times	12	2.0
6 to 10 times	171	28.7
11 times or more	119	20.0
Don't know how many times	236	39.6
No answer[b]	17	-

[a]"Percent" column may not total 100 due to rounding.

[b]Respondents giving "I don't know" answers are excluded from the population from which percentages are calculated.

TABLE 10-8. SUBJECT OF HAZARDOUS WASTE INFORMATION RECENTLY READ OR HEARD BY RESPONDENTS

Frequency	Respondents[a] Number	Percent
Respondent's town	244	39.9
Respondent's state	453	74.0
Entire nation	414	67.6

[a]Columns do not total because the "subjects" are not mutually exclusive--i.e., because the information read or heard by respondents could concern some combination, or all three, of the subject areas.

the numerical values reported in the following two subsections are intended to provide an index of the degree of harm associated with hazardous wastes or the degree of effectiveness of the governmental unit, respectively.

Severity of the Problem

Table 10-9 displays respondent ratings of the degree of harm posed by pollution from eight current environmental problems, including hazardous wastes. As shown in the table, respondent perceptions of the harm of the eight environmental problems is fairly evenly distributed, with a few important exceptions at each end of the scale of harm. Specifically, 79 percent, considered pollution from strip mining "not harmful," while 40 percent thought that pollution from nuclear and other radioactive wastes is "not harmful." However, perhaps because of their recent and, for the most part, frequent encounters with information on hazardous wastes, 18 percent of the respondents felt that pollution from hazardous waste is "very harmful." In addition, respondents clearly felt most pollution sources--e.g., sewage, nuclear wastes, acid rain, strip mining--are less harmful than hazardous wastes.

Especially interesting for our case and for the likely performance of contingent valuation questions involving the risks of exposure to hazardous wastes are the numbers of "I don't know" answers given by respondents for each of the eight pollution sources. In particular, as shown in Table 10-9, only 27 respondents did not know how to rate the relative harm of pollution from hazardous wastes, compared to 36 for sewage, 66 for nuclear wastes, 76 for acid rain, and 94 for strip mining. Only automobiles, manufacturing, and solid wastes had fewer "I don't know" answers than hazardous wastes. Given the detailed information that has been provided in this area over the past 6 years, this enhanced degree of knowledge concerning hazardous wastes is not surprising.

Organizational Effectiveness

Table 10-10 summarizes the respondent effectiveness ratings of six key types of organizations that have responsibilities for dealing with hazardous wastes, including Federal, State, and local governments, local water districts, and both waste-producing and waste-disposal firms. Based on this information, few respondents rated any of these organizations as "very effective." Local

TABLE 10-9. RESPONDENT HARMFULNESS RATINGS OF ENVIRONMENTAL POLLUTION SOURCES

Degree of harmfulness		Number and percentage of total respondents by pollution sources[a]															
		Automobiles		Manufacturing		Solid wastes		Sewage		Nuclear wastes		Hazardous wastes		Acid rain		Strip mining	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Not harmful	1	21	3.5	113	19.0	91	15.2	121	21.0	222	40.7	112	19.2	107	20.0	411	79.3
	2	31	5.1	60	10.1	84	14.0	62	10.8	78	14.3	49	8.4	26	4.9	29	5.6
	3	57	9.4	52	8.7	88	14.7	65	11.3	36	6.6	49	8.4	37	6.9	14	2.7
	4	64	10.6	45	7.6	62	10.3	55	9.6	25	4.6	35	6.0	40	7.5	9	1.7
	5	111	18.3	64	10.7	78	13.0	73	12.7	36	6.6	45	7.7	60	11.2	19	3.7
	6	67	11.1	49	8.2	56	9.3	43	7.5	13	2.4	42	7.2	40	7.5	10	1.9
	7	73	12.0	49	8.2	48	8.0	39	6.8	26	4.8	51	8.7	50	9.3	7	1.4
	8	70	11.6	52	8.7	43	7.2	47	8.2	19	3.5	58	9.9	61	11.4	10	1.9
	9	35	5.8	39	6.5	17	2.8	21	3.6	17	3.1	38	6.5	42	7.8	1	0.2
Very harmful	10	77	12.7	73	12.2	33	5.5	50	8.7	74	13.6	106	18.1	73	13.6	8	1.5
"I don't know"[b]		6	-	16	-	12	-	36	-	66	-	27	-	76	-	94	-

[a] "Percent" columns may not total 100 due to rounding.

[b] Respondents giving "I don't know" answers are excluded from the population from which percentages are calculated.

TABLE 10-10. RESPONDENT EFFECTIVENESS RATINGS OF ORGANIZATIONS THAT DEAL WITH HAZARDOUS WASTES

Degree of effectiveness		Number and percentage of total respondents by rated organization[a]											
		Federal government		State government		Local government		Local water district		Waste-generating firms		Waste-disposal firms	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Not effective	1	69	11.9	37	6.6	46	8.8	45	9.0	92	18.2	75	18.0
	2	59	10.2	51	9.0	35	6.7	24	4.8	83	16.4	57	13.7
	3	90	15.6	75	13.3	47	9.0	27	5.4	78	15.4	61	14.6
	4	87	15.1	84	14.9	52	9.9	34	6.8	65	12.9	49	11.8
	5	123	21.3	133	23.6	91	17.4	80	16.0	86	17.0	60	14.4
	6	59	10.2	71	12.6	42	8.0	44	8.8	35	6.9	36	8.6
	7	42	7.3	64	11.3	70	13.4	55	11.0	29	5.7	38	9.1
	8	34	5.9	31	5.5	76	14.5	89	17.7	22	4.4	20	4.8
	9	4	0.7	8	1.4	38	7.3	45	9.0	6	1.2	13	3.1
Very effective	10	11	1.9	10	1.8	27	5.2	59	11.8	9	1.8	8	1.9
"I don't know"[b]	-	34	-	48	-	88	-	110	-	107	-	195	-

[a] "Percent" columns may not total 100 due to rounding.

[b] Respondents giving "I don't know" answers are excluded from the population from which percentages are calculated.

water districts received the greatest number of high ratings (59 "very effective" ratings, or 11.8 percent of all respondents who rated the water districts), and four of the five remaining organizations are approximately comparable in their small number of "very effective" ratings (between 8 and 10, for 1.8 to 1.9 percent of all respondents who rated those organizations). On the other hand, few respondents (from 7 to 11 percent) rated any of the organizations as "not effective," although approximately twice as many (about 18 percent) rated waste-generating and waste-disposal firms as "not effective." Respondents gave ratings of five on the effectivness scale of 1 to 10 more often than any other rating for all the organizations but one--local water districts. Consistent with the "very effective" rating results reported earlier, respondents who rated the local water districts gave them more ratings of 8 on the scale of 1 to 10 than any other rating and also gave them more ratings of 6 and higher.

It is also interesting to note the varying numbers of respondents who answered "I don't know" in response to the request to rate each of the six types of organizations. For example, 34 respondents declined to rate the effectiveness of the Federal government, 48 declined to rate their State government, 88 declined to rate their local government, 110 declined to rate their local water district, 107 declined to rate waste-generating firms, and 195 declined to rate waste disposal firms.

10.5.3 Respondent Awareness of Risk

Focusing on comparisons of annual risks of death from a variety of sources, on the levels of risk associated with various hazardous waste exposure pathways, and on specific likely causes of death, this section summarizes the extent to which respondents were aware of their actual risks of exposure to hazardous wastes and the health effects that might be associated with that exposure.

Annual Risks of Death

Table 10-11 reports how respondents' perceptions of their annual risk of death from exposure to hazardous wastes compare to their annual risks of death as a result of an automobile accident, heart disease, and exposure to air pollution. These data were collected from the respondents using a risk ladder that

TABLE 10-11. RESPONDENT-RELATED ANNUAL RISKS OF DEATH FROM SELECTED CAUSES USING RISK LADDER

Annual risk of death		Number and percentage of total respondents by cause of death[a]							
		Automobile accident		Heart disease		Air pollution		Hazardous wastes	
Anchor from risk ladder	Chance of death in 100,000	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Flood	0.05	53	8.8	159	26.2	223	36.9	191	31.7
Poisoning	0.6	40	6.6	99	16.3	120	19.9	123	20.4
Airplane	0.8	56	9.3	60	9.9	56	9.2	57	9.5
Home fire	2.8	72	11.9	54	8.9	54	8.9	55	9.1
Insurance agent	4.0	46	7.6	33	5.4	32	5.3	40	6.6
Banker	6.0	42	7.0	25	4.1	27	4.5	41	6.8
Home accident	11.0	92	15.2	22	3.6	22	3.6	24	4.0
Diabetes	15.1	32	5.3	17	2.8	10	1.7	15	2.5
Police	22.0	28	4.6	14	2.3	12	2.0	5	0.8
Homebuilder	47.0	49	8.1	17	2.8	16	2.6	17	2.8
Stroke	77.0	29	4.8	65	10.7	8	1.3	11	1.8
Truckdriver	99.0	39	6.5	11	1.8	9	1.5	12	2.0
Skydiver	200.0	11	1.8	3	0.5	0	0.0	1	0.2
Smoker	300.0	7	1.2	21	3.5	12	2.0	9	1.5
Stuntman	2,000.0	8	1.3	7	1.2	3	0.5	2	0.3
"I don't know"[b]	-	8	-	5	-	8	-	9	-

[a] "Percent" columns may not total 100 due to rounding.

[b] Respondents giving "I don't know" answers are excluded from the population from which percentages are calculated.

was developed in the focus group sessions (see Chapter 8). Figure 10-2 presents the ladder.*

In general, respondents who did not decline to answer the questions rated their chances of dying from hazardous waste exposure as considerably more remote than that of dying as a result of heart disease or of an automobile accident.† Almost 32 percent (191) of the respondents selected the most remote possibility--0.05 chance in 100,000 (the same as the chance everyone faces of dying in a flood)--as their own risk of dying during the next year as a result of exposure to hazardous wastes. Only air pollution was selected by more respondents--223, or approximately 37 percent--as the most remote cause of death possible. Also as shown in the table, another 123 respondents (a little more than 20 percent) selected the second most remote possibility--0.6 chance in 100,000 (the same as the chance everyone faces of dying of poisoning)--as their risk of dying doing the next year as a result of exposure to hazardous wastes. Approximately the same number of respondents--120, or nearly 20 percent--chose air pollution exposure as the second most remote cause of death possible.

In contrast to the annual risk results for hazardous waste exposure, many fewer respondents considered their chances of dying as a result of an automobile accident or as a result of heart disease so remote. Only 53 respondents (or not quite 9 percent) selected the most unlikely possibility (0.05 chance in 100,000) as their annual chance of dying as a result of an automobile accident.

<u>Exposure Risks by Exposure Pathway</u>

Table 10-12 summarizes respondent perceptions of the various levels of their risk of exposure to hazardous wastes for five different exposure pathways--drinking water, breathing air, touching soil, eating food, and eating fish (from contaminated waters). The respondents generally felt themselves more at risk for hazardous waste exposure through drinking water, breathing air, and eating fish than through touching soil or eating foods other than fish.

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*The actual form of the ladder used in the interviews identified the segments of the ladder with different colors.

†A small number of respondents declined to rate their risk of dying in each category.

Card 5

Risk Ladder: Comparing Annual Risks of Death

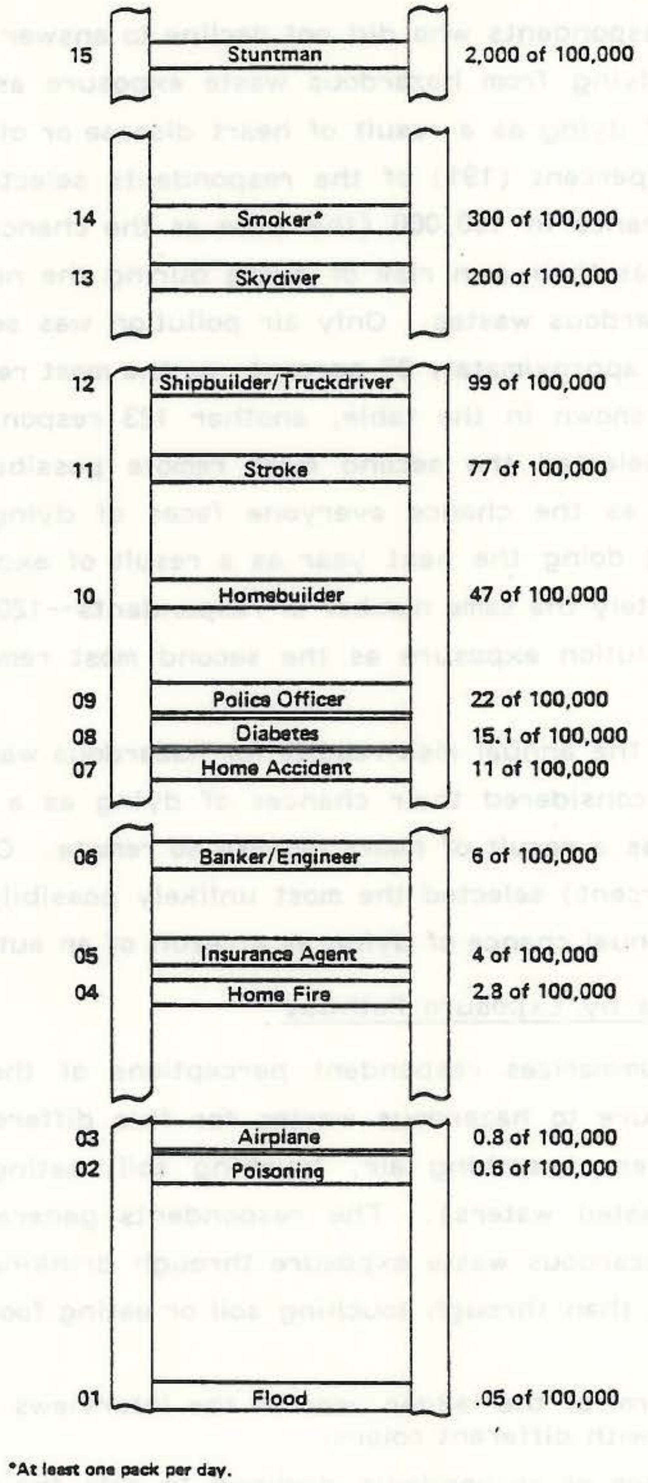

Figure 10-2. Final version of risk ladder incorporating suggestions from participants.

TABLE 10-12. RESPONDENT-RATED CHANGES OF EXPOSURE THROUGH TYPICAL EXPOSURE PATHWAYS

Chance of exposure		Number and percentage of total respondents by exposure pathway[a]									
		Drinking water		Breathing air		Touching soil		Eating food		Eating fish	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
No chance at all	1	116	19.4	50	8.2	190	31.9	80	13.5	74	12.3
	2	61	10.1	48	7.9	105	17.6	54	9.1	39	6.5
	3	49	8.2	57	9.4	73	12.3	52	8.8	37	6.2
	4	41	6.8	46	7.6	42	7.1	47	7.9	38	6.3
	5	55	9.2	85	14.0	58	9.7	90	15.2	81	13.5
	6	33	5.5	38	6.3	29	4.9	51	8.6	49	8.2
	7	19	3.2	47	7.7	33	5.6	41	6.9	49	8.2
	8	55	9.2	63	10.4	17	2.9	62	10.5	85	14.2
	9	29	4.8	30	4.9	7	1.2	27	4.6	33	5.5
Certain exposure	10	141	23.5	144	23.7	41	6.9	88	14.9	115	19.2
"I don't know"[b]	-	13	-	4	-	17	-	20	-	12	-

[a] "Number" columns exclude respondents who answered "I don't know." "Percent" columns may not total 100 due to rounding.

[b] Respondents giving "I don't know" answers are excluded from the population from which percentages are calculated.

Indeed, 141 respondents, or more than 23 percent, felt that they risked "certain exposure" through drinking water; 144 respondents (nearly 24 percent) felt they risked certain exposure through breathing air; and 115 respondents (or more than 19 percent) felt they risked certain exposure through eating contaminated fish.

The varying numbers of respondents who answered "I don't know" may indicate their knowledge of the various exposure pathways, or at least their level of confidence in their knowledge. For example, that fewer respondents declined to rate their exposure risk for drinking water, breathing air, and eating fish (13, 4, and 12, respectively) than declined to rate their exposure risk for touching soil (17) or eating food (20).

Likely Causes of Death From Exposure

Table 10-13 summarizes the causes of death that respondents had in mind when they responded to the contingent valuation questions for reductions in their risks of exposure to hazardous wastes. As shown in the table, most respondents (nearly 54 percent) indicated that they had no specific cause of death in mind. However, of the remaining respondents, 226 indicated that they believed cancer to be the health effect that would result from exposure, and 27 indicated they had either lung disease or leukemia in mind. These findings, together with the fact that only 14 respondents answered "I don't know," indicate that a large number of respondents (nearly half) had definite ideas about the potential health effects of hazardous waste exposure when they responded to the valuation questions associated with reducing their exposure risks.

10.5.4 Respondent Actions to Reduce Risks

Finally, Tables 10-14, 10-15, 10-16, and 10-17 provide a summary of several types of respondent action to reduce their risk of exposure to hazardous wastes. Table 10-14 provides a kind of overview of the then current respondent actions. Only 1 respondent (0.2 percent of the total surveyed population) was taking no action whatsoever. However, 41 respondents (nearly 7 percent) were using water filters; 175 (or nearly 29 percent) were using bottled water; and 48 (or nearly 8 percent) were attending public meetings. Table 10-15 reports total respondent expenditures for water filters during the last 5 years.

TABLE 10-13. NUMBER AND PERCENTAGE OF TOTAL RESPONDENTS WITH PARTICULAR CAUSE OF DEATH IN MIND, FOR WILLINGNESS-TO-PAY BID

Cause of death	Number and percentage of total respondents	
	Number	Percent[a]
None	321	53.7
Cancer	226	37.8
Lung disease	10	1.7
Lukemia	17	2.8
Poisoning	4	0.7
All others	20	3.3
"I don't know"[b]	14	-

[a] "Percent" column may not total 100 due to rounding.

[b] Respondents giving "I don't know" answers are excluded from the population from which percentages are calculated.

TABLE 10-14. CURRENT RESPONDENT ACTIONS TO REDUCE RISK OF EXPOSURE TO HAZARDOUS WASTES

Action	Number and percentage of total respondents	
	Number	Percent
None	1	0.2
Using water filters	41	6.7
Using bottled water	175	28.6
Attending public meetings	48	7.8

TABLE 10-15. TOTAL RESPONDENT EXPENDITURES ON WATER FILTERS DURING LAST 5 YEARS

	Number and percentage of respondents who bought water filters	
Amount, $	Number	Percent[a]
4 to 10	6	16.2
11 to 20	8	22.0
21 to 30	13	35.1
31 to 40	4	10.9
41 to 100	4	10.9
101 to 300	0	0
301 to 500	2	5.4

[a]"Percent" column may not total 100 due to rounding.

TABLE 10-16. TOTAL RESPONDENT EXPENDITURES ON BOTTLED WATER DURING LAST 5 YEARS

	Number and percentage of respondents who bought bottled water	
Amount, $	Number	Percent[a]
0.10 to 10	43	23.2
11 to 30	27	14.6
31 to 70	30	16.2
71 to 160	30	16.2
161 to 300	20	10.8
301 to 500	15	8.1
501 to 750	6	3.2
751 to 1,000	8	4.3
1,001 to 3,000	4	2.2
3,001 to 10,000	2	1.1

[a]"Percent" column may not total 100 due to rounding.

TABLE 10-17. TOTAL PUBLIC MEETINGS ATTENDED BY RESPONDENTS DURING LAST 5 YEARS

	Number and percentage of respondents who attended public meetings	
Number of meetings	Number	Percent[a]
1 to 2	26	36.6
3 to 5	21	29.6
6 to 10	11	15.5
11 to 15	9	12.7
16 to 25	1	1.4
26 to 50	1	1.4
300	1	1.4
500	1	1.4

[a] "Percent" column may not total 100 due to rounding.

As shown, the 41 respondents who used water filters spent between $4 to $500 on water filters during the 5-year period, although most spent a total of less than $30. Table 10-16 summarizes total respondent expenditures for bottled water during the last 5 years. The 175 respondents who used bottled water spent between $0.10 to $10,000 on bottled water, although 80 percent spent a total of less than $300.00.* Finally, Table 10-17 reports the total number of public meetings attended by respondents during the last 5 years. The 48 respondents who attended public meetings to learn more about hazardous wastes attended a total of anywhere from 1 to 500 meetings during the last 5 years, though most respondents attended only 5 meetings or fewer. Here too, there appears to be a few implausible responses. For example, two respondents indicated that they had each attended 300 town meetings during the past 5 years--an average of 100 meetings per year, or about one meeting every 3.5 days.

10.6 SUMMARY

This chapter has described a diverse array of background material important to the interpretation of our contingent valuation estimates for household valuations for risk reductions. Four general themes that emerge from this overview. First, the economic and demographic characteristics of our sample respondents closely parallel those of the target population. Second, the residents of the Boston SMSA have had substantial experience with incidents involving hazardous wastes. As a result, there has been nearly continuous coverage of issues associated with hazardous wastes in the Boston Globe and several local newspapers. There are several external indications of citizen concern and involvement with the problem. In addition, the local governments in the area have also had to deal with contamination episodes. As a consequence, citizens have a performance record on which to base their expectations of government involvement in any future incidents.

Based on both of these considerations we would expect that the circumstances described in our contingent valuation question would be familiar. They were structured, in part, based on experiences in this area. Respondents can be expected to have had the equivalent of valuation experience as a result

*The upper end of the range seems rather implausible and does not, as the table indicates, involve many respondents.

of these past episodes and the respective roles of town government and citizen groups.

Third, our review of the actual information of our survey respondents confirms what was expected based on the record. On the whole, they do appear to be aware of the problem. Their perception of the risks involved do not appear to be irrational responses to these incidents. Rather, their perception of relative risks seems quite sensible. This is not to suggest that the risk of exposure is not regarded as a serious problem. Rather, it indicates that we have not selected a case where a set of frenzied or irrational responses to recent contamination incidents would condition all responses to the contingent valuation questions.

Finally, residents have themselves undertaken tangible actions and expenditures that should also provide a basis for gauging their respective valuations for risk changes associated with regulations governing the disposal of hazardous wastes.

While much of this information has been informal, it is also quite consistent in its message. The degree of familiarity with the problem and past experience with contamination incidents serve to aid in satisfying the conditions we expected would need to be satisfied for the development of plausible valuation estimates involving risk reductions within a contingent valuation framework.

PART III

PRELIMINARY EMPIRICAL ANALYSIS

PART III

PRELIMINARY EMPIRICAL ANALYSIS

Part III of this draft interim report consists of six chapters that describe the preliminary findings of the empirical analysis of the contingent valuation survey data for individual's values of changes in hazardous waste risks. Part III consists of the following six chapters:

- Chapter 11 - Option Price Results: The Framing of the Commodity and an Analysis of Means
- Chapter 12 - Option Price Results: Preliminary Regression Analyses Using Unrestricted Models
- Chapter 13 - Valuation Estimates for Risk Reductions: Using Restricted Models
- Chapter 14 - The Use of Contingent Ranking Models to Value Exposure Risk Reductions: Preliminary Results
- Chapter 15 - A Comparison of Contingent Valuation and Hedonic Property Value Models for Risk Avoidance
- Chapter 16 - Policy Implications and Research Agenda

The objective of this part of the report is to summarize the status of the empirical results at the end of the first phase of the research effort. It should not be interpreted as completed empirical analyses. The findings are suggestive but require further analysis before they will be regarded as final. Indeed, based on the work to date, it seems clear that we have only begun to scratch the surface of the complex issues involved in our research plan.

Some examples of the empirical issues may help to illustrate the preliminary nature of our analysis. The treatment of "outliers" is probably the most illustrative case. In our previous work, we have emphasized the importance of the treatment of "outliers," or influential observations. Use of regression diagnostics and judgments about thresholds for influential observations, we suggested that it was possible to identify outliers in a more systematic way. In this earlier research we expected a relationship between the contingent valuation bids and income. In the present effort the issues are much less clear-cut. Both theoretical and econometric problems must be resolved before considering the treatment of outliers in a final set of models. This problem is addressed in Chapter 13.

Equally important, our design provides an alternative basis for dealing with any survey respondent's incomplete understanding or acceptance of the contingent valuation framework. It is possible to estimate the variance in the error associated with each individual's valuation response in relation to the models used to explain marginal valuations for risk. Using generalized least-squares procedures, differences among individuals are explicitly taken into account. The models with this adjustment differ from the unadjusted models. Thus, our treatment of outliers is incomplete in this report. It also implies that our mean values presented in Chapter 11 are presented with "outliers" included because these responses are not yet identified. Clearly, as suggested in Chapter 13, this is a crucial area needing more research.

Several other chapters are preliminary for different reasons. For example, Chapter 12, which presents some preliminary regression results using unrestricted models, contains no adjustments for outliers or unequal variances. In addition, some variable specifications attempted in this chapter, and found unfruitful, have not been attempted in the more robust restricted models presented in Chapter 13 due to time limitations. Clearly, this is another issue for additional consideration.

In addition, the focus of the contingent ranking analysis presented in Chapter 14 is directed toward attempting to understand exactly how the respondents reacted to the ranking task. In this regard, it explores several new dimensions of contingent ranking to evaluate the effect of the four versions in the ranking research design on how people processed the information provided. However, the models used in this specification testing to provide preliminary benefits estimates are somewhat ad hoc. There is an obvious need to evaluate models using more theoretical considerations. This is another area for further research.

The comparative analysis in Chapter 15 is preliminary for a somewhat different set of reasons. The most important of which is the preliminary nature of the models estimated with our survey response and the analysis of the property value data performed by David Harrison. Clearly, more detailed analysis will be required before any final judgments will be possible on the performance of contingent valuation compared to the hedonic property value model.

The empirical analysis is organized within a specific framework. The first three chapters--Chapters 11, 12, and 13--form one specific body of analysis. Chapter 11 begins the investigation of the survey data under the assumption that survey respondents are homogeneous. It describes the framing of the contingent commodity, changes in hazardous waste risks, and then examines the responses classified as "protest" bidders throughout the remainder of the report. The remainder of the chapter examines many of the key features of our research design--levels of risk, the role of the conditional risk, the assignment of property rights, the certainty effect and intrinsic values--by using tests for mean responses and analysis of variance procedures.

Chapter 12, the second empirical chapter, relaxes the assumption that individuals are homogeneous in their response to risk changes. It uses multivariate regression techniques which specifically examine the influence of individuals' characteristics on the responses to the design issues. However, this chapter is primarily exploratory in nature. It provides some preliminary insights about the effect of different variable specifications. Since the results of this chapter were somewhat discouraging, they suggested the need for adding more theoretical structure to the analysis.

Chapter 13 is the most detailed empirical chapter. It interprets the option price bids as providing information for deriving point estimates of the individuals' marginal valuations of a risk change. In other words, it approaches the analysis of the bids from the perspective of the incremental value for an incremental change in the risk of exposure to hazardous wastes. This chapter also addresses the nature of the distribution of bids and the treatment of outliers and provides some generalized least-squares estimates that adjust for the substantial differences in the estimated variances among individual respondents.

Chapter 14 is the second unit of empirical research. It follows the same logical structure developed with the analysis of the contingent valuation bids. Ranks were first analyzed as if respondents' characteristics had no effect on how they responded to the combinations of risk and payment presented to them. This assumption was relaxed and the rank-logit maximum likelihood model used to estimate random utility functions. Finally, these estimated models were then used to estimate their implied valuations for risk changes and to develop a preliminary comparison with the contingent valuation results.

Chapter 15 summarizes the comparison between Harrison's hedonic property value model and the position of the survey devoted to developing comparable information. It is also preliminary because the hedonic model used was an early version of the Harrison models and because further consideration will need to be given to the assumptions used in developing the comparison.

Finally, Chapter 16 offers some discussion of the implications of these very preliminary analyses and begins the process of outlining an agenda for further research.

CHAPTER 11

OPTION PRICE RESULTS: THE FRAMING OF THE COMMODITY AND AN ANALYSIS OF MEANS

11.1 INTRODUCTION

This chapter, the first of five empirical chapters, describes our preliminary empirical analysis of the features of the valuation responses. Before presenting these results we highlight the role that framing plays in contingent valuation and describing how the contingent commodity was framed in our study.

Framing, or the process of describing the contingent commodity in a questionnaire, is always an important part of a contingent valuation analysis. In our case it is especially important because the commodity we describe to each respondent is a reduction in the risk of exposure to hazardous wastes. And ultimately, many of the inferences that will be drawn from our research will depend on this framing of the commodity. However, our framing discussion is not an exhaustive synthesis of the literature. Rather, it draws on the existing literature only to the extent it is necessary to provide the rationale behind the framing of our contingent commodity.

The empirical analysis presented in this chapter has several dimensions. First, it describes our evaluation of the sample respondents who refused to participate in the valuation of the contingent commodity, usually termed "protest bidders." This evaluation includes a description of the procedure used to identify these respondents, a profile of their characteristics, and the effect of our research design. This evaluation is important because it affects the subsequent analyses of the valuation responses. Second, it considers the user and intrinsic values that have been elicited in the survey. To aid the presentation of our user and intrinsic value results, we describe the valuation responses for each of a set of questions individually. The first set summarizes our preliminary empirical results for user values measured as incremental option price bids for risk decreases. Following these findings, the chapter describes the effect on option price bids of alternative property rights, certainty as a risk endpoint, and alternative risk outcomes. Finally, the chapter presents estimates for intrinsic values which are viewed as incremental option price bids for reduced risks to the ecosystem.

11.2 GUIDE TO THE CHAPTER

Section 11.3 presents a preliminary classification of potential biases that can arise from framing the contingent commodity. Section 11.4 describes specifically the process of framing our contingent commodity--changes in the risk of exposure to hazardous wastes. It addresses the development of the context, character, and the question format to elicit individuals' values. Section 11.5 explains our procedure for classifying protest bids, examines the potential determinants of the likelihood of someone being classified a protest bidder, and compares our results with those of another recent contingent valuation study. Section 11.6 presents the mean option price bids for reductions in hazardous waste risk and analyzes the influence on those bids of the initial levels of risk and the conditional risk--two key elements in our research design. Section 11.7 presents the mean option price bids for avoiding an increase in the risk of exposure to hazardous wastes and examines the influence of risk levels, the conditional risk, and the assignment of property rights on these bids. It also compares the mean bid for avoiding a risk increase with those for obtaining a risk decrease. Section 11.8 describes the summary results for a reduction in the risk of exposure to zero. Section 11.9 considers the effect of changing the outcome at risk on the mean option price bids for a decrease in risk. Section 11.10 presents our estimated mean values for intrinsic benefits. Section 11.11 concludes the chapter with an overall summary of its principal findings.

11.3 FRAMING AND CONTINGENT VALUATION

The objective of this section is to provide an interpretive and selective overview of the literature on the role of framing in a contingent valuation analysis. The Cummings, Brookshire, and Schulze [1984] state-of-the-art assessment, along with research by Mitchell and Carson [1984] and Bishop and Heberlein [1984], have reconsidered and, as a consequence, revised the previous conclusions concerning contingent valuation. However, this new research

I. Conventional Classification

A. General Biases
- Strategic
- Information
- Hypothetical

B. Instrument Related Biases
- Starting point
- Payment vehicle

C. Procedural Biases
- Sampling
- Interviewer

II. Mitchell-Carson Classification

A. Incentives to Misrepresent Responses
- Strategic bias
- Compliance bias
  - — Sponsor bias
  - — Interviewer bias

B. Multiple Valuation
- Vehicle bias
- Method of provision bias

C. Implied Value Cues
- Starting point bias
- Range restriction bias
- Yea-saying bias
- Relational bias

D. Misspecification of Market Scenario
- Vehicle misspecification
- Budget constraint misspecification
- Amenity misspecification
- Probability of provision misspecification
- Context misspecification

E. Aggregation Bias
- Sampling design bias
- Nonresponse bias
- Item nonresponse bias
- Sequence bias

III. Post Palo Alto Classification

A. Framing Biases
- Situation or context
  - — Interview situation
  - — Mental image
  - — Strategic effects
- Commodity specification
  - — Perceptions
  - — Property rights
  - — Implied linkage to behavioral activities
- Elicitation
  - — Question format
  - — Payment vehicle
  - — Sequence

B. Procedural Biases
- Sampling and nonresponses
- Interviewer

Figure 11-1. Classifications of potential biases in contingent valuation.

of the contingent commodity itself. Arrow [1984] suggests that information "bias" is not a bias at all. It could imply explaining the commodity to be valued in greater detail to make the entire contingent valuation exercise more realistic. Our classification endorses this view by emphasizing the importance of context and commodity specification under the framing umbrella. These two facets of the contingent valuation method provide a more tangible notion of the potential effects of information on the elicitation of people's values. This position on information bias is also consistent with the conclusion of the state-of-the-art assessment for contingent valuation (see Cummings, Brookshire, and Schulze [1984]).

For example, they observed that:

> The information bias rubic seems to serve no useful purpose for assessments of CVM [contingent valuation method]; indeed, it may be counter productive. [p. 253]

By eliminating hypothetical bias from the revised classification, the revised taxonomy accepts the position of Mitchell and Carson [1984].

> We conclude that hypothetical bias is a misnomer since there is no one bias which uniquely results from the hypothetical character of CV surveys. The hypothetical character of a CV survey may make it vulnerable to one or more biases and/or it may affect the reliability of its findings. [p. 43].

However, they are not alone in this conclusion. Arrow [1984] also has noted there is nothing inherently wrong with the hypothetical character of contingent valuation. To support this view, he cited the number of new products that are introduced each year that likely were evaluated for the market by potential consumers when they involved hypothetical elements. Yet, Arrow does add caution about drawing conclusions solely from contingent valuation. That is, without the discipline provided by "real" payments for commodities, there is potential for inaccuracy. This point is also consistent with Bishop and Heberlein [1984] who argue that their simulated market experiments provide better estimates of value because actual cash transactions are involved.

However, Mitchell and Carson [1984] in their reinterpretations of both the early Bishop-Heberlein [1979] study and the Bohm [1971] study, challenge the position that actual cash transactions are necessary for eliciting "accurate" estimates of willingness to pay. Cummings, Brookshire, and Schulze [1984] concur with the Mitchell-Carson view by citing the experimental results of Vernon Smith and the results of various comparisons as providing additional evidence of the accuracy of contingent valuation for public goods that satisfy their reference operating conditions. Unfortunately, as both Smith [1984c] and Freeman [1984b] have observed, these conditions are usually satisfied when one would be least likely to need contingent valuation.

Therefore, our conclusion is that treating the hypothetical character of contingent valuation as a "bias" is confusing. Instead, it is both the strength of the approach and its greatest weakness. Because it can be based on hypothetical commodities and circumstances, contingent valuation offers a wide range of possibilities for addressing many different problems. In effect, it is a malleable approach that can be shaped to meet the needs of the problem at hand. Yet, this malleability and its basically hypothetical character expose contingent valuation to the pitfalls associated with describing the hypothetical situation (whether commodity or circumstances governing the provision of a known commodity) in sufficient detail to make it tangible and believable for respondents to a contingent valuation survey. Unfortunately, the existing body of research is inadequate for obtaining a definitive answer to questions raised by the hypothetical character of contingent valuation. Nevertheless, this does not imply it should be treated as "bias"; it is an attribute of the method itself.

11.3.2 Context

Context is an important element in the framing section of Figure 11-1. In our use of the term, context consists of the physical setting in which the interview takes place and the mental setting or milieu (see Mitchell and Carson [1984]) that is created by the survey questionnaire.

Context: Physical Setting

The contingent valuation literature contains little information on the effect of physical setting on the outcome of an interview. For example, Mitchell and Carson [1984] note that the survey research literature has indicated some concern that the respondent may feel the need to accommodate the "visitor" (the interviewer) and try to provide responses that he feels the interviewer wants to hear if the interview is conducted in his home. To minimize the potential of this "bias" occurring, Mitchell and Carson [1984] and Desvousges, Smith, and McGivney [1983] have told interviewers to emphasize the notion that there were no right or wrong answers. In both surveys, interviewers prefaced each interview with that philosophy.

Another aspect of the possible influence of the physical setting is that respondents are "on their own turf" when they give their responses in most contingent valuation surveys. In effect, they respond to the "hypothetical" situations in the same setting in which they are likely to make many of their household decisions. Moreover, the respondents can set certain basic ground rules for the interview. For example, they can simply ask the interviewer to leave if they find the questions annoying or troublesome.

While it is unclear exactly what effect the setting has on an interview, it does differ considerably from the setting, usually a laboratory or a classroom, in which the majority of psychology and experimental economics data are collected. Although, the survey questionnaire still sets the terms under which the contingent commodity is offerred, the home setting may put the respondent more at ease in answering questions. This does not imply that empirical evidence from a laboratory setting is not relevant to contingent valuation. What it does suggest is that the differences in physical setting and frequently in the types of respondents--college students are the usual respondents in the laboratory setting--may complicate the transfer of learning between the two environments.*

Context: Mental Setting

Mitchell and Carson [1984] suggest that the mental setting created within the contingent valuation survey is even more important than the physical setting. This aspect of context is the atmosphere or milieu that the contingent valuation questionnaire establishes. Poster boards with pictures of different vistas from the Grand Canyon, questions about familiar household activities like recreation, and general attitudinal questions on a particular theme are all examples of how a mental image can be established in questionnaires. Again, there appears to be little or no research that has systematically tested for the

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*It would be interesting to compare the results of Charles Plott and Vernon Smith who have conducted experiments using nonstudent subjects with those with student subjects. To our knowledge, this has not been done in a wide variety of problem settings.

effect of this dimension of the context for individuals' valuation responses for contingent commodities.

As noted in Chapter 8, our experiences with the focus groups and videotape interviews also indicated the importance of context. In fact, the sessions themselves elicited ideas that aided in creating the mental setting and later in qualitatively evaluating their effectiveness. Yet, this is not a substitute for a well-designed empirical test of context effects.

The Post Palo Alto classification (PPAC) in Figure 11-1 still retains a possible role for strategic effects in contingent valuation as an element in context effects. This concern for strategic effects emanates from sources other than the usual ones. That is, while it is possible to agree with Cummings, Brookshire, and Schulze's [1984] conclusion that there is virtually no evidence of strategic behavior in almost all previous contingent valuation surveys, there is nonetheless a type of strategic response in certain contexts. For example, using contingent valuation in the siting of undesirable facilities or for some other highly emotional issue, respondents can attempt to engage in strategic behavior to try to influence the outcome. While the possibility of strategic behavior may be a limited one, it may not be prudent to conclude on the basis of past studies where the issues may not have been as closely tied to the local interests of the respondents that strategic bias would not arise in other contexts.

The specification of the contingent commodity is a prominent part of the overall framing process. That specification must consider the procedures used by individuals to form perceptions and their ability to process the information provided. It should also be cognizant of the implied links that are presented between the valuations elicited and the behavioral actions described. As a rule, the conceptual foundations for these links come from economic theory. Thus, a description may have implicit maintained hypotheses concerning feasible responses available to the household. In fact, we consider these features as the basic elements of the contingent commodity itself. That is, it is difficult, if not impossible, to interpret the values elicited in contingent valuation independent of the specification of the commodity. This seems to be consistent with both Randall [1984] and Arrow [1984]. This is one reason why our contingent valuation commodity, changes in the risk of exposure to hazardous wastes, was described under two different property rights allocations to assess the relative importance of this aspect of the specification.

The perceptions component of the commodity specification refers to how people perceive and process the information used to describe the commodity. While some of the perception issues were discussed in Chapter 7, several other aspects of perception deserve attention. For example, Tversky and Kahneman's [1981] mental accounts concept, or the notion that people process information and make allocation decisions by grouping items into aggregate accounts like recreation, food, and housing, can be interpreted as falling under the perceptions component of the commodity specification.* In effect, they are suggesting that the way people process information to make decisions may affect how they perceive the commodity.

In addition, Mitchell and Carson's [1984] part-whole bias can be viewed as being part of how people perceive the specification of the contingent commodity. In their words, part/whole bias arises when the respondent views the contingent commodity differently than the researcher. For example, the researcher might have attempted to elicit a value of improved water quality in all the nation's water bodies while the respondent may very well be providing a value for only part of that, i.e., for a particular water body. Thus, part/whole bias occurs when people's perceptions are quite different from those of the researcher who designs and then interprets the results derived from a contingent valuation analysis. The PPAC classification considers part/whole bias as a part of framing the contingent commodity that deals with people's perceptions of the commodity.

Another key element of commodity specification in our classification is the elicitation process or, more specifically, the various parts of the elicitation process. This process can be viewed as consisting of the question format, the type of question used to elicit the value, and the payment vehicle that denotes the terms in which the hypothetical payment would be made. Chapter 7 has discussed the importance of question format as part of the elicitation

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*This concept should not come as a surprise to economists. It is nothing more than a specification of additional structure on the utility function completely consistent with the budget decomposition assumptions made in the theory associated with developing aggregate price or quantity indexes (see Blackorby, Primont, and Russell [1978] for example.

process. Therefore this discussion will not consider these issues beyond a recognition that the existing evidence seems to suggest that question format can have an impact on the individuals' valuation responses for contingent valuation commodity.

The payment vehicle is also a crucial part of the elicitation process. In this case, the research on the effect of payment vehicle does not seem as well established or as well documented as that for question format. For example, Cummings, Brookshire, and Schulze [1984] were unable to establish any definite problem arising from payment vehicles. Yet, they were unwilling to dismiss it as a potential problem in contingent valuation. Mitchell and Carson [1984] point out that perhaps one of the most sensitive aspects of the payment vehicle may be the implied value that results from the payment vehicle. That is, the vehicle itself may imply a specific starting point to people. In effect, it may provide them an implicit anchor for their responses. For example, when one is asked to make a hypothetical payment in the form of a utility bill, what comes to mind is one's typical monthly bill, from either the gas or electric utility. However, if one is offered a payment vehicle that is a user fee, e.g., a pass to use a lake during a year, then a range of comparable user fees like $5 to $10 (per person) more than likely comes to mind. Thus, the Mitchell/ Carson position is that payment vehicles may create problems for the elicitation process similar to the anchoring problems that arise with different question formats, particularly the bidding games. Ultimately, more research is needed to verify this position.

In addition, Arrow [1984] has noted that he does not find it surprising that different payment vehicles would result in different values but for reasons other than anchoring. Arrow's position is that the institutional arrangements by which payments are to be made are an integral part of the contingent valuation commodity itself. Our classification seems consistent with the Arrow position in that we have placed vehicle bias underneath the commodity specification.

The lower part of the PPAC classification deals with procedural issues. Two of the most important procedural questions considered in regard to contingent valuation are sampling bias and interviewer bias. Unfortunately, there is little evidence on the potential effects of alternative sampling procedures on contingent valuation estimates. In fact, with the exception of Mitchell and Carson [1984], the literature is almost devoid of any consideration of interactions between the procedures used to select the sample and other research design considerations.

The second form of procedural bias, interviewer bias, has received some attention in the contingent valuation literature. This bias results from individual interviewers affecting the valuation process. Desvousges, Smith, and Fisher [1984] have observed from a survey to measure the benefits of improved water quality that a couple of interviewers seemed to have a differential effect on people's bids. However, these effects were not widespread and seemed not to have a significant overall impact on the valuation estimates. On the other hand, Boyle and Bishop [1984] do find some evidence of interviewer effects in their recent study of scenic beauty on the Wisconsin River.

In summary, what has been defined as the PPAC classification is an attempt to provide a brief description of the evolution of thought on the problems in using contingent valuation. It is also a preliminary attempt at synthesis that is intended to provide background for the specific framing decisions made as part of the present contingent valuation. Clearly, a final classification awaits both more research and more thorough reflection.

11.4 FRAMING THE COMMODITY: REDUCTIONS IN HAZARDOUS WASTE RISKS

This section describes how we framed the contingent commodity for this research--reductions in the risk of exposure to hazardous wastes. Four key aspects of our contingent commodity are examined:

- Behavioral actions implied by our conceptual linkages for individuals' responses to risk
- Context for the contingent valuation questions
- Procedures used to specify the commodity
- Procedures used to elicit valuation.

This section also describes the framing of the initial commodity that was presented to the respondents. Later sections of the chapter will highlight the variations on this initial commodity that follow from our research design. For example, the variation used to examine the effects of property rights is deferred until the section on empirical results that presents these estimates. This pattern is maintained in the remaining empirical chapters.

11.4.1 Conceptual Linkages

The theory of welfare measurement generally provides the basic guidelines for the overall definition of the valuation concepts used in a contingent valuation survey. For example, the debate over Greenley, Walsh, and Young's [1981] estimates of the values of changes in water quality relates to the conceptual basis for their framing of the contingent commodity. They have interpreted their description as providing measures of option value while others (Mitchell and Carson [1982] and Desvousges, Smith, and McGivney [1983]) have argued that they elicited two slightly different measures of option price. Thus, the importance of the conceptual foundations in contingent valuation follows from the intended use of the results: to obtain measures of individuals' values of commodities that are not exchanged in conventional markets. Without its conceptual linkages, contingent valuation estimates can be difficult if not impossible to interpret. An additional aspect of what we have referred to as conceptual linkages concerns the behavioral responses that are described or implied by the question to be feasible actions available to the respondent.

The conceptual foundations for our contingent valuation survey were developed in Part I of this report. Our objective in this section is a more limited one: to highlight the measurement guidelines that the conceptual analyses of both user and intrinsic benefits provides for our survey questionnaire. For more detailed explanations of the rationale underlying the guidelines, the reader is referred to Part I. This section first considers the implications of the conceptual analysis of user benefits and then discusses the same topic as it applies for intrinsic benefits.

"User" or Household Benefits

The basic valuation measure used in our conceptual analysis to define what we refer to as the user benefits from a change in the household's risk of exposure to hazardous wastes as the increment to planned expenditures required to maintain the constant expected utility. There are several aspects of this valuation concept that are important to our contingent valuation analysis and to the specific process we used to implement the framework. First, it is an ex ante welfare concept, defined as if the individual were capable of making payments prior to knowing the outcome of the events at risk. This is an analytical method for describing the individual as planning consumption choices, contingent upon the events at risk, rather than explicitly making those choices. To use this framework within a contingent valuation setting we must describe the institutions that organize (or restrict) how contingent payments are made. In effect, is it possible to precommit to different payments now that would vary based on the events that do take place? Or must one specify a payment now for a desired outcome (in our case a change in the likelihood of some event) that must be made regardless of what the actual events are? Our description selects the second and implies that the change in planned expenditures will correspond to the option price payment that would be made for the risk change.*

The individual's valuation response, or hypothetical payment, is then the maximum constant payment the individual would be willing to make to obtain the risk change. The individual is willing to pay the option price because the payment, by reducing his risk of exposure to hazardous wastes, will enable him to obtain the same expected utility level with a lower risk of the detrimental event--exposure to hazardous wastes. In effect, the option price is the difference between the individual's planned expenditures made before the risk change and those made after the risk changes. However, this difference is an option price, only if the individual has no other avenues of state-dependent adjustments. If these avenues are perceived to be available, then the valuation response is conditional on these perceived opportunities for state-dependent adjustments.

In fact, an individual who has different avenues of adjustment available may well have different valuation responses for risk reductions as the level of the risk changes than would be predicted under the assumption of option price payments. This suggests caution in interpreting the payment amounts in our survey. An alternative interpretation may be that we have not fully reflected the perceived "planning process" individuals think they can use when faced with uncertainty. Several parts of the questionnaire elicit information about

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*For more discussion of this result see Chapters 4 and 5.

some of these avenues of adjustment to aid in interpreting both the plausibility of the responses themselves and their implications for benefits measurement.

Intrinsic Benefits

As we noted earlier in this report, we are using intrinsic values and existence values as synonyms. This departs from earlier benefit taxonomies (including our own adaptation of the Mitchell-Carson [1981] work presented in Desvousges, Smith, and McGivney [1983]). It is a deliberate departure because these past efforts mixed an ex ante and an ex post perspective for welfare analysis. We have argued that it is probably not desirable to try to distinguish other nonuser components of valuation from existence values. Institutions for ex ante adjustment also affect intrinsic values. Nonetheless, our conceptual analysis in Chapter 6 assumes that the option price is the appropriate welfare measure. That is, the focus of our contingent valuation question that poses reductions in the risk of exposure to hazardous wastes that "critters" experience in their natural ecosystem should be to elicit constant ex ante payments for these risk reductions. As with user values, the payments are independent of the state of the world that actually occurs.

However, there are three important features that distinguish these values from the user values. First, the outcome at risk is the risk of exposure and possible death for the creatures themselves, not the household. Second, the events at risk are specifically described as not implying the extinction of a species. Third, the endpoint of the risk change is described in somewhat vague terms: to the level these creatures face in their natural habitats. It is likely that different individuals will perceive this endpoint differently. As noted in Chapter 7, both the outcome at risk and the risk endpoint may influence individuals' values for changes in hazardous waste risks. Thus, it is not possible to develop estimates of the values for reductions in these risks on a per-unit basis.

11.4.2 Context

This section briefly describes the physical setting or locational context in which the interviews were conducted and the "mental image" or context that the questionnaire attempted to set for respondents.

Physical Setting

Generally, our interviewers conducted the interview within the confines of the respondent's residence, often as not seated at the respondent's dining room or kitchen table. The interviews usually were conducted at a prearranged time. However, in some cases they were completed at the same time that our interviewer compiled the list of household decisionmakers. On average, the interviews lasted 53 minutes, though some lasted as long as 1½ hours. Despite the length, only three of the interviews were not completed after initiation (see Chapter 9 for details).

The interviewers prefaced each interview with a statement that there were no right or wrong answers and that the respondent could refuse to answer any question or simply reply "I don't know." During the training sessions and practice interviews, the interviewers were reminded of the importance of this preface. Thus, the main intent was to keep the physical context as comfortable as possible for the respondent and to minimize the opportunity for implying that the interviewer was interested in any particular response. The interviewers identified themselves as employees of the Research Triangle Institute. No mention was made of the sponsoring agency, either before or after the session.

Context: Mental Setting

As noted in Chapter 8, the focus group and other questionnaire development activities consistently pointed out the importance of establishing an effective mental setting with the survey questionnaire. Mitchell and Carson [1984] argue this point quite persuasively based on their efforts to develop their questionnaire for eliciting values of improvements in national water quality.

The final context established by our questionnaire resulted through a trial and error process documented in Chapter 8. The questionnaire opened with a general question asking the respondent to rate the potential harm to people and the environment itself from different sources of pollution, including hazardous wastes. This was the first mention of hazardous wastes during the interview with the intent being to elicit a relative rating of hazardous wastes to other pollution sources prior to providing any information about the main questionnaire topic.

Next, the interview turned the focus to hazardous wastes by defining them and then differentiating between radioactive wastes and hazardous wastes with the stress on factories and landfills to help make the distinction. Figure 11-2 shows the visual aid that the interviewer gave to the respondent to help create the mental image. While the respondent was looking over the card, the interviewer said the following:

> To give you an idea of what hazardous wastes are and where they come from, here's a list of some products we use every day and some wastes that are left over after they're made. For example, a common waste is the chemical solution used to tan the leather in shoes, wallets, or purses. After the chemical solution is used, it must be thrown away. Because the solution contains chromium, it's considered a hazardous waste. Hazardous wastes are left over after making a wide range of other consumer products--from the gasoline and batteries for cars to the plastic containers used to package and store food. Some companies put these wastes in their own special facilities; others pay companies to dispose of their wastes in special dumps called hazardous waste landfills. Some products that we use--like paint, varnish removers, and weed killers--are themselves considered hazardous wastes when we throw them away. Although hazardous wastes often have been handled carefully, sometimes the practices have been inadequate.

The next two building blocks for context involved eliciting the frequency at which the respondent had obtained information about hazardous wastes and the name of the nearest factory that produced hazardous wastes and its distance from the respondent's residence. The second block involved obtaining a rating of the respondent's perceived effectiveness, at the time of the interview, of different organizations in dealing with hazardous wastes. Among those included in the list were several levels of government and generators of hazardous wastes.

The interviewer next moved into the crucial section of the questionnaire, which included several perception questions. These included the respondent's perceived likelihood of exposure--using a 1-10 scale card--to hazardous wastes from various environmental media and the use of the risk ladder to obtain the respondent's perceived annual risk of dying from different causes during the next year. The interviewer used the multicolor ladder, shown earlier in Figure 8-1, to ask about death from auto accident, heart disease, illness caused by air pollution, and an illness caused by hazardous wastes. Thus, these perception questions constituted the last links in the chain of context in the ques-

Card 2

Products and Their Hazardous Wastes

Consumer Products	Discarded Hazardous Substances
Automobile batteries	Lead
Dry cleaning fluid	Carbon tetrachloride
Paint/textiles	Chromium, chlorinated organic compounds
Shoes and other leather goods	Chromium
Glass/electronics	Selenium
Steel	Manganese, phenols, benzene
Plastics	Vinyl chloride
Pesticides—aldrin, dieldrin DDT, chlordane	Chlorinated organic compounds
Chemical and petroleum products	Phenols, benzene, organic compounds, brines
Pharmacy products	Organic solvents

Figure 11-2. Hazardous waste information card.

tionnaire before the specific commodity of hazardous waste risks were introduced.

11.4.3 Contingent Commodity Specification

The questionnaire specified the contingent commodity in four steps. The steps include describing hazardous waste as a risk, explaining the payment vehicle, specifying the ground rules for the valuation process, and, finally, highlighting the character and circumstances of hazardous waste risks.

Hazardous Wastes and Risk

The first step in specifying the commodity is describing the concept of hazardous wastes as a situation involving risk. Table 11-1 shows the text the interviewer used to introduce the concept of hazardous waste as risk. In this text, the interviewer also explains the risk circles or probability wheels that are the visual aid used to communicate risk. Figure 11-3 shows one card with risk circles that were described.

To aid the respondent in using the risk circles, and to provide a link to the hedonic property value study, the interviewer handed the respondent a second card with risk circles and asked him to translate the risk change into a distance, in miles, that would provide an equivalent risk reduction. The question was posed as a hypothetical situation involving a chemical contamination of the local drinking water supply.

The Payment Vehicle

The second step in specifying the commodity is explaining the payment vehicle that would be used in the elicitation of values. The interviewer first introduced the general idea of the payment vehicle:

> Next, I would like you to think about the costs of more controls on hazardous wastes. When the government decides to clean up abandoned dump sites, place stricter controls on landfills, or stop some very toxic wastes from being generated, these actions would reduce the risk of exposure. However, they cost someone. As consumers and as taxpayers, we pay for the costs of better control of hazardous waste.

After the introduction, the interviewer handed the payment vehicle card, shown in Figure 11-4, to the respondent and then described it by saying:

TABLE 11-1. THE INTRODUCTION TO HAZARDOUS WASTE AS A RISK

Another way to think about hazardous wastes and risk is with this card. It uses circles to stand for two different kinds of risks we face from hazardous waste.

Since risk involves chance, we can also think of risks by putting pointers that would spin easily on each of the circles. A pointer has an equal chance of landing at any spot on its circle. The larger the portion of the circle that is "cut out" by the blackened area--that is, the bigger the slice--the more likely the pointer would land there. On the first circle on Card A, for example, 20 percent of this circle is blackened. There is one chance in 5, or 20 percent chance, the pointer will land in the blackened area. This means that, on the average, for every 100 spins the pointer would land in the blackened slice twenty times.

The numbers on the cards are hypothetical because even experts disagree about the sizes of the risks. However, in the rest of this interview, I want you to think of these numbers as actual risks you face.

Look at the differences between each circle. The first circle shows the risk or chance that you (and your household members) would be exposed to hazardous waste. By exposed, I mean touching, breathing, eating, or drinking a large enough amount of a hazardous waste over a period of time so that it could be harmful. Exposure through the pathways we have discussed could be a brief, one-time thing, or it could happen over several months or years.

The importance of the middle circle is that it stands for the second, and different, type of hazardous waste risk--the chance of dying after being exposed. This means that even if you're exposed, there's a separate chance--not a certainty--that you would die. For example, some people are healthier or have better resistance. Whether or not you're actually harmed is based upon your physical makeup, heredity, and overall health. An important thing to remember about the first two circles is that you would never have to spin the pointer on the second circle as long as the pointer on the first circle never landed in the blackened area. In other words, there's no chance you would die from the effects of hazardous wastes if you're never exposed to them.

The third circle combines the two types of risks into a person's overall risk. It shows the bottom line: your chances both of being exposed to hazardous wastes and, once exposed, dying. The combined risk of exposure and death is found by multiplying the chance you see in the first circle by the chance in the second circle.

Card A

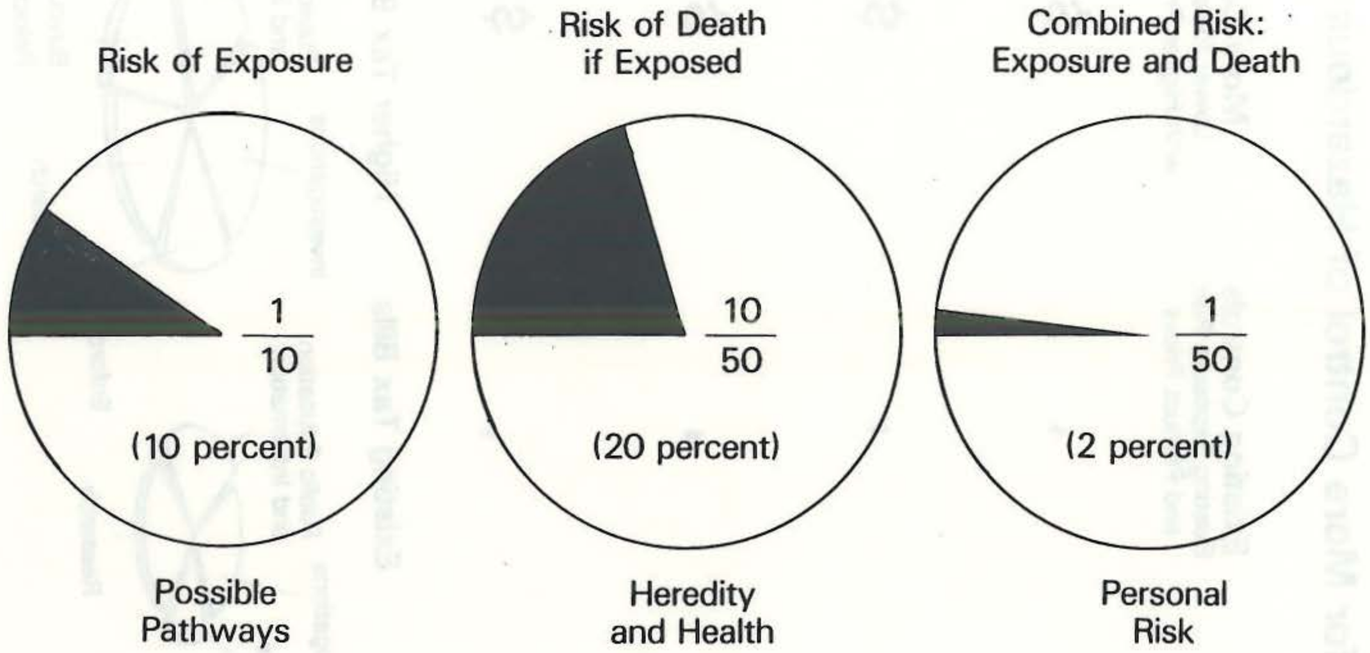

Figure 11-3. Risk circles.

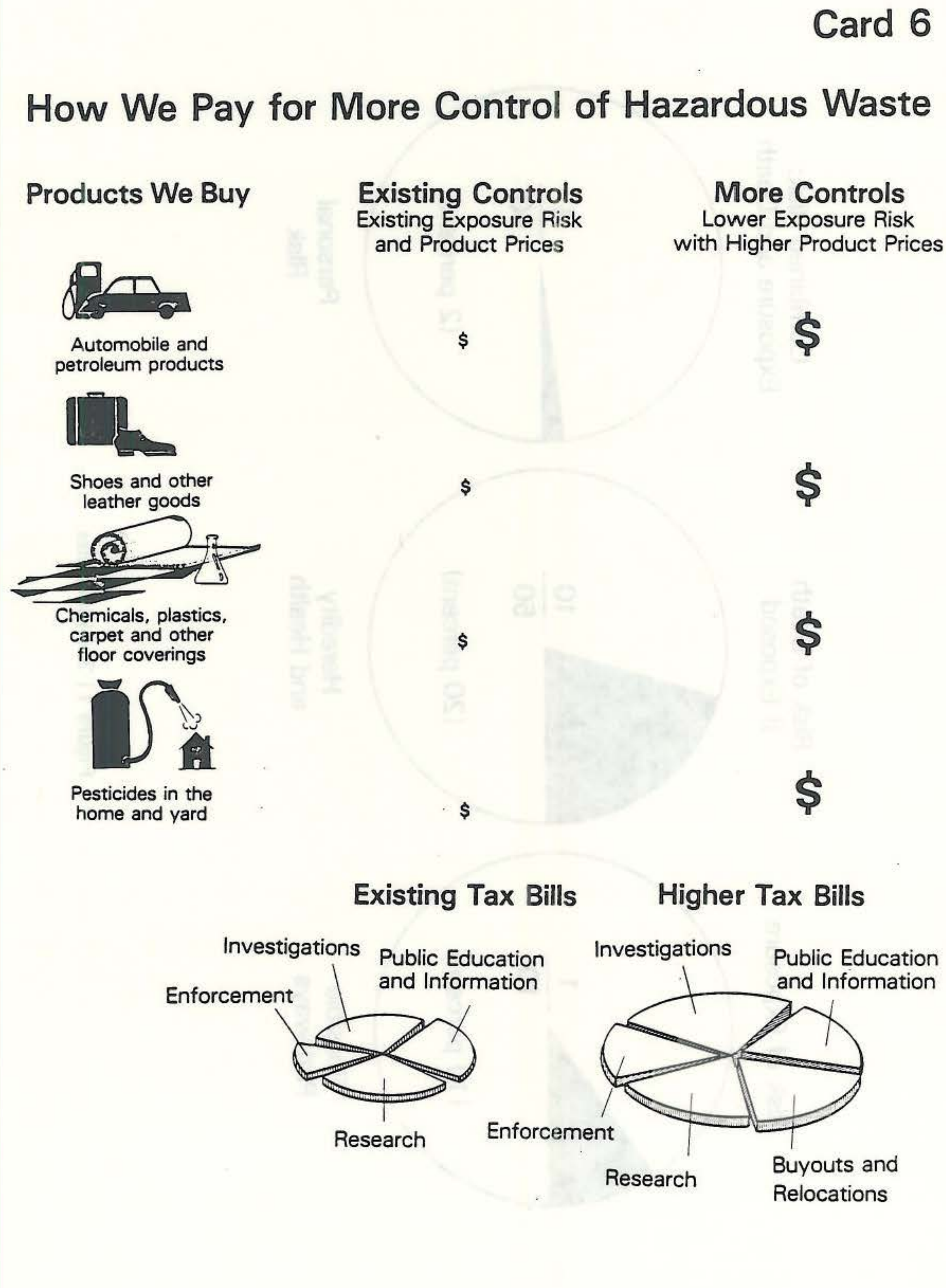

Figure 11-4. Payment vehicle card.

> The top part of this card shows how we would pay for lower exposure risks through higher prices for the products we buy. If the government puts stricter regulations on car makers, shoe companies, or chemical companies, it would cost them more to make their products. Then if you buy a pair of shoes or a pesticide, you would pay a higher price than you would without the regulations.
>
> The lower part of this card shows how we would also pay for lower exposure risks through higher local, state, or federal taxes. The card shows the higher tax bills providing more money to investigate and enforce the regulations and to clean up places like Times Beach or Love Canal.

We chose higher prices and taxes as the payment vehicle for several reasons. First, it has no implied starting value like a utility bill or user fee. Second, it corresponds closely with how people actually pay for regulations on hazardous wastes. Even though our hypothetical situation was structured in terms of a local company located 3 miles from the respondent's house, our focus group experiences suggested that the general vehicle was more tangible to respondents, making it easier to comprehend than trying to develop a hypothetical vehicle that would be tied directly to the local situation. Finally, this payment vehicle had proved effective in several previous contingent valuation studies, in particular Mitchell and Carson [1981, 1984] and Desvousges, Smith, and McGivney [1983].

In summary, our payment vehicle is a practical compromise between the need for credibility and comprehension and the need for consistency with the hypothetical situation. The effectiveness of this compromise is an empirical issue that is considered later in this chapter in the evaluation of the reasons for protest bids. If there was insufficient correspondence between the commodity, the circumstances under which it occurred, and the method of payment, we anticipate there would be a sizable percentage of participants who would reject the terms of the market.

Valuation Ground Rules

Explaining the ground rules for the valuation exercise to the respondent is the third step in specifying the contingent commodity. This step consists of three key parts: informing the respondent in advance of the sequence of valuations, offering the opportunity to review this sequence, and benchmarking the valuation perspective.

The interviewer explained the sequence of the valuation exercise by reviewing the three risk circle cards with the respondent and describing how they would be used. The interviewer said:

> Now, think about these cards and about paying higher prices and taxes. Based on a hypothetical situation, I'm going to ask you some questions about paying to reduce your (and your household members') risk of exposure from the level on Card A to the levels on Card B, and Card C. As you can see on the cards, the risk of exposure decreases in the first circle from 1 chance in 5 on Card A, to 1 chance in 10 on Card B, to 1 chance in 25 on Card C. It also means your combined risk of exposure and death gets smaller each time.
>
> After asking about paying for these risk reductions for people, I am going to ask about paying an <u>additional</u> amount to reduce risks for fish, wildlife, and plants only--not for humans. Do you have a question about how I am going to continue?

This prenotification is important for three reasons. First, it enabled the respondent to be informed in advance of what he was going to be asked to do. This was necessary because focus group participants pointed out that they likely would have divided their bid differently between the two risk levels, A to B and B to C, had they known they were going to be offered a second level. Thus, we added the advance notice and explained the incremental nature of the intrinsic value question.

The second reason accounts for how some of our respondents were able to refuse to pay anything for the first change but were willing to make an option price bid for the entire change from A to C later. These bids of these respondents have been evaluated separately and are discussed later in this chapter.

Finally, the prenotification gave the interviewer the opportunity to ask the respondent if he would like to review these terms prior to the actual valuation exercise. This proved useful because it minimized the need to review even more material if the respondent experienced difficulty later in this part of the interview.

The second part of the ground rules for the valuation exercise involved the interviewer establishing two mental benchmarks for the respondent to use in developing his responses. The interviewer said:

Before I go on, there are two things to keep in mind. One, please decide how to respond as though you actually were facing this hypothetical situation. In other words, I would like you to keep in mind your (and your household members') income, how you budget your money, the kinds of products you buy and the taxes you pay. Two, any amounts that you're willing to pay would be in addition to what you're now paying for hazardous waste controls and would affect only hazardous waste problems. The amounts are not to reduce acid rain or any other environmental problem.

These benchmarks are important because they help to orient respondents' thought processes for this crucial part of the interview.

Character and Circumstances of Risks: The Hypothetical Situation

The last step in the sequence for specifying the contingent commodity consisted of the interviewer explaining the hypothetical situation. This situation is important because it described the specific circumstances under which the respondent would experience the risk and outlined the features, or attributes, of that risk. Figure 11-5 shows the card that the respondent received as a reminder of the exact circumstances.

There are three important aspects of the hypothetical situation. First, it describes the commodity--the change in the risk of exposure to hazardous wastes--from the level shown on Card A to the level on Card B--and it links this exposure to tangible actions, the use of liners and a monitoring system, in response to government regulations.* Our focus group experiences contributed substantially to the use of this specification. Participants suggested that such concrete terms were necessary to make it tangible. The importance of concrete terms and examples seems consistent with the psychology literature, in particular Slovic, Fischhoff, and Lichtenstein [1982] and Wallsten and Budescu [1983].

The second important aspect of the hypothetical situation is that it describes the timing of the risk. That is, death from the exposure would not occur until 30 years later. This aspect is important for two reasons. First, it may account for some of the differences among individuals in their responses

*The only other attempt to use contingent valuation to value regulations involving hazardous wastes emphasized the inherent uncertainty in the process and asked for the valuation of a regulation in the presence of this overall uncertainty. See Burness et al. [1983] for further discussion.

Exposure Risk Circumstances

- Electronic parts company
- Located 3 miles from your home
- Generates 2,000 gallons of hazardous waste each day
- Company disposes of the wastes in a landfill at company site
- If you are exposed, there is a chance you will die in 30 years

Figure 11-5. Description of hypothetical situation.

to the risk. For example, older people may well view the risk as less relevant to them because of its timing. Second, the timing makes it difficult, if not impossible, to compare values from our situation with many of those in the existing literature (see Violette and Chestnut [1983] for a review). For example, the outcome of risks in labor markets that are estimated with hedonic wage models relate to annual risk. While we present a simple and crude attempt to compare these valuations in Chapter 16, it is prudent to view this as an area for further research. This comparison is intended to highlight the issues involved. As noted in Chapter 7, there is substantial evidence that the types and attributes of risk are likely to be important considerations in how people value risk changes.

The third important aspect of the hypothetical situation is that it does not specify a particular cause of death. Consequently, we asked people if they had a cause of death in mind, and if so, which one. As noted in Chapter 10, a sizable majority of the people, not surprisingly, envisioned cancer as the cause of death. This provides a good indication of individuals' perceived character of hazardous waste risks.

In addition, not specifying a cause of death allowed us to modify the situation to describe a particular cause--immune system damage--and a different type of risk--birth defects--and ask the respondents if they would like to change their bids if the nature of the event at risk was modified in either of these ways. Finally, the hypothetical situation provided a baseline for the intrinsic values question and the reduction in risk to zero to address the importance of these two parts of our research design.

11.4.4 Elicitation of the Option Price Bids

The final task in framing the commodity is eliciting the individual's value for the contingent commodity. While we have noted the importance of this step throughout this report, Cummings, Brookshire, and Schulze [1984] add another dimension to the importance of the elicitation process. They suggest that this part of the framing of the contingent commodity provides the opportunity to mitigate attitudinal bias as in contingent valuation. This bias occurs when an attitudinal response is interpreted as an indication of behavior, a potential problem noted by Bishop and Heberlein [1979, 1984]. Cummings, Brookshire, and Schulze [1984] suggest that by carefully structuring the elicitation process, contingent valuation can be interpreted as "intended behavior."

Our elicitation procedure consisted of the following:

Interviewer statement:	Think about your monthly income and what you spend it on in your budget.
Purpose:	Reminds respondent of budget constraint and how they typically make expenditures.
Interviewer statement:	How much would you be willing to pay each month...
Purpose:	Gives specific action/time frame
Interviewer statement:	in higher taxes and in higher prices for products you buy
Purpose:	Explains specific action
Interviewer statement:	to lower your (and your household members')* risk of exposure from the level on Card A to the level on Card B?
Purpose:	Identifies a specific target.

In this procedure, the interviewer used the direct question format that was discussed in Chapter 7. The same procedure was also followed for the second risk change. Chapter 14 will describe the contingent ranking format and how we used it to elicit individuals' responses.

Finally, the interviewer offered the respondent an opportunity to revise his bid. By transforming the monthly bid into its annual equivalent and verifying its accuracy with the respondent, the interviewer enabled the respondent to reconsider if he thought his bid was either too high or too low. This rechecking helped to minimize problems if the respondent did not fully appreciate the magnitude of the monthly amount, which Mitchell and Carson [1984] refer to as the "easy monthly payments" syndrome. It also allowed the respondent to reconsider his response with a minimum of pressure. Equally important, the procedure does not change the terms under which the risk reduction is to be provided, a potential problem we discussed in Chapter 7 with the iteration process that has been used in several past studies.

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*Parentheses imply that interviewer only read if more than a single person household.

This opportunity for revisions was provided for each valuation question that appeared in the questionnaire. Table 11-2 profiles the bidders who revised their bids and the questions or valuation circumstance in which the revisions occurred. Somewhat surprisingly, the revisions were distributed almost evenly between increases and decreases. Of the total of 30 revised bids, 13 bids were increased and 17 were decreased. We had expected individuals would primarily lower their bids because of underestimating the annual equivalent of monthly amounts. Another important feature is the infrequent occurrence of the revisions. If the direct question format for the valuation questions for risk changes are totaled across all sections of the questionnaire, 2,038 valuation responses were obtained, which implies a revision rate of 0.001, or about 1 out of every 1,000 bids.

There does not seem to be a particular pattern to the revisions. Most of the revisions appear plausible, although there is one potential exception.* The only other characteristic that seems prevalent among the revised bidders is that they had rated the potential harm of hazardous wastes toward the more harmful end of the scale. Yet, this characteristic does not seem to correlate with the direction of the revision.

Finally, we are somewhat unsure of how to interpret the infrequency of revisions, but it does not seem to indicate any implausible behavior on the part of the majority of the respondents. Nevertheless, it does offer another check on the consistency of responses that has not been widely used in prior studies. Our finding also seems consistent with Mitchell and Carson [1984] who used a slightly different procedure but with the same objective.

11.5 PROTEST BIDDERS

This section describes the protest bidders from various sections of the contingent valuation questionnaire. In addition, it examines characteristics

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*There is one individual who revised his bid from $80 to $500 a month for the reduction to zero who merits a specific explanation. Our first thought was that the accurate response was $50 and that we had made a coding or keying error. However, when we reviewed the questionnaire, we found that the revision was indeed to $500. The respondent was a creative writer making $22,500 annually. Thus, this response likely will be reflected when our analysis of outliers is performed on the certainty questions. Since the treatment of outliers was not resolved as part of Phase I's research activities, we have left this response in the mean values that are presented later in this chapter.

TABLE 11-2. PROFILE OF RESPONDENTS WITH REVISED BIDS

Willingness-to-pay question: Initial bid	Willingness-to-pay question: Revised bid	Questionnaire format	Version number	Respondent revised bid--more than one question[a]	Household income ($\$10^3$)	Age	Education (years)	Sex	Homeownership	Years lived in town	Number of children under 18	Rated harm of hazardous waste pollution[b]	Rated effectiveness of Federal government in dealing with hazardous waste[c]	Bottled water is a current activity	Public meetings are a current activity
Risk decrease from card A to card B[d]															
0	25	Direct	5	No	47.5	45	18	Female	Own	7	0	10	1	Yes	No
1	5	Direct	8	No	NA	38	18	Female	Own	11	1	2	3	Yes	No
5	2	Direct	1	No	17.5	48	16	Female	Own	6	0	2	3	No	No
5	2	Direct	6	No	32.5	27	14	Male	Rent	2	0	4	3	No	No
5	10	Direct	7	No	57.5	42	16	Male	Own	12	1	9	3	Yes	No
10	4	Direct	3	No	82.5	40	18	NA	Own	1	1	NA	3	No	No
15	25	Direct	7	No	62.5	38	16	Male	Own	7	2	4	4	No	Yes
20	10	Direct	7	No	42.5	38	14	Female	Own	10	0	5	6	No	No
20	15	Direct	6	Yes	27.5	25	14	Female	Rent	6	1	10	5	No	No
30	20	Direct	5	No	37.5	44	4	Male	Rent	2	1	NA	7	Yes	No
100	50	Direct	5	No	47.5	55	12	Female	Own	28	0	10	8	Yes	Yes
Risk decrease from card B to card C[d]															
10	5	Direct	6	Yes	27.5	25	14	Female	Rent	6	1	10	5	No	No
10	5	Direct	7	No	52.5	57	18	Male	Rent	19	0	8	8	No	No
50	150	Direct	7	No	52.5	32	16	Female	Own	8	1	10	1	No	No
Risk increase from card X to card Y															
10	25	Ranking	3	No	27.5	60	12	Female	Own	32	0	10	2	Yes	No
10	120	Direct	3	No	7.5	33	12	Male	Rent	6	0	10	4	Yes	No
20	25	Ranking	3	No	17.5	68	14	Male	Rent	6	0	10	4	No	No
30	20	Ranking	3	No	27.5	31	16	Male	Rent	1	0	NA	4	No	No
Risk decrease from card A to zero risk[e]															
20	5	Ranking	1	No	12.5	64	12	Male	Own	25	0	5	10	No	No
40	20	Ranking	2	No	NA	35	12	Female	Rent	6	0	5	4	Yes	No
50	83	Ranking	1	No	67.5	35	18	Male	Own	6	0	1	2	No	No
80	500	Ranking	4	No	22.5	53	18	Male	Own	14	0	8	1	No	No
100	25	Ranking	4	Yes	17.5	29	12	Male	Rent	2	2	10	4	Yes	No
100	75	Ranking	2	Yes	17.5	46	18	Female	Rent	12	0	10	3	Yes	Yes
150	100	Ranking	3	No	27.5	70	14	Female	Own	70	0	5	10	No	No
Risk decrease to wildlife[f]															
10	20	Direct	2	No	27.5	46	18	Male	Own	6	0	8	4	Yes	Yes
20	30	Ranking	1	No	72.5	67	18	Male	Own	25	0	8	2	No	No
25	18	Direct	4	No	57.5	46	14	Female	Own	10	0	9	5	Yes	Yes
50	25	Ranking	4	Yes	17.5	29	12	Male	Rent	2	2	10	4	Yes	No
50	75	Ranking	2	Yes	17.5	46	18	Female	Rent	12	0	10	3	Yes	Yes

[a] Three respondents had revised their bids for two questions; hence, these respondents are counted twice within this table.

[b] Represents a scale card response from 1 to 10 with 1 = not harmful and 10 = very harmful.

[c] Represents a scale card response from 1 to 10 with 1 = not at all effective and 10 = very effective.

[d] Applicable only to the direct-question format.

[e] Applicable only to the ranking-question format.

[f] Includes only nonzero bidders for a reduction in household risk; consequently, the posited level of household risk is equal to the level purchased in previous questions.

that influence the likelihood of someone being a protest bidder. It also provides a brief comparison of our results with those of Mitchell and Carson [1984]. It is important to consider the reasons underlying protest bids because this process helps to assess whether or not they are influenced by the nature of our contingent commodity. Finally, we evaluate whether or not any of the features of our research design--e.g., property rights assignment and the low probability vectors for the exposure risks--had any effect on the likelihood that someone would reject the terms of the contingent market.

Examining the role and influence of protest bidders has taken on increasing importance in contingent valuation research over the last few years. Randall, Hoehn, and Tolley [1981] stressed that the elimination of protest bidders, as well as outliers, enables one to obtain a solid core of data from a contingent valuation survey. A number of studies, including Desvousges, Smith, McGivney [1983] and Mitchell and Carson [1984], have argued for detailed examination of the characteristics of protest bidders as one mechanism for evaluating the framing properties of a contingent valuation instrument.

An important consideration for protest bids is the procedure used to classify them. In our case, the protest bids were determined using ex post classification of the reasons that people gave for zero bidding. If people gave any reasons other than that's what it's worth to them, or they cannot afford anything, they were considered a protest zero. In addition, we classified nonrespondents to the valuation question as protest bidders. Table 11-3 shows the frequency of reasons for zero bids for questions eliciting option prices for risk decreases. The results in Table 11-3 are quite interesting. Only 15 percent of the sample were protest bidders for the questions associated with the valuations for risk reductions. Within this group there are several interesting subsets. For example, 11 of the 55 total protest bidders, or 20 percent, felt that companies or government should bear the cost of controlling hazardous wastes. This would imply that the reason most frequently given for protesting the terms of the market was related to our payment vehicle--higher taxes and product prices. People did not accept our explanation that when companies or government do pay the cost, they ultimately pay part of the share. Alternatively, they could simply feel that they have an implicit property right to reduced exposure to hazardous wastes. That is, they should

TABLE 11-3. FREQUENCY OF REASONS FOR ZERO BIDS BY LEVEL OF RISK, DECREASE DIRECT QUESTION FORMAT

	Decrease in risk of exposure per conditional risk								
	1/5 to 1/25		1/10 to 1/50		1/30 to 1/150		1/300 to 1/1,500		
Reasons for zero bids	1/10	1/20	1/10	1/20	1/10	1/20	1/100	1/200	Total for all versions
Protest bids									
Not enough information	0	1	1	1	1	1	0	1	6
Did not want to place a dollar value on change	1	1	1	3	0	1	0	1	8
Objected to the presentation of the question	1	0	1	0	0	1	1	0	4
Multiple response[a]	0	0	2	0	1	1	0	2	6
Costs should be borne by companies or government[b]	1	1	1	1	0	2	2	3	11
Objected to more taxes[b]	0	1	0	0	0	0	1	1	3
Objected to the existing management of government[b]	1	1	0	1	0	3	0	1	7
Objected to the distribution of payments[b]	1	0	0	0	1	0	0	1	3
Further controls could be imposed with no costs[b]	0	0	0	0	1	0	0	0	1
Nonresponse	0	1	0	0	1	0	0	1	3
Other[b]	1	0	0	0	1	0	1	0	3
Total protest bids	6	6	6	6	6	9	5	11	55
Nonprotest bids									
That is what it is worth	0	0	0	0	0	0	0	0	0
Cannot afford anything	2	4	6	5	6	4	11	3	41
Other[b]	0	0	1	0	1	3	0	0	5
Total nonprotest zero bids	2	4	7	5	7	7	11	3	46
Total of all zero bids	8	10	13	11	13	16	16	14	101
Total sample sizes	42	47	47	46	49	45	53	42	371
Protest bids as a percent of sample size	.14	.13	.13	.13	.12	.20	.12	.26	.15

[a] Respondent stated a reason that was a combination of the reasons formatted within the survey.
[b] Response was not formatted within the survey.

sample size appears sufficient to support further analysis of certainty as a risk endpoint.

11.9 RISK OUTCOMES

This section describes our design for, and preliminary analysis of, alternative risk outcomes on the mean option price bids for reducing the risk of exposure to hazardous wastes. Recall our framing of the initial commodity did not describe a particular risk outcome. Instead, it asked each respondent what cause of death he envisioned. However, the design subsequently called for changing the framing of the commodity to elicit responses for two alternative outcomes: death caused by damage to the body's immune system and a risk of severe lifetime birth defects.

The interviewer asked the respondent if he would like to change his bid for the risk change (decrease) for each case. This sequence was introduced by the statement:

> Think about this [hypothetical] situation. Most experts agree that exposure to hazardous wastes may cause different kinds of health problems. . . You might decide that you would be willing to pay something different [from the total for risk reductions that the interviewer had just mentioned] if you thought about different kinds of health problems.

Table 11-16 provides summary statistics for the bidders who revised their responses for the immune system damage and birth defects as risk outcomes. These results and subsequent evaluation of a profile of the respondents are interesting. For example, only two respondents out of a total of 172 respondents who changed their bids lowered their responses. In one case, the respondent lowered his bid from $175 a month to $50 a month for each of the alternative outcomes. However, the reliability of this respondent is somewhat suspect given that his initial bid is high relative to his income. Generally, the mean revisions are quite sizable, ranging from $12 to $30 per month for immune system damage and from $10 to $20 per month for birth defects. A sizable number of these means are significantly different from zero. This is especially true for birth defects where the mean for only one design point is not significantly different from zero at the 0.01 level of significance.

In addition, the means for birth defects appear much less skewed than those for immune system damage. Indeed, there are a sizable number of large

TABLE 11-16. SUMMARY STATISTICS OF THE CHANGE IN OPTION PRICE BIDS GIVEN A SPECIFIC ILLNESS, PROTEST BIDS EXCLUDED, OUTLIERS INCLUDED

		Changed bids													
		Change in option price to avoid immune system damage							Change in option price to avoid birth defects						
Conditional risk	Exposure risk change[a]	Mean	Median	Standard deviation	Number of obser- vations	Minimum value	Maximum value	t-statistic[b]	Mean	Median	Standard deviation	Number of obser- vations	Minimum value	Maximum value	t-statistic[b]
1/10	1/5 to 1/25	12.00	10.00	7.53	10	5.00	25.00	5.04**	16.07	10.00	14.07	14	2.00	50.00	4.27**
1/20	1/5 to 1/25	40.09	5.00	113.89	11	-125.00	300.00	1.17	20.33	64.38	10.00	15	-125.00	200.00	1.22
1/10	1/10 to 1/50	28.67	10.00	40.90	9	1.00	100.00	2.10*	15.32	7.50	25.75	14	0.50	100.00	2.22**
1/20	1/10 to 1/50	30.25	7.50	52.46	6	0.50	135.00	1.41	11.23	10.00	14.03	11	0.50	50.00	2.65**
1/10	1/30 to 1/50	15.64	10.00	17.51	11	2.00	50.00	2.96**	18.69	10.00	27.01	19	-15.00	100.00	3.01**
1/20	1/30 to 1/50	19.00	10.00	18.17	5	5.00	50.00	2.34*	15.30	10.00	13.78	11	2.00	50.00	3.68**
1/100	1/300 to 1/1,500	15.23	5.00	24.57	10	0.25	80.00	1.96*	10.66	5.00	13.91	14	1.00	50.00	2.87**
1/200	1/300 to 1/1,500	14.30	10.00	15.48	5	0.50	40.00	2.06	11.75	15.00	7.91	7	0.25	20.00	3.93**
All versions combined		22.25	10.00	51.46	67	-125.00	300.00	3.54**	15.46	10.00	29.47	105	-125.00	200.00	5.37**

**Significant at the 0.01 percent level using a one-tail test.
*Significant at the 0.05 percent level using a one-tail test.

[a]All risk changes represent a movement frm card A to card C.

[b]for the null hypothesis that the population mean is zero.

revisions, with the largest being $300/month for immune system damage. This occurred when a 66-year-old male with an income of $27,500 doubled his monthly bid. A 55-year-old female with household income of $52,500 also changed her bid substantially for the immune system outcome when she increased it from $8/month to $200/month. (However, she did not change for the birth defects.) The largest change for birth defects occurred when a 59-year-old male with an income of $42,500 doubled his monthly bid of $200. Thus, it appears that the outcome of death by damage to the immune system affected somewhat fewer respondents (67 vs. 102) than the birth defects outcome, but some of the responses were quite large. Clearly, further analysis of these responses is warranted in order to judge their plausibility.

Table 11-17 provides some additional information on the influence of the specific risk outcomes on the option price bids. It compares the summary statistics of respondents who changed their bid in response to either or both outcomes with those respondents who did not change. In general, the mean bids for the "changers" exceeds those for the nonchangers. This is true for both birth defects and the immune system effects. While this is not surprising given their willingness to change, the substantial size of some of the mean bids--over $80/month in one case--was somewhat surprising. It should be noted that these results relate to the sum of the option price bids for risk reductions from A to B and B to C.

In summary, the effects of risk outcomes offer one clear area for additional research. The description of specific outcomes generally resulted in about one-third of the respondents altering their bids. The research issue that must be considered is to develop a framework that provides a better understanding of the influence of individuals' characteristics on this process. The size and number of changes should provide sufficient sample for these additional analyses.

11.10 INTRINSIC VALUES

This section presents our results on intrinsic or existence values. It describes the framing of the commodity--risk reductions for critters--and highlights the summary statistics for the option price bids. Finally, it considers the implications of differences in the initial levels of risks posed to individuals

TABLE 11-17. SUMMARY STATISTICS OF OPTION PRICE BIDS FOR A RISK DECREASE GIVEN A SPECIFIC ILLNESS, PROTEST BIDS EXCLUDED, OUTLIERS INCLUDED

				Nonprotest bids									
				Respondents who changed their bids					Respondents who maintained their original bid				
Stated illness	Conditional risk	Exposure risk change	Questionnaire version[a]	Mean	Median	Standard deviation	Number of observations	t-statistic[b]	Mean	Median	Standard deviation	Number of observations	t-statistic[b]
Immune system damage	1/10	1/5 to 1/25	3	37.50	30.00	21.51	10	5.51**	23.65	12.50	29.87	26	4.04**
	1/20	1/5 to 1/25	4	79.27	20.00	136.24	11	1.93*	42.63	14.00	59.05	30	3.96**
	1/10	1/10 to 1/50	1	61.44	35.00	67.28	9	2.74*	24.56	10.00	33.89	32	4.10**
	1/20	1/10 to 1/50	2	66.42	27.50	82.17	6	1.98	55.85	27.50	83.81	34	3.89**
	1/10	1/30 to 1/150	5	72.36	35.00	68.23	11	3.52**	22.46	12.50	26.23	32	4.85**
	1/20	1/30 to 1/150	6	35.00	30.00	21.79	5	3.59**	43.35	15.00	92.95	31	2.60**
	1/100	1/300 to 1/1,500	7	46.73	20.00	51.22	10	2.88**	33.13	15.00	53.05	38	3.85**
	1/200	1/300 to 1/1,500	8	34.90	20.00	37.88	5	2.06	27.42	15.00	27.59	26	5.07**
Brith defects	1/10	1/5 to 1/25	3	37.28	27.50	29.11	14	4.79**	26.04	15.00	31.87	22	3.83**
	1/20	1/5 to 1/25	4	84.87	22.00	116.04	15	2.83**	28.54	11.50	39.35	26	3.70**
	1/10	1/10 to 1/50	1	42.11	35.00	49.18	14	3.20**	26.15	10.00	36.44	27	3.72**
	1/20	1/10 to 1/150	2	44.77	40.00	39.48	11	3.76**	60.24	25.00	90.11	29	3.60**
	1/10	1/30 to 1/150	5	54.32	30.00	57.10	19	4.15**	27.75	10.00	37.88	24	3.59**
	1/20	1/30 to 1/150	6	35.85	30.00	22.37	11	5.32**	47.92	15.00	102.85	25	2.33*
	1/100	1/300 to 1/1,500	7	38.68	17.50	46.98	14	3.10**	34.68	15.00	54.46	34	3.71**
	1/200	1/300 to 1/1,500	8	30.75	30.00	17.52	7	4.64**	28.46	15.00	29.23	24	4.77**

**Significant at the 0.01 level.

*Significant at the 0.05 level.

[a]All risk changes represent a movement from card A to card C.

[b]For the null hypothesis that the population mean is zero.

for their valuations and described to be relevant to other elements in the ecosystem (i.e., critters) for the option price bids.

As noted both in Chapter 7 and in the discussion of the conceptual linkages in Section 11.4, the intrinsic value question was also framed in terms of state-independent option price bids for risk reductions to be experienced only by critters. The bids are state independent because they are ex ante amounts that are made without prior knowledge of the eventual outcome of the risk reduction. The interpretation of the bid as an option price requires that the individual does not have any other avenues for adjusting the risks to critters. For example, he does not participate in a community hazardous waste collection near some ecosystem, which could reduce the risk of exposure to hazardous wastes for the critters.

The text to describe the framing of risk reductions for critters is shown below.

> Now suppose that the risk of exposure to you (and your household members) has been reduced to the level on Card ____.*
>
> Suppose that the government adds regulations on this landfill. These additional regulations would not lower your (or your household members') risk, but would lower the risk of exposure to hazardous waste for fish, wildlife, and plants only. Their combined risks would be lowered to the levels they face in nature. Suppose also that none of them is in danger of becoming extinct.
>
> In addition to the (READ TOTAL OF F.6.a + F.6.b OR AMOUNT FROM F.6.c ON REMINDER SHEET) you have said you would be willing to pay, how much more in higher product prices and taxes per month would you be willing to pay for these regulations that would reduce risks of exposure for fish, wildlife, and plants only?

The framing of this risk reduction affects the interpretation of the empirical results for the risk reductions. For example, the outcome at risk differs from all the previous outcomes for risk changes: it is only for critters and does not affect the household's risk in any way. Not only does the outcome differ, the endpoint for the risk is less specific than in the earlier risk changes. The endpoint is to levels the critters face in nature.

---

*Blank line refers to the level of risk that each respondent had purchased for their household. The interviewer supplied this value.

In addition, the framing also affects the attributes of the population (i.e., fish, wildlife, and plants) experiencing the risks. It states that none of the members of the ecosystem are in danger of becoming extent. Our intent here was to suggest that the population did not include snail darters, or Indiana bats, or some other creatures on the endangered species lists. Clearly, a more comprehensive design would have varied this attribute to see if it affected the option price bids. Nonetheless, it is important to recognize that our conceptual analysis for these values has not provided a specific description of the potential importance of the attributes of the creatures at risk.

Instead, the design considers only differences in the initial levels of risk for option price bids for intrinsic values. This design feature followed logically from our treatment of intrinsic values as an increment to the user values. Because respondents differed in the amount of household reductions they purchased--e.g., Level A (zero bidders), Level B, Level C, or zero--the initial levels of exposure risk for creatures also varied. The framing reflects this feature by requiring the interviewer to remind the person of the endpoint for the household risk.

The summary statistics, shown in Table 11-18, provide some insights as to the importance of our research design for intrinsic values. The monthly option price bids are statistically significant from zero for three of the five initial levels of risk. The two values that are not different are those for zero bidders. Nevertheless, it seems premature to conclude that providing these respondents an opportunity to relfect intrinsic values was not useful. The summary statistics include responses for all bidders, including protest bidders and potential outlying bids. A final assessment of our attempt to include zero bidders for household risks in the design for intrinsic values will require more analysis.

The results in Table 11-18 also suggest that the starting level for the risk reduction affected the mean values of option prices for risk reductions to fish, wildlife, and plants. In particular, the bidders who purchased a zero risk reduction had larger, and statistically different, mean option price bids than any of the means in the first three rows of the table. This is surprising given the vague specification of the initial level of risk in this case.

TABLE 11-18. SUMMARY STATISTICS OF OPTION PRICE BIDS FOR INTRINSIC VALUES (RISK REDUCTIONS TO CRITTERS), ALL BIDDERS

Initial level of risk	Version	Mean	Standard deviation[a]	N	t-statistic[b]
Zero bidders	D	7.55	11.99	11	2.09
Bid for A→B only	D	2.77	6.02	53	3.35**
Bid for A→B and B→C	D	6.72	13.10	196	7.18**
Bid to zero[c]	R	13.6	17.91	167	9.85**
Zero bidders	R	5.77	28.36	49	1.46

**Significant at the 0.01 level using a two-tail test.

[a]Standard deviation = $\sqrt{\frac{1}{n-1}\Sigma(Xi-\bar{X})^2}$ where $\bar{X}$ is the sample mean and Xi is the observation for individual i and N is the sample size.

[b]For the null hypothesis that the population mean is zero.

[c]In this case the initial level of risk was vaguely defined. It was described as positive, greater than their natural state but not specified. This outcome resulted from the effects of our design and the sequence of responses to it that individuals could make with each design point.

Differences in the information provided to respondents in the two questionnaire versions could account for the significant different option price means for intrinsic values. That is, the direct question version notified respondents in advance that they would be asked to bid for two distinct risk decreases for their household and then an additional amount for reducing the risk of exposure to hazardous wastes for fish, wildlife, and plants. In effect, these respondents might have been able to mentally allocate their respective total valuations between risk reductions for their household and those for critters, resulting in lower amounts for critters than in the ranking version where there was no prior notification. This could imply a variation on Tversky and Kahneman's [1981] "mental accounts" concept is operating.

Other possible explanations are possible for these results. For example, a simultaneous equation model of the decision process for valuation responses for the respondents in the direct question part of the design who were prenotified of the bids to be requested may help to explain their behavior. Indeed, both Smith [1984] and Hanemann [1985] have argued for the need of such models in analyzing contingent valuation responses.

An alternative explanation may lie in a basic assumption of any analysis of mean values: differences in the characteristics among individuals are not important. Relaxing this assumption is a high priority for future research activities, especially given the sensitivity of the "use values" for risk reductions that is discussed in Chapter 13. While many of our explanations are very speculative at this juncture in the research, the quality and diversity of information on intrinsic values merits more intensive investigation than is now possible.

11.11 IMPLICATIONS

Given the objectives of this chapter, a summary of our results seems inappropriate. Essentially, its purpose is to initiate the empirical analysis of the option price bids for changes in the risk of exposure to hazardous wastes. In achieving its purpose, the chapter has stressed the importance of the framing of the contingent commodity for interpretations of the contingent valuation results.

Overall, the results described in this chapter indicate that further research is clearly warranted. Our examination of protest bidders revealed an overall rate of protest bids that is most encouraging. These bids accounted for only about 15 percent of our valuation responses. Had respondents been completely unable to deal with our interpretation of hazardous waste as a risk, we would have had a much higher rate of protest bids in our sample. While the findings on protest bidders do not necessarily provide evidence on the quality of the valuation responses in the nonprotest component of the sample, they do seem to indicate that individuals did not reject the framing of our commodity as one involved with a risk change. Whether or not they experienced difficulty in processing the framing information is a crucial objective of any subsequent empirical analyses.

While the option prices for risk changes do not appear to be consistent with our a priori expectation that risk changes from a higher initial level would be valued more highly, they are not implausible, especially if one accepts the view that individuals may perceive that state-dependent adjustments are feasible. Nearly all mean bids are significantly different from zero. Clearly, additional analysis of the outlying responses and the differences among individuals that may affect the mean bids should help to clarify some of the relationships between the values for risk changes and the initial levels of risk.

Our preliminary investigations into the option prices motivated by intrinsic values are also encouraging. The relative sizes of the means compared to the use value means suggest that respondents understood the incremental nature of our design. The preliminary nature of our research in this area precludes further general conclusions. The plausibility of the responses seems to suggest that efforts to model the nature of individuals' responses to these questions may be beneficial.

Additionally, our preliminary results on the effect of certainty as a risk endpoint offer encouragement that the responses to this design question merit further attention. This implication also appears to hold for the questions that elicited changes in option price bids when specific risk outcomes, death from immune system damage and birth defects, are posed.

Thus, the main implication to be drawn from these results is that considerably more research is required to discern the patterns and processes that underlie these responses. Yet, the data seem capable of fulfilling at least some of the requests from both economic and psychological analyses.

CHAPTER 12

OPTION PRICE RESULTS: PRELIMINARY REGRESSION ANALYSES USING UNRESTRICTED MODELS

12.1 INTRODUCTION

This chapter presents our statistical analysis of how differences in characteristics among individuals may affect their values for reductions in the risk of exposure to hazardous wastes. The basic assumption underlying this analysis--that these differences can influence responses--is an extension of the analysis of means presented in Chapter 11, which assumes that the only sources of differences in valuation responses are related to the specified features of the risk changes. That is, the analysis in Chapter 11 assumes that the level of the exposure risk, conditional risk, and size of the risk change are the only potential sources of differences in the estimates. Unfortunately, however, the results of our examination using the simple model are largely uninformative. Consequently, detailed interpretations of these findings are not presented. Instead, the chapter focuses on summarizing our attempts to develop measures of several characteristics that our conceptual analysis, other literature, and the focus groups suggested would be important to understanding the valuation responses. The two main characteristics which organized this empirical work are the household's available avenues for adjustment and its health status. Following a discussion of the information available on these issues, the chapter presents some illustrative regression results based on our use of the simple model.

12.2 GUIDE TO THE CHAPTER

Section 12.3 of this chapter presents the simple model that provides an organizational structure for the chapter. Section 12.4 discusses the role of a household's avenues of adjustment in our analysis and describes several variables that are used to represent these avenues. Section 12.5 considers the influences of a household's health status on the valuation responses and details our various alternative specifications of measures of health status. Section 12.6 presents our illustrative regression results for risk increases and decreases. Section 12.7 summarizes some implications that can be drawn from this chapter.

12.3 SIMPLE MODELS

This section develops the underlying rationale for a simple model to analyze individuals' valuations of changes in hazardous waste risks. The model is primarily a heuristic device to reflect several major points from our conceptual analysis (see Part I) and some of the elements of our research design (see Chapter 7). This basic structure is then varied to attempt to reflect factors other than the risk change for the valuation responses. Nonetheless, all of the models considered are simplified in three respects: they are assumed to be linear in variables and parameters, they are used to examine values both for risk decreases and for avoiding risk increases, and they pertain only to use values.

12.3.1 The Model's Rationale

The object for starting with a simple model is to guide the process of examining how differences in particular characteristics across individuals can influence their valuation responses. There are several reasons to test for the influence of these differences in respondents' characteristics for their respective valuation responses. First, our conceptual analysis clearly indicates that on economic grounds individuals should differ in how they value changes in risk. This same conclusion can also be inferred from psychologists who suggest that either differences in perceptions or differences in the ability to process the information presented in our questionnaire should lead to variations in the valuation responses. Equally importantly, our experiences in the focus group sessions (see Chapter 8) suggested that variations in individual's valuations could frequently be linked to certain attitudes or perceptions. For example, individuals who expressed concern over the effectiveness of the government in delivering the risk change frequently gave low, or zero, values for reductions in hazardous waste risks. Additionally, the presence of children at home--and especially younger children--seemed to have a positive effect on valuation responses. Finally, participants who perceived that their genetic make-up or overall health status made them more susceptible to experiencing ne health effects if exposed to hazardous wastes frequently expressed higher aluation responses.

In summary, our conceptual analysis, the findings of psychologists related o risk perception, and our focus group experiences point the way toward a iodel that can account for differences among individuals' attributes and per-eptions in the formulation of their valuation responses.

2.3.2 The Model

The basic model used to begin our evaluation of the option price results ; described in Equation (12.1):

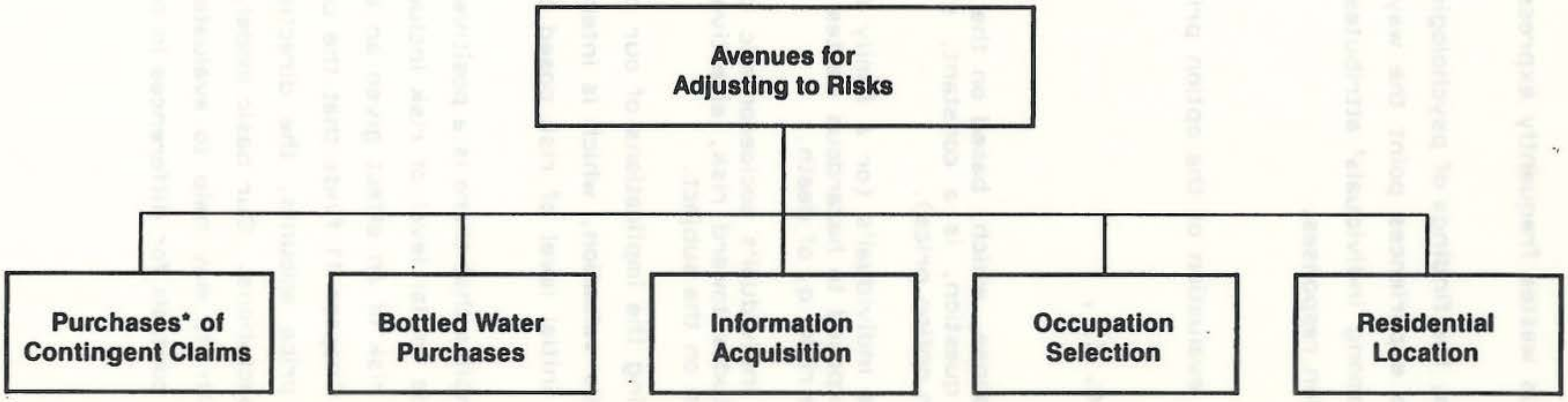
$$\Delta E = f(R, q, Z) \quad (12.1)$$

'here

- ΔE = the contingent valuation response, which, based on the form of the contingent valuation question, is a constant, state-independent payment (i.e., an option price).
- R = postulated initial level of the individual's (or a family member's) probability of being exposed to hazardous wastes sufficient to imply a second-stage risk, q, of death.
- Z = a vector of measures of the individual's socioeconomic characteristics, measures of attitudes toward risk, effectiveness of government, and information on the subject.

his basic model is a first step in reflecting the implications of our conceptual ıalysis. It suggests that the individual's valuation, which is interpreted as ı option price, will be affected by the initial level of risk posed to the re-ɔondent in the framing of the commodity.

Generally, our conceptual analysis implies that there is a positive relation-ıip between the option price bid and the initial level of risk including both ıe risk of exposure and the conditional risk of an effect given an exposure. hile the analysis of means presented in Chapter 11 finds that the conditional sk has a strong effect on the option price amounts, the direction of the 'fect is the opposite of our a priori expectations. Our basic model, and the ɘgression analyses that will be used with it, may help to evaluate whether ıis effect stands up when the framework controls for differences in character-tics among individuals.



*Not covered in survey questionnaire.

Figure 12-1. Potential avenues for adjusting to risk exposure.

fied in our conceptual analysis, but we were unsure how to elicit this information in the survey.

Instead, the survey requested information on activities individuals were currently undertaking (or had undertaken in the past). Some of these actions were associated with perceived risks of exposure to hazardous wastes and some with the types of risk. Consequently, this chapter assumes that these responses provide an indirect indication of each respondent's potential for seeking to adjust to the circumstances described in our contingent valuation questions. Clearly, the specific activities undertaken in the past and the other variables used to measure this potential could not have been in response to our contingent valuation questions.

Another limitation of our attempt to reflect these effects on individuals valuation responses stems from our understanding of what each individual's perceived avenues for adjustment might be. It is somewhat vague at best. Nevertheless, comments from our focus group participants can be interpreted as giving an approximate idea of how at least a few of these avenues might work. For example, participants frequently mentioned that they purchased bottled water as a way of avoiding exposure to hazardous wastes and other possibly harmful materials. Others said that they attended public meetings and workshops and sought out other information sources to better understand hazardous wastes and the ways of limiting their exposure. In particular, the Acton, Massachusetts, residents who participated in our focus groups stressed the relevance of both bottled water and better information as ways of avoiding risks. (See Desvousges et al. [1984b] for details on the Acton sessions. Also, see Chapter 10 for summary statistics on bottled water and information acquisition.) The regression analysis uses a qualitative variable to reflect the presence or absence of these two adjustment avenues for this household.

Occupation selection and residential location are also avenues for adjusting to several types of risk including the possibility of being exposed to hazardous wastes. For example, white collar workers are likely to have very small risks of being exposed on their jobs, while the chances of exposure are probably higher for certain types of blue collar workers. Thus, individuals could reduce their exposure risk by their occupation choice.

Additionally, it is possible that workers in technical occupations may have a better understanding of, and access to, information about risks. This may be another way that occupation influences the perceived avenues for adjusting to risks. In our empirical analysis we developed several occupational classifications to try to account for these potential information differences. The rationale for this approach follows our earlier argument. These occupational and the differentials in risk and information on risk may have required some individuals to consider adjustments to risk. Therefore, they have provided experience and familiarity with the process. This could as a result influence how they responded to the risk changes posed in our contingent valuation questions. These were tried in the model both as an additive term and as an interaction with the conditional risk. Unfortunately, neither was significant in any of the regression models.

As noted in Chapter 1 and in the discussion of the property value model in Chapter 15, changing the location of one's dwelling could alter the risk of exposure to hazardous in several ways. For example, a move could change the level of air quality and the source and subsequent quality of the drinking water. It also could change the flow of information available to the household should it move into a town in which the town council or newspaper provides information about hazardous wastes. As noted in Chapter 10, anyone moving to the town of Acton, Massachusetts, after it experienced a series of hazardous waste contamination incidents would probably have experienced a considerable increase in the flow of information on hazardous wastes.

As a very crude attempt to account for the influence of the residential location as an avenue for information on risk and familiarity with adjusting to it, we have included qualitative variables for several of the towns in our sample. The approximate nature of these qualitative variables is attributable to the possibility that they could also reflect some other town characteristic or household characteristic related to the town that are omitted from our model. Nevertheless, improved modelling of this avenue may yield some substantial payoffs in future research because of the pervasiveness of residential location in the household's risk of exposure to hazardous wastes.

12.5 HEALTH STATUS

This section describes the potential effect of health status on individuals' valuations. It also provides summary information on the health status of our respondents. It concludes by discussing the analysis variables that were constructed to measure the effect on differences in health status on individuals' valuations.

12.5.1 The Role of Health

A household's value for reductions in hazardous waste risks is likely to be influenced by its health status. Differences in value could be attributed to perceptual or economic factors, or both. For example, a household that has experienced the consequences of a disabling disease may place a very different value on risk reductions than one who has not. However, the implications of differences in health status are not clear on a priori basis. A household with lower health status may perceive itself more predisposed to experiencing the health consequences of hazardous wastes and therefore have a higher value for reducing these risks. Conversely, it may be willing to pay less for a risk reduction because it has already contracted a major disease, and any effects from hazardous wastes are viewed as of secondary importance. Or its poor health may have resulted in lower earnings for the household and, therefore, reduced its ability to pay for reducing exposure to hazardous waste risks.

A behavioral model that includes a household's health status would seem a logical way to improve our understanding of the effects of this characteristic on valuation responses. Unfortunately, such a model has not been developed for this phase of the research. Instead, we have tried several ad hoc specifications that include health status in our simple model. Nevertheless, our survey questionnaire does provide a substantial amount of information on the health status of our sample individuals. Figure 12-2 depicts the main health-related questions that were included in the questionnaire.

Both self-assessed health status measures and objective health indicators were elicited in the questionnaire. The self assessment included the respondent's rating of his health and a comparison of his health with others of the same age. Table 12-1 shows the respondent's ratings for these two perceived health indicators. Generally, our respondents considered themselves to be in good health. Only 12.7 percent of the respondents rated their health as fair or poor, while less than 6 percent considered their health worse or much worse than average for someone their age.

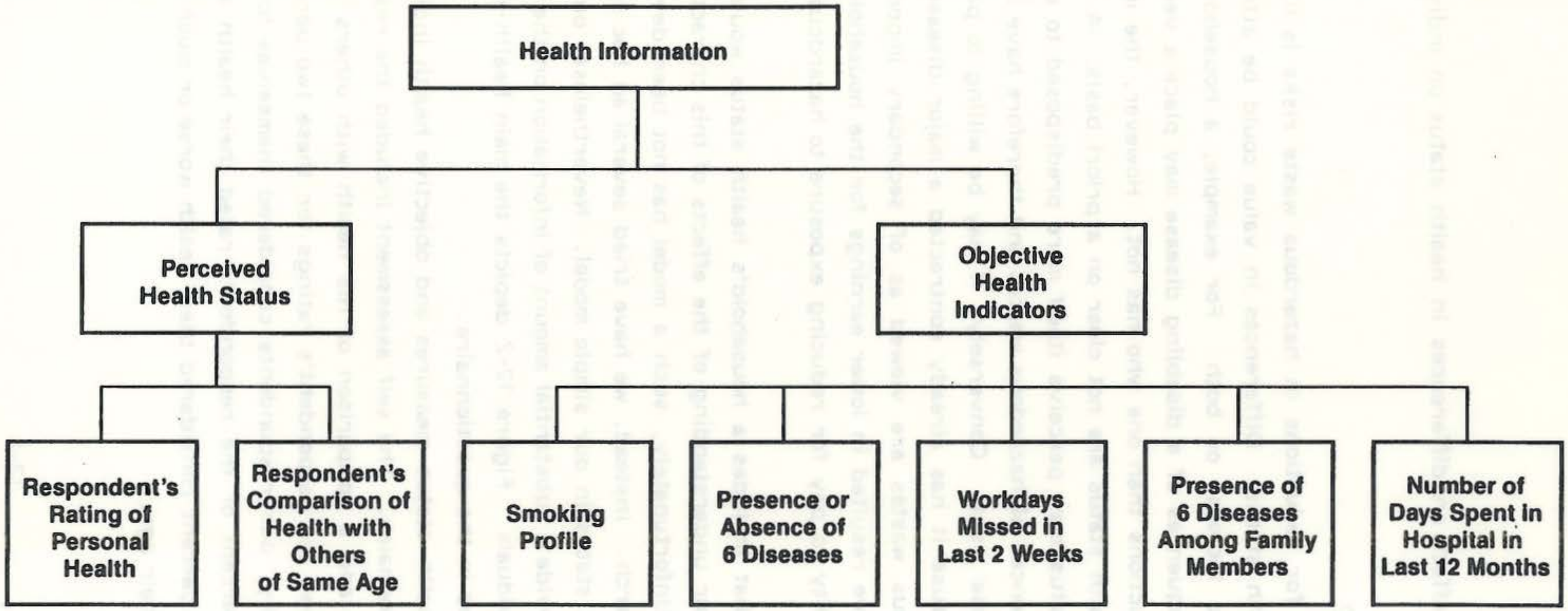


Figure 12-2. Overview of health information.

TABLE 12-1. SELF-ASSESSED HEALTH STATUS

Own health			Own health compared to others of same age		
Rating	Number of respondents	Percent of total sample	Rating	Number of respondents	Percent of total sample
Excellent	278	45.8	Much better	97	16.1
Good	252	41.5	Better	211	35.0
Fair	60	9.9	Same	261	43.3
Poor	17	2.8	Worse	31	5.1
			Much worse	3	0.5
Total	607	100.0	Total	603	100.0

TABLE 12-2. QUANTITATIVE INDICATORS OF HEALTH STATUS

Workdays missed in last 2 weeks			Overnight stays in hospital		
Number of days	Number of respondents	Percent of total sample	Number of nights	Number of respondents	Percent of total sample
0	560	91.5	0	538	87.8
1-2	25	4.1	1-2	16	2.6
3-4	5	0.8	3-4	15	2.5
5-7	7	1.1	5-7	15	2.5
8-13	3	0.5	8-14	16	2.6
14	12	2.0	15-30	12	2.0
Total	612	100.0	31-70	612	100.0

The questionnaire included the objective or quantitative indicators of health status shown in the right side of Figure 12-2 to supplement the perceived health information. These quantitative measures could be used either to verify the self-assessed health status or simply as alternative measures. We have used them to try to provide a set of more discriminating distinctions in health status. Nonetheless, future investigations may well consider the correspondence between perceived and objective measures of health and its implication for the valuation of risk reductions using the two types of health information.

Table 12-2 provide summary information on our respondent's health status using the quantitative measures. Again, the respondent's appear to be in reasonably good health based on workdays missed and overnight hospital stays. Less than 10 percent of the sample had missed a day of work in the 2 weeks prior to their interview, while only 12.2 percent had spent any time in the hospital during the last year. Table 12-3 provides additional information on the incidence of six common diseases or ailments--heart disease, hypertension, diabetes, kidney trouble, cancer or leukemia, and the effects of a stroke.*

12.5.2 Health Analysis Variables

To account for differences in health status among individuals we constructed a variety of proxy variables. As noted earlier, these are largely ad hoc measures. The majority of the variables were qualitative, or dummy variables. These variables were used in regression models either to test for intercept changes or as interactions with the conditional risk variable to reflect possible influences on individuals' perceptions of the events at risk. These health variables† are as follows:

- A qualitative variable equal to 1 for status categories excellent and good and equal to 0 if respondent rated health either fair or poor.
- A qualitative variable equal to 1 if respondent rated health at least average in his age and equal to 0 if rated worse than average for his age.

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*Another possible issue for further research is to compare these quantitative measures with comparable measures from other health surveys to better appriase the health of our respondents.

†All listed variables were used both as intercept shifters or as interactions with conditional risk.

TABLE 12-3. INCIDENCE OF SIX DISEASES AMONG SAMPLE RESPONDENTS

Diseases	Incidence		
	Yes	No	Total
Heart disease			
Number	47	565	612
Percent	7.7	92.3	100.0
Effects of stroke			
Number	4	608	612
Percent	99.3	0.7	100.0
Hypertension			
Number	98	514	612
Percent	16.0	84.0	100.0
Diabetes			
Number	15	597	612
Percent	2.5	97.5	100.0
Kidney trouble			
Number	28	584	612
Percent	4.6	95.4	100.0
Cancer/Leukemia			
Number	17	595	612
Percent	2.8	97.2	100.0

- A set of qualitative variables interacted with the assessed health categories.

- A qualitative variable equal to the respondent had spent 7 or more days in the hospital during the last year.

- A set of qualitative varibbles interacted with days spent in hospital.

- A qualitative variable equal to 1 if the individual was presently a smoker and equal to 0 if nonsmoker.*

- Qualitative variable equal to 1 of respondent or family member had experienced cancer or leukemia and equal to 0 if no incidence of cancer.

- Qualitative variable equal to 1 if respondent had indicated incidence of disease among family members and equal to 0 otherwise. (Measures were constructed for each disease and across diseases.)

Unfortunately, these efforts yield measures that were statistically insignificant, at conventional significance levels, determinants of option price. In fact, the vast majority of the variables showed virtually no relationship across all model specifications.† Presently, we are unsure whether or not this is attributable to the ad hoc nature of our variables.‡ If so, then developing a more formal model to reflect health status may be warranted. If not, the poor performance may be suggesting that there is inadequate variability in health status among our sample individuals for the differences to be significant.

12.6 REGRESSION RESULTS

This section presents some illustrative results from regression analysis using the simple unrestricted model. The results are presented for both risk decreases and risk increases.

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*The questionnaire contained detailed smoking histories. Future research may include constructing more thorough measures to indicate intensity of smoking activity.

†Smoking was the only exception. In a few models, this variable was significant at about 0.15 levels. This suggests that attempts to improve the smoking variable may be more fruitful than any with the other health variables.

‡Resolution of this issue will require a review of the literature on health status and other behavioral decisions, such as participation in the labor force.

12.6.1 Option Price Results for Risk Decreases

The option price regression results based on the simple model in Equation 12-1 are presented in Table 12-4. Separate models are shown for the first risk change from Level A to Level B, for the second risk change from Level B to Level C, and for the pooled sample of the two risk changes. Table 12-5 defines the variables that are used in the models throughout this chapter.

In general, the models do not explain a large percentage of the variation in the option price bids, and the explanatory power does not increase as more variables are added to the simplest version of the basic model. Nevertheless, there are several features of the models that merit additional discussion. The relationship between option price and income is quite strong when each of the two risk changes is estimated separately and when estimated using the pooled sample. This is consistent with our experience in the focus group sessions, and especially our videotaped interviews, in which respondents consistently mentioned that their income (and their expenses) was the most important factor they considered in forming their valuation responses.

The level of the conditional risk also has a significant influence on the option price bids. As in the analysis of means in Chapter 11, the sign of the variable is the opposite of our a priori expectations. The negative sign on the conditional risk variable implies that the respondents with the lower risk level (1/20 in our design) had higher option price bids, all other things being equal. This inconsistency is explored more thoroughly in Chapter 13 in the analysis using the restricted models.

The level of exposure risk does not affect the option price bids in any models estimated using samples composed of either of the risk decreases. However, in the simplest model estimated on the pooled sample, there is a positive and significant relationship between increases in exposure risk and option price, which is consistent with a priori expectations. Yet this is the only case that shows any significant relationship. This lack of significance is also consistent with the analysis of variance results presented in Chapter 11.

Additionally, the coefficient for the dummy variable for Versions 7 and 8 has a negative sign and is statistically significant for the initial risk change (Level A to Level B). This suggests that the lower probability portion of the design was associated with lower option price valuation responses, which

TABLE 12-4. MODELS FOR OPTION PRICES FOR RISK REDUCTIONS: COMMON SAMPLE[a]

Model variables and summary statistics	Level A to Level B risk change					Level B to Level C risk change					Pooled risk changes				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
INTERCEPT	7.249 (1.458)	25.284 (2.738)	30.845 (2.815)	29.961 (2.650)	29.601 (2.592)	4.536 (1.006)	13.270 (1.709)	16.989 (1.840)	16.047 (1.686)	15.204 (1.585)	5.613 (1.627)	15.047 (2.480)	19.208 (2.661)	18.200 (2.449)	17.614 (2.348)
EXP	0.041 (1.390)	0.004 (0.104)	0.004 (0.099)	0.004 (0.113)	0.004 (0.107)	-0.006 (-0.117)	-0.041 (-0.745)	-0.042 (-0.751)	-0.040 (-0.714)	-0.043 (-0.764)	0.060 (2.648)	0.040 (1.603)	0.040 (-3.302)	0.041 (1.643)	0.041 (1.616)
COND	-0.109 (-1.769)	-0.267 (-2.911)	-0.267 (-2.885)	-0.266 (-2.890)	-0.266 (-2.884)	-0.041 (-1.368)	-0.149 (-1.944)	-0.149 (-1.941)	-0.149 (-1.946)	-0.147 (-1.917)	-0.117 (-2.886)	-0.205 (-3.322)	-0.203 (-3.302)	-0.205 (-3.317)	-0.203 (-3.302)
INCOME	0.521 (5.766)	0.509 (5.668)	0.494 (5.412)	0.492 (5.367)	0.489 (5.304)	0.356 (4.479)	0.353 (4.441)	0.353 (4.450)	0.350 (4.373)	0.345 (4.295)	0.435 (7.040)	0.429 (6.937)	0.421 (6.790)	0.419 (6.711)	0.415 (6.621)
VER78		-20.343 (-2.310)	-19.933 (-2.260)	-19.941 (-2.258)	-19.942 (-2.254)		-10.193 (-1.380)	-10.307 (-1.394)	-10.200 (-1.376)	-10.288 (-1.386)		-10.874 (-1.888)	-10.676 (-1.853)	-10.654 (1.848)	-10.662 (-1.848)
AGE			-0.119 (-0.944)	-0.107 (-0.813)	-0.106 (-0.801)			-0.091 (-0.745)	-0.079 (-0.631)	-0.079 (-0.631)			-0.095 (-1.064)	-0.081 (-0.882)	-0.081 (-0.873)
NUMCHD17				0.649 (0.326)	0.666 (0.333)				0.686 (0.423)	0.713 (0.439)				0.762 (0.577)	0.785 (0.594)
INFORM					0.986 (0.244)					2.554 (0.743)					1.616 (0.591)
R^2	0.12	0.13	0.14	0.14	0.14	0.09	0.10	0.10	0.10	0.10	.0.11	0.11	0.11	0.11	0.11
F	12.28	10.69	8.72	7.26	6.21	7.36	6.02	4.92	4.11	3.60	19.85	15.85	12.91	10.80	9.30
n	282	282	282	282	321	233	233	233	233	233	516	516	516	516	516

[a]The numbers in parenthesis below the estimated coefficients are t-statistics for the null hypothesis of no association.

TABLE 12-5. DEFINITION OF VARIABLES

Variable	Definition
COND-RISK	Conditional probability of death given exposure that was postulated to respondent, multiplied by 1,000.
EXP	Exposure risk at the starting point for the risk change (i.e., A for the first risk change, B for the second), multiplied by 1,000.
AGE	Age of the respondent in years.
SEX	Sex of the respondent, 1 = male, 0 = female.
NUMCHD17	Number of children in the household under 17.
INCOME	Household income in thousands of dollars.
OWN/RENT	Qualitative variable = 1 if respondent owned his home.
EDUC	Categorical variable for last grade of school completed.
INFORM	Qualitative variable = 1 if individual recalled reading about hazardous wastes in news articles and the information involved his town.
CAUSE	Qualitative variable = 1 if individual had a particular cause of death in mind and 0 otherwise.
PUBMEET	Qualitative variable = 1 if respondent has attended a public meeting about hazardous wastes and 0 otherwise.
Acton, Peabody, Woburn, Wakefield, Stoneham, Wellsley, Norwood, Franklin	Qualitative variable = 1 if respondent is a resident of the relevant town and 0 otherwise.
DUMR	Qualitative variable = 1 if respondent has received ranking question for risk decrease valuation.

is consistent with our a priori expectations. However, this relationship does not hold for the valuations of the second risk change, which suggests that respondents may have reacted differently to the lower probability versions for the second valuation. Equally important, the performance of this variable suggests that attempts to model how individuals process risk information differently may yield substantial dividends.

In general, models estimated with the pooled sample have more significant coefficients at higher levels than do the separate models. Although due in part to the larger sample sizes, this suggests that more thorough investigations of the pooling issue seem warranted. (See Chapter 13 for some of our first attempts at examining issues related to pooling.)

As noted earlier, our efforts to improve the specification using our simple unrestricted model were not effective. Table 12-6 shows one model that includes some of the additional variables for adjustment avenues, including residential location and health status. Again, income is the most significant explanatory variable in the equation. In addition, the qualitative variable for Acton is also positive and statistically significant across the three samples. This relationships is intuitively plausible. Acton residents with their greater awareness of hazardous wastes, due both to more information and the drinking water contamination, would more likely be willing to pay more to reduce hazardous waste risks. Nevertheless, the qualitative variable for the Town of Woburn, which also has experienced problems with hazardous wastes, is not significant. However, this lack of significance may be attributable to the relatively few interviews conducted in Woburn.

12.6.2 Option Price Results for Avoiding Risk Increases

We also estimated the simple unrestricted model on the sample of option price amounts for avoiding an increase in hazardous waste risks. (See Chapter 11 for the framing of the commodity for risk increases.) Table 12-7 presents the risk increase results for the same models presented in Table 12-4. The questionnaire elicited a valuation for only one risk change in this risk increase case.

The pattern of the results for these models is very similar to those presented earlier. However, the income variable is again a significant determinant of the option price bids for avoiding risk increases. Additionally, the age

TABLE 12-6. MODEL FOR OPTION PRICES FOR EXPOSURE RISK REDUCTION--COMMON SAMPLE[a]

Model variables and summary statistics	Level A to Level B risk change	Level B to Level C risk change	Pooled risk changes
INTERCEPT	4.869 (0.329)	-5.767 (-0.411)	0.124 (0.012)
COND-RISK	-0.092 (-1.479)	-0.073 (-1.389)	-0.110 (-2.762)
EXP	0.081 (1.362)	0.025 (0.207)	0.146 (3.267)
AGE	-0.102 (-0.664)	-0.116 (-0.832)	-0.092 (-0.883)
SEX	-3.407 (-0.788)	-6.148 (-.696)	-4.763 (-1.665)
NUMCHD17	-0.597 (-0.285)	-0.676 (-0.397)	-0.481 (-0.350)
INCOME	0.404 (3.501)	0.238 (2.523)	0.322 (4.289)
OWN/RENT	5.264 (1.060)	7.125 (1.668)	5.834 (1.750)
EDUC	0.509 (0.648)	0.975 (1.281)	0.660 (1.200)
INFORM	-8.487 (-1.784)	-5.483 (-1.332)	-7.158 (-2.236)
CAUSE	-1.162 (-0.282)	-0.919 (-0.264)	-1.520 (-0.555)
PUBMEET	2.486 (0.359)	8.702 (1.588)	5.595 (1.248)
Acton	17.826 (3.199)	10.200 (2.240)	14.118 (3.861)
Peabody	17.209 (1.011)	23.928 (1.601)	19.550 (1.692)

(continued)

TABLE 12-6 (continued)

Model variables and summary statistics	Level A to Level B risk change	Level B to Level C risk change	Pooled risk changes
Woburn	13.194 (0.857)	19.811 (1.512)	16.613 (1.613)
Wakefield	-21.951 (-1.179)	-7.196 (-0.283)	-16.641 (-1.105)
Stoneham	34.023 (1.018)	43.553 (1.713)	39.659 (1.867)
Wellsley	-31.109 (-1.599)	-17.138 (-0.672)	-25.808 (-1.723)
Norwood	25.380 (1.507)	31.308 (2.087)	27.600 (2.407)
Franklin	35.583 (1.356)	-16.113 (-0.877)	7.059 (0.462)
Poor health	0.193 (0.032)	1.387 (0.239)	0.536 (0.127)
R^2	0.20	0.20	0.19
F	3.23	2.61	5.59
n	240	230	470

[a] The numbers in parenthesis below the estimated coefficients are t-statistics for the null hypothesis of no association.

TABLE 12-7. MODELS FOR OPTION PRICES FOR AVOIDING RISK INCREASES[a]

Model variables and summary statistics	Level X to Level Y risk change					
	1	2	3	4	5	6
INTERCEPT	14.653 (1.156)	28.759 (2.04)	33.043 (2.279)	30.726 (2.120)	30.525 (2.089)	36.996 (2.522)
EXP	-0.011 (-0.465)	-0.096 (-0.042)	-0.101 (-0.426)	-0.103 (-0.438)	-0.106 (-0.446)	-0.032 (-0.137)
COND	-0.013 (-0.118)	-0.013 (-0.113)	-0.020 (-0.176)	-0.027 (-0.247)	-0.028 (-0.248)	-0.220 (-1.704)
INCOME	0.654 (6.547)	0.620 (6.162)	0.625 (6.213)	0.601 (5.948	0.600 (5.935)	0.601 (5.993)
VER78	-15.551 (-1.249)	-14.197 (-1.144)	-14.761 (-1.189)	-15.630 (1.264)	-15.675 (-1.265)	-21.887 (-1.754)
AGE		-0.309 (-2.266)	-0.355 (-2.509)	-0.352 (-2.500)	-0.350 (-2.477)	-0.341 (-2.431)
NUMCHD17			-2.080 (-1.211)	-2.585 (-1.173	-2.606 (-1.177)	-2.084 (-0.946)
INFORM				9.153 (2.073)	9.142 (2.068)	8.933 (2.037)
CAUSE					0.500 (0.114)	1.689 (0.386)
DUMR						16.225 (2.866)
R^2	0.10	0.11	0.11	0.12	0.12	0.14
F	12.29	10.95	9.38	8.71	7.61	7.79
n	444	444	444	444	444	444

[a]The numbers in parenthesis below the estimated coefficients are t-statistics for the null hypothesis of no association.

variable is statistically significant in all models and has the negative relationship that we would expect. Older individuals would benefit considerably less from the reduction in a risk that will not be experienced until 30 years later. Models 4 through 6 also show that the inclusion of an adjustment variable for whether the respondent had recently acquired information about hazardous wastes in their town had a positive and statistically significant effect on the option price amounts. This also seems intuitively plausible.

The qualitative variable (in Model 6) for the respondents who received the ranking version for the risk decrease questions is statistically significant with a positive sign. This effect may be attributable to the differences in the sequence of valuation questions. For example, in the previous section of the questionnaire, the ranking respondents were asked to value a reduction to zero for their household risks along with the intrinsic value question. Respondents receiving the direct question version for risk decreases had been asked to purchase two different levels of risk reductions as well as the risk reductions for the ecosystem. The option prices for risk increases for ranking respondents may have been influenced in some way by the certainty question. If the certainty question elicited higher values, and if the respondents "anchored" on these higher values in responding to the risk increase question, then this may account for the differences.

Alternatively, the ranking respondents may have been influenced by the dollar amounts on the ranking cards used in these risk decrease valuation exercises. If they anchored on these amounts, this also could have affected their option price bid. Clearly, this is a question to be investigated further because it may enable us to understand the process individuals used in developing their valuation responses.

12.7 IMPLICATIONS

This chapter has discussed our largely unsuccessful attempts to use a simple model to examine the influence of differences in characteristics among individuals on option price values. The principal finding of the empirical analyses of a large set of models (only a few of which have been discussed here) is that throughout all the models income is an important determinant of the valuation responses. Also encouraging is the better performance of the models estimated on the pooled sample of risk changes. Even without accounting for unequal variances among individuals, the models are generally better than ones estimated on the separate risk change samples. This suggests one direction for the further research that is presented in Chapter 13.

Finally, the attempts to include variables on health status and qualitative measures of the potential availability of avenues for adjustment in the basic model also were unsuccessful. The direction of further research involving these important considerations will require further evaluation of related research and examination of the survey results.

CHAPTER 13

VALUATION ESTIMATES FOR RISK REDUCTIONS: RESTRICTED MODELS

13.1 INTRODUCTION

The purpose of this chapter is to report the findings of further analyses of the contingent valuation responses associated with individuals' valuations of risk changes. Our primary focus is on the reported valuations for risk reductions; however, we also discuss some initial results on valuations for avoiding risk increases. This analysis is intended to suggest potential avenues for future research with the contingent valuation data.

According to the original design of our study, this report on Phase I activities would have concluded the contingent valuation analyses with the results reported in Chapters 11 and 12. However, based on the inconclusive results in Chapter 12, we felt that the second phase of the project could not be adequately planned without some indication of the results of further analysis of the contingent valuation responses. Thus, this chapter examines three dimensions of this further analysis:

1. Respecification of the models for the contingent valuation response to reflect restrictions implied by the conceptual analysis.
2. Pooling of each individual's responses to two exposure risk change questions to determine the individual's comprehension of those questions.
3. Evaluation of the procedures for determining the outlying responses to the contingent valuation questions.

13.2 GUIDE TO THE CHAPTER

Section 13.3 of this chapter provides an overview of the issues associated with the relationship between the conceptual analysis and the empirical modeling of the valuation responses. Section 13.4 discusses four econometric qualifications that apply to the analyses presented in this chapter. Section 13.5 describes our restricted model and presents estimates for models to describe the marginal values of reductions in exposure risks. Section 13.6 performs a test for the appropriateness of pooling samples of valuation responses. Section 13.7 presents estimates for the pooled sample that account for differences among individuals in their ability to comprehend the framing of the contingent commodity. Section 13.8 presents results for models of the payments to avoid risk increases. Section 13.9 evaluates procedures for determining influential observations, along with presenting some results of tests for thick-tailed distributions. Finally, Section 13.10 suggests some implications based on the results of this chapter.

13.3 OVERVIEW

Based on the conceptual analysis developed in Part I of this report, it is reasonable to expect that the initial level and the size of the reduction in the exposure risk as well as the specified level of the conditional probability of death given exposure would all influence an individual's value of reductions in hazardous waste risks. For a variety of reasons, important among them the cost of the increased complexity in the questionnaire, our design was not sufficiently detailed to allow all three of these aspects of the risk to be distinguished. Consequently, the proposed respecification of the model to be considered in this chapter interprets the valuation responses as providing the information necessary for estimating the "arc" derivatives of the planned expenditure functions described in Chapters 4 and 5. That is, this respecification interprets the contingent valuation questions as requesting the equivalent of a value for the derivative of the individual's planned expenditure function. This interpretation follows from the structure of the valuation questions. They present the individual with a risk change and ask that person to make a state-independent payment (i.e., an option price) for it.* This approach is

*The payment mechanism is explained as a change in prices and taxes. It does not identify all the specific commodities whose prices would increase. It does attempt to indicate that one could not choose to consume them and avoid the problem. Thus, our objective was to give the impression of constant increment in the effective cost of living and taxes to individuals regardless of the state of nature. To the extent individuals felt that changes in the composition of their budget would be possible or other state dependent planned expenditures could be made, then the valuations do not correspond to an option price measure of the risk change. Rather they are a change in the planned expenditure function associated with the perceived mechanisms for adjustment.

equivalent to restricting the role of the exposure risk reduction as a determinant of individuals' valuation responses.

The second dimension of further analysis evolves from the psychological literature on behavior under uncertainty and our experience with individuals' own interpretations and explanations for their behavior in these circumstances during the focus group sessions. When confronted with decisions involving uncertainty, individuals comprehend the questions differently and, given the fixed time interval of an interview, may not respond as we would expect a priori. Although this is not a new insight, it must be considered if we are to represent these responses within a single model.

While our survey format gave each respondent the same amount of explanatory information, we can expect that some individuals' responses will yield more reliable information due to their varying abilities to understand and to answer the questions. This expectation is based on a simple, and somewhat informal, model of the response process, which assumes that each individual's valuation response has two components. One component is systematic and is influenced by the information provided and the questions asked, as well as by the standard socioeconomic variables. The second component is purely random. To evaluate the reliability of responses, we assume that the greater the individual's understanding of what is asked, the smaller, ceteris paribus, will be the variance in the random error as a fraction of the variance in valuation responses.* To gauge the relevance of this logic to the survey responses, sufficient information is needed to estimate these error variances for each respondent. With several assumptions, our research design permits some crude estimates of these variances to be developed.

In the survey design, each individual was asked to provide valuation responses for two changes in the exposure risk--from an initial level (Level A) to a level (B) that was one-half the initial exposure risk and then to a level (C) that was 40 percent of this intermediate level. If these two responses can be viewed as being determined by a single model, there is some basis for

*This framework is broadly consistent with the framework recently discussed by Hanemann [1985] as a basis for modeling the process by which individuals form their contingent valuation responses. See Smith [1985a] for a discussion of the Hanemann framework.

estimating the extent of conformity of the individual's responses to that model. In this framework, an observed lack of conformity, or large residual variance, is assumed to stem from the individual's incomplete understanding the framing of the contingent commodity. Consequently, there is greater variance in the random component of the valuation responses.

By pooling responses for these two valuation responses, then, an Aitken generalized least-squares (GLS) estimator can be defined using the residuals from first-round ordinary least-squares (OLS) estimates of the model to estimate the variances in the errors attributed to each individual's responses. While there are a number of qualifying assumptions underlying this approach, it nonetheless responds to the suggestions of economists and psychologists who have used experimental studies to investigate behavior under uncertainty. In most cases these analysts have commented on the differing abilities of individuals to process information associated with risk.

The third and final aspect of the extensions discussed in this chapter concerns the sample selection activities of researchers analyzing data from contingent valuation experiments. Conventional practice has been to delete some responses, in addition to the protest bids (or refusals),* as outliers or ineffective participants in the hypothetical market assumed to be represented by the contingent valuation question. There are a variety of explanations for this practice. (See Randall, Hoehn, and Tolley [1981]; Desvousges, Smith, and Fisher [1984]; and Mendelsohn [1984] for discussion of alternative approaches.) All acknowledge that this prescreening of the data relies heavily on the analyst's judgments as to responses that are inconsistent with the contingent valuation framework based on some norm. Given the somewhat arbitrary nature of these judgments, it is important to consider this activity as a sample selection process and to evaluate the rationale used in implementing the process as well as its implications for the results. Moreover, rather than automatically deleting the outliers, explicit consideration should be given to the tendencies for skewness and thick-tailed distributions that have been observed as typical of these studies. Consequently, in the final part of our discussion of contin-

*See Chapter 11 for a definition and discussion of the characteristics of the individuals who provided protest bids.

gent valuation data prescreening we discuss the use of "tests" for thick-tailed distributions on the valuation measures used in our models.

13.4 ECONOMETRIC QUALIFICATIONS TO THE USE OF RESTRICTED MODELS

While this chapter focuses primarily on respecifying our contingent valuation response model, several technical qualifications are relevant to using these models. Although we discuss these technical aspects individually, they should not be regarded as independent considerations. They are:

1. Treatment of nonprotest zero values.
2. Selection of a functional form for the model.
3. Interaction effects between the problems posed by missing values for some variables (especially the attitudinal variables) and the problem of model selection.
4. Model selection when respondents display differences in their understanding of the contingent valuation questions.

13.4.1 <u>Nonprotest Zeros</u>

As we observed in Chapter 11, there are a number of zero bids that are not protest bids among the valuations reported for both the first and the second risk reduction questions. Tobin [1958] has shown that ordinary least squares on such samples will yield biased estimates. In addition, omitting the zero observations will not eliminate the bias.*

A Tobit maximum likelihood estimator offers one method for estimating the model. In their standard form, the assumptions for describing the likelihood function of the Tobit estimator are more acceptable when the bids are used to estimate the derivative of the planned expenditure function than when they are used as an option price equation.† While Tobit is an attractive approach

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*See Amemiya [1984] for a thorough review of the Tobit model and the implications of alternative treatment of the limit observations.

†Using a Tobit model for the levels of the valuation responses would face a conflict. The basic framework assumes that the true bids, y, are generated by a stochastic process, such as

$$y_i^* = \chi_i \alpha + \varepsilon_i$$

but that we observe y,

$$y_i = y_i^*$$ (continued)

(and will be pursued further in subsequent research), it implicitly assumes that the zero bids represent the same level of understanding of the contingent valuation questions as the positive bids. That is, all observations are assumed to come from the same framework with equal error variance. Thus, the problem posed by zero responses is treated as one of observing not the true but the unknown values of the dependent variable for bids less than and/or equal to zero. If there is reason to expect differences in these individuals' understanding of the questions relative to other respondents, it may not be a reasonable assumption. Consequently, the first and the last problems are related.

In this chapter, we use the OLS estimates to gauge the likely importance of each of these problems as well as to evaluate the potential "payoff" (in terms of increased understanding of the factors influencing an individual's marginal valuation of a risk reduction) before formulating a specific estimator to take account of any one of the problems posed by the survey responses. However, it is important to consider the likely consequences of using OLS when Tobit is appropriate. In simple cases, this is possible. For example, under the assumption that the independent variables are normally distributed and the error follows an independent normal distribution, Greene [1983] has shown that a consistent estimate of the slope parameters can be derived from the OLS

(continued)

when $y_i^* > 0$ (or equivalently some constant $\bar{y}$ in both cases), and

$$y_i = 0 \text{ when } y_i^* \leq 0 .$$

The two simplest versions of Tobit are distinguished by whether or not we observe the values of X when $y^* \leq 0$. With observation it is referred to as the censored formulation; without observation the model is simply a truncated regression model. What is at issue in our case is the interpretation of the zero responses. The valuation model may only be defined from zero to positive values. This would imply that

$$X_i\alpha \geq 0 \text{ for all } i$$

and that individuals would not report negative valuations even as a result of random errors. Consequently, we might expect that a one-sided error would more appropriately describe the process. Censoring or truncating a normally distributed error is only one way of characterizing a one-sided error. There do not appear to be compelling a priori reasons for preferring it to others. These same considerations are not as relevant to the modeling of the marginal valuation of a risk change where it might be reasonable to assume individuals would have negative marginal valuations.

estimates. The Greene approach simply scales the estimates by a constant that depends on the number of zero values for the dependent variable in the sample. This correction can be used to gauge the asymptotic bias of the OLS estimator. In our case, with 18 percent zero bids, the asymptotic bias of the estimates of the slope parameters would be approximately 0.22 (or 22 percent of the estimated value of the parameter). There are a number of reasons that this should be considered an upper bound.* Even so, it does not seem to pose an enormous problem in relation to a large and complex set of economic issues associated with valuing risk changes.

13.4.2 Functional Form

The second problem to be considered in developing these models arises from the conceptual analysis of the valuation of risk. For example, the dependent variable in our respecified models is an estimate of the marginal value of a risk change, the change in expenditures for a change in exposure risk, $\frac{\Delta E}{\Delta R}$. It is not a constant in R. Nor is it likely to be linear in R. Thus, our analysis considered a variety of functional forms for respecified models, including linear and semi-log forms. It also considered models involving Box-Cox transformations for both dependent variable and the exposure risk measure to gauge the sensitivity of the results to the degree of nonlinearity incorporated in the specification.† Although this analysis does not exhaust the potential approaches for evaluating the appropriate specification for the model, the semi-log specification was accepted as a first step in modeling the nonlinearity in the valuation function. However, using the semi-log specification required a transformation of legitimate zero bids, since $\frac{\Delta E}{\Delta R} = 0$ in these cases. A small

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*This is the maximum proportion of zero responses. As the sample size declines because of missing observations for some of the risk perception and other demographic variables, some zero responses will be omitted.

†There are clearly problems with the Box-Cox procedure. The specification of the dependent variable is not consistent with a continuous, normally distributed random variable. Since the normality assumption provided the basis for the definition of the likelihood function, it would be incorrect to consider the Box-Cox estimates as maximum likelihood estimates. Nonetheless, this transformation and iterative estimation of the transformation parameter has proved to be a fairly effective means of detecting nonlinearities. For discussions on both sides of this issue, see Amemiya and Powell [1981] and Spitzer [1982].

constant value (0.00001) was added to each estimate of the derivative to ensure that the log of ($\frac{\Delta E}{\Delta R}$) could be defined in those cases where the estimate would be zero.

Clearly, there are problems with both of these practices. For example, as noted above, the Box-Cox method is not a maximum likelihood approach to model selection and is probably best interpreted as a diagnostic index of the performance of alternative transformations of the dependent variable in a model. Equally important, the displacement in the estimated derivatives is ad hoc.* However, if the true specification is semi-log and the zero bids reflect an inadequate or incomplete understanding of the contingent valuation questions, then this practice may actually be superior to a Tobit estimator.† Clearly, there is no basis for evaluating this conjecture using the empirical estimates. Further progress in selecting a specification and an estimator will require a model that incorporates the prospects for zero responses and should be an important component of the research undertaken in the second phase of this project.

13.4.3 Missing Observations

The treatment of missing observations poses an equally difficult issue. There is a reasonably large body of literature on the treatment of missing observations and, in particular cases, some information on the relative performance of these approaches.‡ However, in all cases, these analyses assume the true specification for the model is known. In our case, this may be a particu-

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*There has been remarkably little attention given to this problem in the econometrics literature. Presumably the reason for the lack of interest in this practical problem follows from the increased availability of maximum likelihood estimators for a wide range of limited dependent variable problems. Nonetheless, it is not unambiguously clear that these approaches will always be superior to the use of OLS with adjustments. For some early discussion of this problem, see Johnson and Rausser [1971a], Burt [1971], Johnson and Rausser [1971b], and Hu [1972].

†The performance of Tobit in the presence of heteroscedasticity depends on the characterization of the model of the error structure, the extent of difference in error variances, and the extent of censoring in the sample. This issue is discussed further in Section 13.7.

‡See Maddala [1977] for a reasonably good summary of this literature. The most detailed summaries of specific results are in Afifi and Elashoff [1966, 1967, 1969].

lar problem because several of the risk perception and risk attitude variables each have a large number of observations with missing values. These factors are of considerable interest to our analysis, but often there is little a priori basis for specifying a role for these variables in relation to others.

There are at least two ways to proceed in light of missing observations. First, we could reduce the sample size to the largest number with complete observations and use this set as the basis for comparisons of alternative model specifications. Unfortunately, when all attitudinal and risk perception measures are considered, this strategy could lead to the elimination of most of the sample. Second, we could estimate each model on the sample of complete observations for its variables. However, in this case, comparison across models reflects the effects of both the differences in specified determinants and the sample size changes. Generally, we have attempted both approaches where possible in order to evaluate the differences in conclusions implied by each. In particular, we will illustrate some aspects of these differences in our discussion of the models used to describe the risk reductions individually (i.e., from Level A to Level B, and from Level B to Level C).

13.4.4 <u>Pooled Samples</u>

The use of samples that pool individuals' responses to the two risk change questions allows a GLS estimator to be applied to the pooled sample. With rather large differences in the estimated variances for the errors in responses across individuals, there are potentially large efficiency gains to be made in taking account of this heteroscedasticity. This can imply that models regarded as inadequate based on their OLS estimates can appear substantially improved with the GLS estimator. This divergence in performance implies that model evaluation using an estimator that does not take account of this heteroscedasticity may be misleading.

In summary, our analysis does not resolve either this problem or any of the three problems discussed above. It identifies them as areas needing further research before a "final" set of models that describe the factors influencing individuals' marginal valuations of risk reductions can be presented. Thus, the results reported here suggest the potential importance of pursuing these refinements and the relative influence of each of the problems on the results to date.

13.5 RESTRICTED MODELS

The objective of the contingent valuation questions requesting individuals' bids for risk reductions was to estimate the value placed on increments in exposure risk. However, it was recognized that where the process starts and what the individual assumes the exposure will imply should influence the responses given. The conceptual analysis developed in Chapters 2 through 6 highlights both direct hypotheses for specific variables and more indirect expectations for others. The presence of a wide set of these a priori expectations implies that a multivariate statistical framework would seem to be essential to the development of a full understanding of contingent valuation results.

13.5.1 The Model

While our conceptual analysis and valuation concepts have been based on the expected utility model, the structure of the questionnaire and associated research design have attempted to provide sufficient flexibility to recognize the potential role of these findings. For example, throughout this report, the discussions of individual decisionmaking under uncertainty recognize that framing can affect decisions. Individuals may use "mental shortcuts," or what Tversky and Kahneman [1974] describe as heuristics, to derive answers. A frequent example is the use of a reference point or anchor from which final judgments might be made. The level of the initial probability of exposure (or some perception of what it is in the real world) might be serving as an anchor for individuals' responses. If it is reasonable to expect that individuals do engage in what Kahneman and Tversky [1979] describe as an editing phase--i.e., organizing options and gauging probabilities before a choice is made that is ultimately based on the weighted utilities for all the outcomes at risk--then variations in the set of probabilities presented to individuals along with the specific inclusion of cases involving low-probability events may increase our understanding of this process. Moreover, under this view, attempts to determine respondents' perceptions of the events at risk should also be important to understanding these valuation responses.

The basic model used in our further analysis of the contingent valuation results is described in Equation (13.1):

$$\frac{\partial E}{\partial R} \approx \frac{\Delta E}{\Delta R} = f\ (R,\ q,\ X,\ Z)\ , \qquad (13.1)$$

where

ΔE = the contingent valuation response, which, based on the form of the contingent valuation question, is a constant, state-independent payment (i.e., an option price).

ΔR = the reduction in the likelihood of exposure to hazardous wastes.

R = postulated initial level of the individual's (or a family member's) probability of being exposed to hazardous wastes sufficient to imply a second-stage risk, q, of death.

X = a vector of variables describing the framing of the risk posed to each individual.

Z = a vector of measures of the individual's socioeconomic characteristics, measures of attitudes toward risk, effectiveness of government, and information on the subject.

Our conceptual analysis suggests that, for an option price payment, $\frac{\Delta E}{\Delta R}$ would increase with the level of the risk, R, and with income. The expectation for q would be the same as for R--a positive effect on $\frac{\Delta E}{\Delta R}$ with increases in q. However, our characterization of the relationship between the exposure and the event at risk is important to the equivalence of changes in R and q. In Chapter 5, we postulate that the health effect that could result from exposure to hazardous waste was assumed to be exclusively from that exposure. When there was no exposure, there was no risk of incurring the health effect. A change in this specification would alter the role of q in the planned expenditure function. For example, a simple reformulation of the problem would specify a nonzero risk of the health effect even when there was no exposure. This would replace Equation (5.1) from Chapter 5 with Equation (13.2):

$$EU = R[q\ V_1\ (W_1) + (1\text{-}q)\ V_2\ (W_2)] + (1\text{-}R)\ [\pi V_1(W_1) + (1\text{-}\pi)\ V_2\ (W_2)] \quad (13.2)$$

Rearranging terms, Equation (5.1) can be written as follows:

$$EU = (Rq + (1\text{-}R)\pi)\ V_1\ (W_1) + (R(1\text{-}q) + (1\text{-}R)(1\text{-}\pi))V_2\ (W_2)\ . \quad (13.3)$$

Under this specification, the planned expenditure function would include π, and the behavior of $\frac{\Delta E}{\Delta R}$ with respect to changes in R and q would not be equivalent. Indeed, this specification is similar to the form used for the expected utility in Freeman's [forthcoming b] definition of option price in the presence of both supply and demand uncertainty. Not only does this change complicate the analysis of our valuation concepts, but it implies that the valuation of risk changes associated with hazardous wastes cannot be treated in isolation from the other risks of death an individual faces.

Based on the experience with contingent valuation experiments to date, and especially the attempts to measure the value of one public good while recognizing the existence and potential for differences in the levels of others, and based on the difficulties of communicating a single risk to individuals in the focus groups, this refinement seems beyond our current survey abilities. However, this does not mean it can be ignored. Rather, proxy variables reflecting an individual's health status, actions associated with other activities that affect the risk of death, and occupation (for job-related risks) all can be considered in attempts to understand the valuation responses.

Beyond these a priori expectations, our remaining hypotheses for variables in the model are largely informal. Given the nature of the time horizon specified for the health effect to be fully realized (i.e., for the individual to die), we would expect that the payment would decrease with the individual's age.* We also expect that it would increase with the number of children at home.

Since increases in risk aversion should increase the rate of change in $\frac{\Delta E}{\Delta R}$ with R,† we would expect that if a variable measuring an individual's desire

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*The reason for this hypothesis stems from our explanation of the event at risk. It was suggested to each individual that exposure led to a risk of death in 30 years. Older individuals may well condition their response based on their expected lifetime. Under this view, a 30-year-old individual at the time of the proposed exposure would be more concerned about this risk than one 70 years old. An alternative hypothesis, which was also supported in some focus group sessions, is that older respondents based their bids on concern for children and grandchildren. This might imply an interaction effect between age and size of extended family, especially if those family members lived near the hazardous waste facility.

†This result can be seen with some manipulation of the second partial derivative of the marginal valuation with respect to R when an option price is specified as the payment mechanism. The slope of the marginal valuation function for an option price bid can be directly related to the Arrow-Pratt index of absolute risk aversion for one of the state-dependent utility functions.

to participate in gambles accurately measures risk aversion, then the estimated impact of this variable would be negative for $\frac{\Delta E}{\Delta R}$. This qualification is important. To the extent individuals treat different types of risk differently, then we cannot expect that their responses favoring one form of risk-taking behavior will necessarily transfer to another. Unfortunately, this implies that we cannot formulate a clearcut hypothesis on an index of risk-taking behavior without first accepting a questionable (based on an increasing body of psychological research) assumption as a maintained hypothesis.

Several of these same issues are relevant to the "unrestricted" estimates and models presented in Chapters 11 and 12 and may partially explain the disappointing experience with the models reported in Chapter 12. It is clear that prior information has a fairly limited role in determining the specific variables to be considered and the a priori expectations for their effects on the valuation responses. Consequently, analysis of these results requires searching a wide range of specifications and progressive refinements in the model formulation based on the results of that process. This is certainly not a new practice in empirical research in the social sciences generally and economics in particular. Nonetheless, it is a practice that has received increasing criticism. (See Leamer [1983] for a largely informal discussion of the deficiencies in such conventional practices.) At the same time, to dismiss the practice completely is to reject the learning that can take place from such analyses of sample information. This point was made by Theil [1961] 25 years ago. What is really at issue is explaining the process used and the factors in that process that might impinge on what are reported as the "final" results.

The overall sequence of steps in our analysis of the valuation responses corresponds to the structuring of the three chapters that describe the results. The initial analysis was confined to evaluation of the summary descriptive statistics and test results in Chapter 11, then multivariate regression analysis of these responses using models that were linear in variables and parameters. The results we now report are the beginning of the final stage of the process. As we noted at the outset, they involve restricting the form of the models used with the survey data and reexamining the conclusions derived on the determinants of the valuation responses.

13.5.2 Estimates for Marginal Valuation of Exposure Risk Reduction

Table 13-1 reports a selection of the estimates for the semi-log models--i.e., the dependent variable is log $(\frac{\Delta E}{\Delta R})$--for the marginal valuation of risk reductions as a function of a variety of variables. The variable definitions are given in Table 13-2. Several general observations can be made with respect to these models. First, separate equations were estimated for the first and the second risk reductions proposed to each respondent. Second, in contrast to our discussion of the form of the model at the outset of this section, the conditional probability of death given exposure to hazardous waste was not included in any of these models. It was never found to be a statistically significant determinant of the marginal valuation. Table F-1 in Appendix F repeats these models with this variable included.

Overall, these estimates identify several statistically significant determinants of the marginal valuations. Four variables deserve particular attention. Income is generally a significant influence on the marginal valuation. While there are two cases for the risk change from A to B where it would not be judged to be significant using conventional criteria, the estimated parameter for income is quite stable across all models including those for the second risk change (i.e., from B to C).

The exposure risk is not a positive influence on the marginal valuation as our theoretical analysis for the case of an option price predicted. Marginal valuations appear to decline with increases in the exposure risk, but do so at a decreasing rate. It should be noted that the deletion of the squared term for the exposure risk does not change the negative estimate for this term. This quadratic term was included in an attempt to investigate whether or not these reductions in marginal valuations were continuous over the full range of probabilities we considered. The positive effect of the quadratic term would be consistent with a change in direction of the change in the marginal valuation as the level of exposure risk increased.

This finding of a negative effect for the level of exposure risk was clearly not expected a priori. While our conceptual analysis can provide an explanation for this outcome, it requires that we assume individuals have opportunities outside those posed in the contingent valuation question to make state-dependent adjustments in response to the risk changes posed to them. This

TABLE 13-1. MODELS FOR MARGINAL VALUATION OF EXPOSURE RISK REDUCTIONS: COMMON SAMPLE[a]

Model variables and summary statistics	Models for Level A to Level B risk change				Models for Level B to Level C risk change			
	1	2	3	4	1	2	3	4
Intercept	0.214 (0.544)	0.156 (0.391)	-0.128 (-0.259)	-0.268 (-0.544)	0.095 (0.215)	0.080 (0.178)	-0.187 (-0.333)	-0.306 (-0.536)
EXP	-0.024 (-2.913)	-0.024 (-2.884)	-0.023 (-2.799)	-0.022 (-2.671)	-0.045 (-2.504)	-0.045 (-2.511)	-0.044 (-2.443)	-0.042 (-2.330)
EXP^2	0.054×10^{-3} (1.596)	0.054×10^{-3} (1.586)	0.052×10^{-3} (1.513)	0.049×10^{-3} (1.429)	0.177×10^{-3} (1.217)	0.182×10^{-3} (1.243)	0.180×10^{-3} (1.212)	0.172×10^{-3} (1.157)
NUMCHD17	--	--	-0.009 (-0.093)	--	--	--	-.003 (0.025)	--
INCOME	0.011 (2.422)	0.010 (2.235)	0.009 (1.769)	0.009 (1.820)	0.011 (2.389)	0.011 (2.187)	0.011 (1.994)	0.012 (2.197)
VER78	1.611 (4.040)	1.628 (4.056)	1.642 (4.062)	1.670 (4.114)	1.840 (4.161)	1.854 (4.159)	1.882 (4.176)	1.938 (4.250)
Acton	--	0.168 (0.868)	0.154 (0.790)	0.217 (1.088)	--	0.185 (0.879)	0.168 (0.783)	0.184 (0.830)
Cambridge	--	--	--	0.158 (0.347)	--	--	--	-0.274 (-0.609)
Kingston	--	--	--	1.408 (1.143)	--	--	--	1.384 (1.138)
Salem	--	--	--	0.702 (0.972)	--	--	--	0.376 (0.525)
Woburn	--	--	--	1.020 (1.375)	--	--	--	0.490 (0.659)
Age	--	--	0.005 (0.651)	0.004 (0.550)	--	--	0.006 (0.703)	0.006 (0.634)
GEFF	--	--	0.131 (0.293)	0.030 (0.066)	--	--	0.622 (1.256)	0.588 (1.152)
RISK-ATT	--	--	0.247 (1.297)	0.291 (1.506)	--	--	0.024 (0.112)	0.025 (0.115)
REL-RISK	--	0.008 (0.575)	0.006 (0.441)	0.007 (0.531)	--	-0.035 (-0.495)	-0.089 (-1.093)	-0.078 (-0.944)
R^2	0.633	0.635	0.641	0.649	0.674	0.677	0.683	0.688
F	75.05	49.930	29.942	23.482	70.32	46.744	27.942	21.586
n	178	178	178	178	140	140	140	140
s^2	1.448	1.456	1.469	1.460	1.371	1.380	1.397	1.403

[a]The numbers in parentheses below the estimated coefficients are t-statistics for the null hypothesis of no association.

TABLE 13-2. DEFINITION OF VARIABLES

Variable name	Definition
EXP	Exposure risk at the starting point for the risk change (i.e., A for the first risk change, B for the second) multiplied by 1,000.
NUMCHD17	Number of children in the household under 17.
INCOME	Household income in thousands of dollars.
VER78	Qualitative variable that is unity for the low probability design points (versions 7 and 8 of the contingent valuation questionnaires) and zero otherwise.
Acton, Cambridge, Kingston, Salem, Woburn	Qualitative variables that equal unity if the respondent is a resident of the relevant town, zero otherwise.
Age	Age of the respondent in years.
GEFF	A qualitative variable measuring individual's perception of government effectiveness, equal unity if government is considered <u>not</u> at all effective, zero otherwise.
RISK-ATT	An index of attitude toward risk based on individual's responses to a hypothetical lottery with constant expected value; a value of unity corresponds to an individual who is perceived as liking risk, zero otherwise.
REL-RISK	A measure of individual's ability to perceive risk; ratio of risk of death perceived by individual in comparison to estimate of actual risk of death from accidents on the job.
COND-RISK	Conditional probability of death given exposure that was postulated to individual, multiplied by 1,000.
INFORM	Qualitative variable = 1 if individual recalled reading about hazardous wastes in news articles and the information involved his town.
GOVT	Qualitative variable equal to 1 if individual received versions of the questionnaire with Section G specified as the Federal Government has decided to allow the risk increase

explanation may be plausible. However, it is more difficult to interpret given the positive estimated parameter for the VER78 qualitative variable (i.e., VER78 = 1 for the low-exposure probability cases and 0 otherwise). This variable was included to investigate whether the low-probability design points (i.e., design points D7 and D8) elicited a different type of response than the higher probability cases (i.e., design points D1 through D6). The positive statistically significant coefficient for this variable with all models indicates that individuals appear to have a higher marginal valuation in these cases in comparison to the higher probability cases (i.e., those with probabilities 10 times larger). This does seem to conform with arguments of psychologists, most notably Kahneman and Tversky [1979], that individuals have difficulty in dealing with low-probability events, and respond differently in these cases. Nonetheless, these findings must be interpreted cautiously. As we observe in Chapter 8, risk circles were used to convey the probabilities associated with the risk reductions that were asked in each contingent valuation question. In the case of the low-probability design points, it was not possible to display darkened areas for all three probabilities. Figures 13-1 and 13-2 repeat the risk cards used for these design points. As shown, the combined risk circles are blank in all cases; respondents were told that the probabilities on them were too small to display. Nonetheless, it may lead to differences in their responses in comparison to cases where probabilities can be displayed that are not easily explained within conventional models.

This difference in the materials used with the questionnaire for these low-probability design points was investigated in several video-taped interviews as part of the process of evaluating the final questionnaire. In those interviews, it did not appear to influence the respondents' understanding of what was asked. However, this estimated positive effect could be a reflection of the difference in the materials used to explain the risk changes.

Kahneman and Tversky's [1979] analysis would explain this positive effect through their probability weighting function, which is assumed to describe how individuals translate probability information into their perceived likelihood of certain events. Instead of the objective probabilities used in the expected utility framework, the Kahneman-Tversky framework uses these weights to combine the values realized under different states of the world. Based on

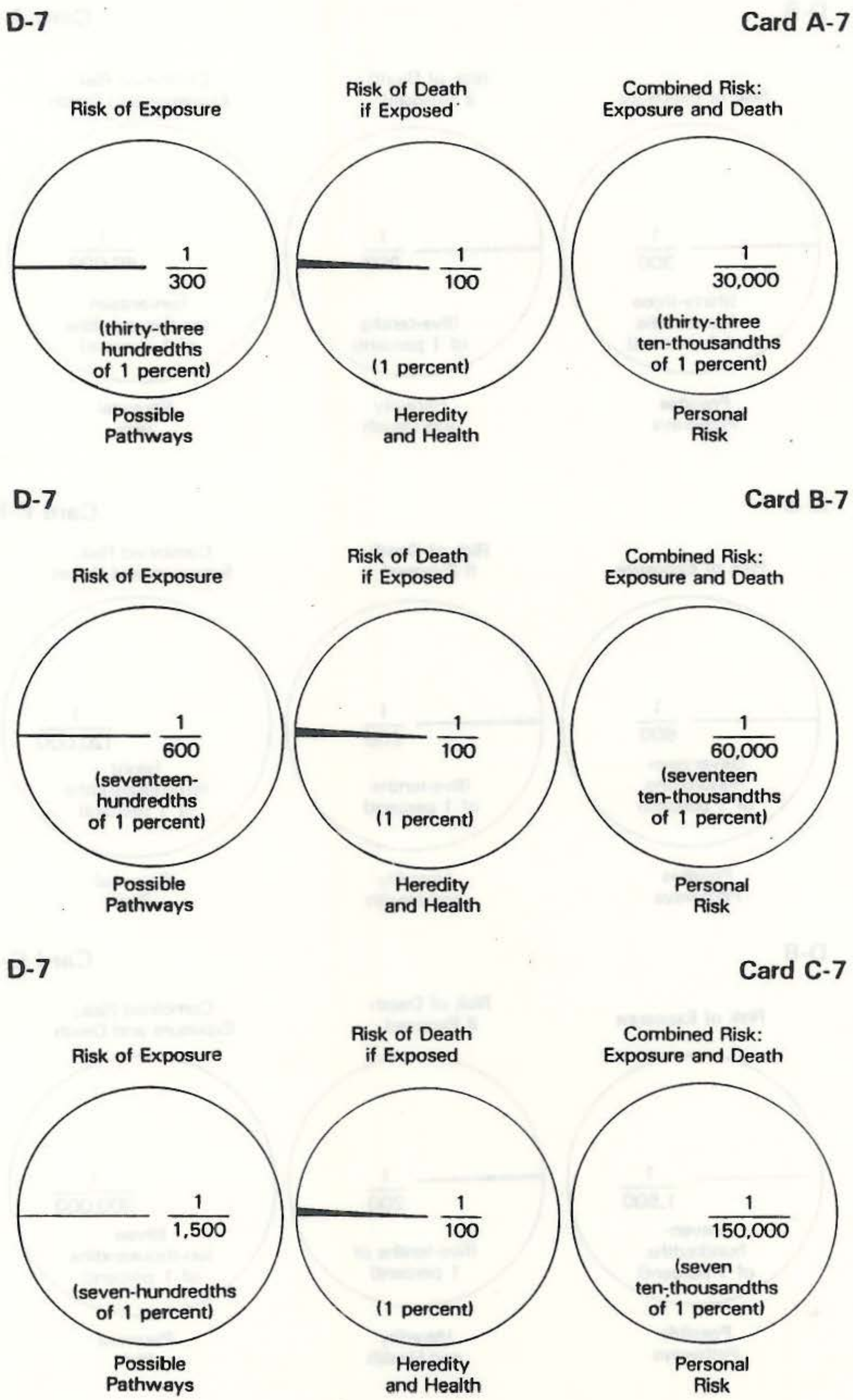

Figure 13-1. Examples of low probability risk cards: design point 7.

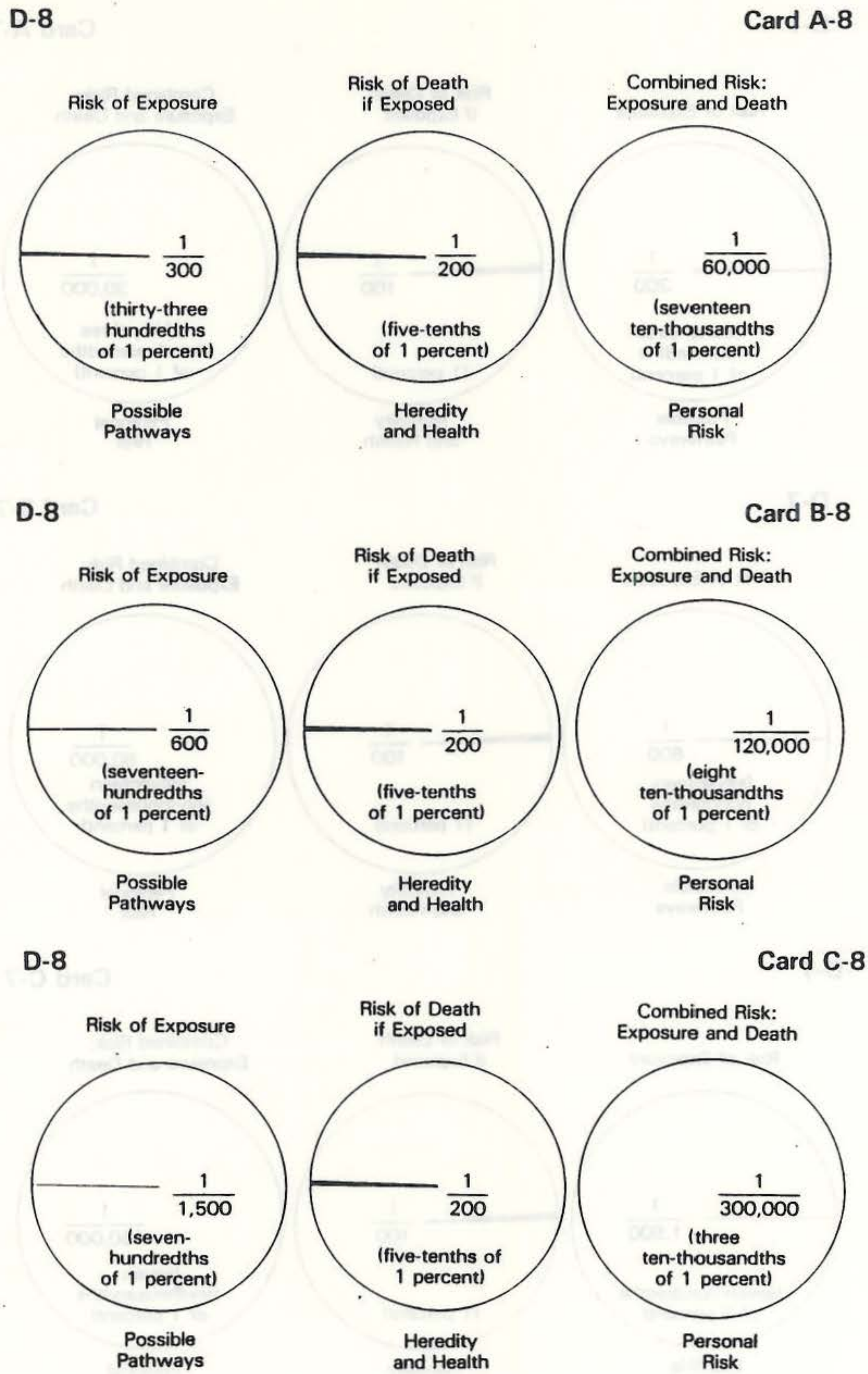

Figure 13-2. Examples of low probability risk cards: design point 8.

their experimental evidence, Kahneman and Tversky have suggested that low probabilities are generally overweighted and high ones underweighted.

An alternative explanation, consistent with the expected utility model, would suggest that individuals have differential confidence in probabilities that are presented to them. That is, each is implicitly regarded as an estimate with a corresponding density function. Low-probability events are rare. Therefore, it would be entirely reasonable to expect that they are less precisely estimated. This would imply greater second-order uncertainty with the low-probability cases and the positive coefficient for VER78 as a reflection of individuals' responses to this perceived uncertainty. At this stage of our conceptual analysis both of these explanations are observationally equivalent. Further conceptual and empirical research will be necessary to explain these differential responses to the low-probability events.

The remaining variables in these models do not appear to exert significant effects on the marginal valuations. Our age and number of children (NUMCHD17) variables have estimated parameters that are inconsistent with our a priori expectations but are not significantly different from zero. The risk attitude (RISK-ATT) and risk perception measures (REL-RISK) are not significantly different from zero. A qualitative variable for whether the respondents have little confidence in government effectiveness (GEFF) does not appear to be a significant determinant of the marginal valuations. This finding was somewhat surprising because these attitudes were found in the focus groups to be closely associated with the individual's willingness to support regulations that would reduce exposure risks from hazardous wastes. In effect, those individuals with confidence seemed more willing to believe that government could "deliver" the risk reductions specified.

Finally, some of the models include qualitative variables for the towns in our survey area that had disposal sites with hazardous wastes as of 1982 (see Chapter 15 for a specific identification). As we observe in Chapter 10, there has been a great deal of information on hazardous wastes in this region. Indeed, Acton residents in particular have had a decade of experience with contamination episodes (see Table 10-4, for example). However, none of these town variables appeared to influence these marginal valuations.

The missing observations problem identified earlier can be easily illustrated with these results. All of the models reported in Table 13-1 for the first risk reduction (i.e., A to B) were estimated using the same sample by reducing it to the set consisting of complete information on all of the variables of interest. Had the process been treated differently, the resulting estimates would have been quite different. Consider, for example, the simplest model for A to B in Table 13-1 (Model 1). Reestimating this model with the sample containing full information for this variable produces the results in the first column of Table 13-3. There is a 58-percent increase in the sample size and substantial changes in the estimated parameters. The most notable of these is the change in the magnitude and statistical significance of the qualitative variable, VER78, intended to identify the responses corresponding to the low-probability scenarios. The same differences arise for the second risk change from B to C and are given in the second column of the table.

It is also interesting to note that these results reinforce the inclusion of the linear and quadratic terms in the exposure risk. Clearly, if this simple specification is regarded as the final form of the model for the marginal valuation of risk reductions, the results based on the larger sample would be preferred. However, the decision is not as clear for the problem of comparing results across models. As we observed earlier, there is the further problem of differential understanding of what has been asked and the potential for heteroscedasticity. Indeed, this problem appears to dominate the missing observation issue in terms of its importance for model selection. Thus, as a practical matter, we shall argue that model comparisons should be based on the pooled, GLS estimates of each model. Only these estimates take account of the potential for differential understanding across respondents and reflect the full available sample information. Of course, these comparisons will need to recognize the potential effects of differences in the sample sizes for the apparent performance of each specification.

13.6 POOLED RESPONSES OF RISK CHANGE VALUES

The estimates reported in Tables 13-1 and 13-3 are not without value. They can be used to gauge whether pooling responses to the two risk reduction questions is warranted based on the estimated parameters for the variables of greatest interest to this analysis. That is, since we have argued that the

TABLE 13-3. MODELS FOR MARGINAL VALUATION OF EXPOSURE RISK REDUCTION: SPECIFIC SAMPLE[a]

Model variables and summary statistics	Model: Level A to Level B risk change	Model: Level B to Level C risk change	Model: Pooled risk changes
Intercept	-3.124 (-2.800)	-4.090 (-2.907)	-4.090 (-5.549)
EXP	-0.050 (-2.218)	-0.033 (-0.560)	-0.032 (-2.148)
EXP^2	0.197×10^{-3} (2.114)	0.168×10^{-3} (0.350)	0.143×10^{-3} (2.156)
INCOME	0.069 (6.026)	0.044 (2.857)	0.057 (6.134)
VER78	0.074 (0.067)	1.278 (0.908)	1.131 (1.531)
R^2	0.151	0.074	0.104
F	12.355	4.544	14.872
n	282	233	516
s^2	18.326	23.937	20.952

[a]The numbers in parentheses below the estimated coefficients are t-statistics for the null hypothesis of no association.

selection of a final model must be made within a framework that takes account of the potential for differences in the understanding of the contingent valuation questions across individuals, we cannot select a specification based on the individual responses to each question. To do so requires that we first test whether the model for responses to the first question appears different from the model for responses to the second question. This type of test would involve a Chow test. However, it requires that the model specification be known in advance.*

For this preliminary analysis, we have used the Tiao-Goldberger [1962] test for stability in individual coefficients of a larger model across alternative estimates of that model (i.e., one for each sample). In this case, it provides the basis for comparing the models associated with the two risk changes.

The specific test statistic is given in Equation (13.4):

$$TG = \frac{\sum_{j=1}^{L} \frac{(\hat{b}_j - \bar{b})^2}{P_j}}{\sum_{j=1}^{L} SSR_j} \cdot \left(\frac{\sum_{j=1}^{L} (T_j - K)}{L - 1} \right) , \tag{13.4}$$

where

L = number of distinct models

b_j = OLS estimate of a parameter from the jth sample

$\bar{b}$ = weighted average of the OLS estimate defined in (13.5) below

P_j = diagonal element of $(X^T X)_j^{-1}$ for the relevant parameter

SSR_j = sum of squared residuals for jth sample

T_j = number of observations in jth sample

K = number of parameters in each model .

Equation (13.5) defines the weighted average of the OLS estimate:

$$\bar{b} = \frac{\sum_{j=1}^{L} (\hat{b}_j / P_j)}{\sum_{j=1}^{L} (1/P_j)} . \tag{13.5}$$

---

*It also assumes homoscedasticity in the errors.

Under the null hypothesis of equality of parameters, TG follows an F distribution with degrees of freedom (L-1) and $\sum_{j=1}^{L} (T_j - K)$. This test was applied to all pairs of parameters from comparable specifications for the models used with the two risk changes. The estimated parameters in Table 13-1 in Models 1 through 4 for the risk change from A to B and those for the corresponding models for the change from B to C do not lead to rejection of the null hypothesis of equality. Moreover, this conclusion does not appear to be affected by allowing the sample size to be different for each model. While we did not consider all of the models in Table 13-1, those that were considered, including the models in Table 13-2, lead to the same conclusions. Consequently, on the basis of the available information, pooling the responses across the two risk changes should provide a reasonable basis for estimating the degree of respondent comprehension of the contingent valuation questions.

13.7 RESTRICTED MODELS: POOLED SAMPLE AND GLS ESTIMATES

Table 13-4 presents the estimated marginal valuation equations based on pooling the responses to the two risk change questions. Each model was estimated with the largest number of complete observations. All of the variables described for the individual analysis of each risk change have been considered, along with some additional variables that were not found to be statistically significant in those initial specifications. They were reconsidered because we have argued that the selection of a final specification requires that the heteroscedasticity induced by differences in the understanding of the contingent valuation questions be taken into account with model specification. The models in Table 13-4 represent the first step in the development of the GLS estimates. They provide the basis for estimating the residuals associated with each respondent's valuation responses. For those individuals answering both questions there are two estimates of the residuals. These are used to estimate the residual variance as follows:

$$\sum_{i=1}^{2} (\hat{\varepsilon}_{ik} - \bar{\hat{\varepsilon}}_k)^2 ,$$

TABLE 13-4. ORDINARY LEAST-SQUARES ESTIMATES OF MARGINAL VALUATION MODELS: POOLED SAMPLE[a]

Model variables and summary statistics	Model 1	2	3	4	5	6	7
Intercept	-4.090 (-5.549)	-4.207 (5.708)	-2.853 (-3.625)	-2.271 (-2.184)	-2.320 (-2.193)	-2.438 (-2.340)	-2.311 (-1.738)
INCOME	0.056 (6.134)	0.052 (5.470)	0.027 (2.509)	0.026 (2.277)	0.025 (2.210)	0.026 (2.240)	0.022 (1.910)
EXP	-0.032 (-2.148)	-0.032 (-2.118)	-0.021 (-1.328)	-0.017 (-1.063)	-0.017 (-1.054)	-0.016 (-0.966)	-0.015 (-0.886)
EXP^2	0.143×10^{-3} (2.156)	0.141×10^{-3} (2.131)	0.087×10^{-3} (1.229)	0.075×10^{-3} (1.052)	0.075×10^{-3} (1.044)	0.071×10^{-3} (0.984)	0.069×10^{-3} (0.948)
VER78	1.131 (1.531)	1.153 (1.565)	1.976 (2.525)	2.144 (2.687)	2.148 (2.687)	2.138 (2.654)	2.036 (1.851)
Acton	--	0.923 (2.039)	--	0.588 (1.258)	0.583 (1.245)	0.787 (1.638)	1.254 (2.172)
REL-RISK	--	--	-0.024 (-0.742)	-0.028 (-0.861)	-0.029 (-0.029)	-0.025 (-0.761)	-0.027 (-0.821)
Age	--	--	--	-0.028 (-1.548)	-0.029 (-1.554)	-0.032 (-1.681)	-0.026 (-1.328)
RISK-ATT	--	--	--	--	0.117 (0.260)	0.164 (0.361)	0.209 (0.456)
GEFF	--	--	--	1.895 (1.800)	1.885 (1.786)	1.702 (1.588)	1.502 (1.369)
Cambridge	--	--	--	--	--	0.901 (0.839)	1.235 (1.123)
Salem	--	--	--	--	--	1.783 (1.090)	1.827 (1.109)
Woburn	--	--	--	--	--	1.548 (0.932)	2.005 (1.188)
Kingston	--	--	--	--	--	3.778 (1.254)	4.652 (1.519)
NUMCHD17	--	--	--	0.097 (0.435)	0.103 (0.456)	--	0.129 (0.565)
INFORM	--	--	--	--	--	--	-0.827 (-1.534)
COND-RISK	--	--	--	--	--	--	-0.003 (-0.312)
R^2	0.104	0.111	0.090	0.107	0.107	0.117	0.123
F	14.872	12.80	7.45	4.874	4.382	3.67	3.156
n	516	516	381	375	375	375	375
s^2	20.952	20.823	17.527	17.545	17.589	17.549	17.560

[a]The numbers below the coefficients are t-ratios for the null hypothesis of no association.

where

k = the subscript to identify each respondent

$\hat{\varepsilon}_{ik}$ = the estimated residual for respondent k to risk change

$I,\bar{\varepsilon}_{ik}$ = the average value of the residual for respondent k.

Two estimates of these residuals were considered in forming the GLS estimates for each model. The first was based on the OLS residuals and the second on a scaled residual that, under the assumption of homoscedastic errors, would have a scalar covariance matrix.* Since there are not substantial differences in the resulting GLS estimates between the two estimated covariances, only those based on the OLS residuals are reported in the following discussion.

Before turning to the GLS results, aspects of these pooled OLS results deserve attention. Income remains a positive and statistically significant determinant of the marginal valuation. However, the estimated effect for income is substantially larger than those reported in Table 13-1 with either risk change using the more limited subsets of the data. It is more consistent with the results observed with the larger samples as reported in Table 13-3. Indeed,

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*The OLS residuals will not have constant variance. If e_i designates the OLS residual, the variance in e_i is given as

$$\text{Var}(e_i) = \sigma^2 (1-h_i) ,$$

where

$h_i = x_i (X^T X)^{-1} x_i^T$

x_i = ith row of matrix X

X = TXK matrix of regressors used in model to derive the model used to form the OLS residual.

The scaled residuals are the studentized residuals:

$$\hat{e}_i = \frac{e_i}{s(i)\sqrt{1-h_i}} ,$$

where s(i) is the standard deviation of the residuals omitting the ith observation. If the error structure has constant variance, the studentized residuals will also have constant variance. See Belsley, Kuh, and Welsch [1980] for further discussion.

the pooled results for the simplest model are repeated in that table for comparison purposes. The same pattern also characterizes the results with the exposure probability variables for the models associated with responses to the first risk change question. The estimated parameters have the same sign pattern but the absolute magnitude of the measured effects is larger for the model estimated with larger samples. The estimated parameter for the qualitative variable associated with the low-probability design points is also somewhat unstable across the alternative samples. However, in this case, the estimated parameters are larger with the smaller sample. Again, this problem seems to be confined to the models for the valuation responses to the first risk change question.

Table 13-5 reports the GLS estimates for the same models. Clearly there are rather substantial differences in the ability of the model to "explain" the determinants of these estimated marginal valuations. The absolute magnitude of the income effect tends to rise with the number of variables included in the model, but in all cases falls within the range of estimates derived from the analysis of the subsamples with OLS. The absolute magnitude of the exposure probability effects declines with the inclusion of additional variables. The signs conform to the earlier results.

In contrast to those earlier findings, a large number of factors appear, based on the GLS results, to influence the marginal valuations. A few variables will be discussed in particular. One notable change is the negative and statistical significant effect for the conditional probability. Had we relied exclusively on the OLS results, the models would have remained very simple (i.e., similar to Models 1 through 3 in Table 13-5). With the OLS results, this variable was never a statistically significant determinant of the marginal valuation. These estimates contradict our a priori expectations, indicating that higher levels of "susceptibility," as might be implied by a higher conditional probability, reduce an individual's marginal valuation.*

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*They are, however, consistent with the results with the estimated means for the valuations of risk changes for the design points with comparable exposure risk changes and differing conditional risks. See Chapter 11 and Figures 11-7 and 11-8.

TABLE 13-5. GENERALIZED LEAST-SQUARES ESTIMATES OF MARGINAL VALUATION MODELS[a]

Model variables and summary statistics	Model 1	2	3	4	5	6	7
Intercept	-0.018 (-0.074)	-0.165 (-0.573)	-0.282 (-1.003)	-0.665 (-1.944)	-0.761 (-2.286)	-2.187 (-7.484)	-2.536 (-10.380)
INCOME	0.017 (6.065)	0.012 (4.167)	0.019 (5.615)	0.039 (12.418)	0.038 (12.229)	0.049 (18.284)	0.051 (20.261)
EXP	-0.051 (-11.222)	-0.043 (-7.631)	-0.044 (-9.116)	-0.036 (-8.304)	-0.037 (-8.732)	-0.025 (-6.880)	-0.017 (-14.927)
EXP^2	0.201×10^{-3} (10.060)	0.175×10^{-3} (6.451)	0.164×10^{-3} (8.237)	0.127×10^{-3} (7.172)	0.130×10^{-3} (7.441)	0.090×10^{-3} (5.819)	0.075×10^{-3} (18.502)
VER78	1.578 (3.900)	1.959 (3.587)	1.623 (5.180)	1.456 (5.642)	1.445 (5.737)	1.760 (7.351)	1.773 (7.680)
Acton	--	-0.487 (-3.701)	--	0.218 (1.660)	0.118 (0.917)	0.301 (2.204)	0.504 (3.399)
REL-RISK	--	--	0.118 (3.324)	-0.044 (-0.700)	-0.078 (-1.279)	-0.049 (-0.754)	-0.049 (-0.759)
Age	--	--	--	-0.008 (-1.302)	-0.010 (-1.812)	-0.003 (-0.498)	0.015 (2.328)
RISK-ATT	--	--	--	--	0.554 (4.479)	0.496 (4.058)	-0.036 (-0.287)
GEFF	--	--	--	1.003 (2.161)	1.014 (2.243)	0.796 (1.729)	1.118 (2.584)
Cambridge	--	--	--	--	--	-0.229 (-0.890)	-0.442 (-1.480)
Salem	--	--	--	--	--	1.263 (1.827)	1.249 (1.918)
Woburn	--	--	--	--	--	1.277 (2.422)	0.991 (1.955)
Kingston	--	--	--	--	--	2.000 (2.121)	3.368 (3.858)
NUMCHD17	--	--	--	-0.235 (-3.799)	-0.179 (-2.893)	--	-0.143 (-2.164)
INFORM	--	--	--	--	--	--	-0.260 (-1.883)
COND-RISK	--	--	--	--	--	--	-0.010 (-4.284)
R^2	0.394	0.264	0.555	0.693	0.708	0.787	0.987
F	75.33	33.06	89.297	87.306	84.183	97.601	1552.57
n	467	467	363	357	357	357	357

[a]The numbers in parentheses below the estimated coefficients are the ratios of the parameter estimate to the estimated standard error and follow normal distribution asymptotically.

There are a variety of potential explanations of these results, including incomplete understanding of the role of the conditional probability in the process; a form of cognitive dissonance such that individuals assigned higher conditional probabilities were unwilling to accept them as relevant to their specific circumstances; or the ability to take actions to mitigate the effects of these risks which implies state-dependent adjustments. Clearly, there may also be others. At this stage, we cannot discriminate between them. However, it should also be acknowledged that the negative sign for the conditional risk measure appears to be relatively sensitive to model specification. Table F-2 in Appendix F reports a selected set of the simpler models estimated with generalized least squares but expanded to include this variable.

The estimated effects for age and the number of children less than 17 years old in our most detailed model (Model 7 in Table 13-5) are also contrary to our a priori expectations, although, in both cases, there are plausible arguments to explain these measured effects. For example, the larger the number of children under 17, the greater the demand on household income and hence the lower the ability to pay. This effect could easily be expected to affect both the level of feasible payments and the marginal increment to those payments with a further reduction in risk.

The qualitative variable associated with the individual's lack of confidence in government's effectiveness has a positive and statistically significant effect on the marginal valuation contrary to what we would have anticipated based on the focus group sessions. Of course, it should be acknowledged that the coding of this variable focused on the lowest extreme in perceived ineffectiveness on a scale from 1 to 10. Further analysis will be necessary of the implications of how this and other attitude variables are used in understanding the determinants of the valuation responses.

One more encouraging result concerns information-related variables. Where the variables measuring familiarity with hazardous waste--the information variable and the qualitative variables for residents in towns with hazardous waste facilities--are statistically significant, they generally exhibit a plausible association with the marginal valuation. Neither the risk perception nor the risk attitude variables were significant determinants of the marginal valuation in the most detailed model. While they did appear to be statistically significant determinants for other specifications, the signs of the measured parameters changed with the model and were opposite to those in the most detailed model. It is difficult to evaluate the implications of this instability with our available information.

However, in both cases, improvement in the information used in these measures is possible. At present the variables are fairly crude attempts to reflect these influences. Other potential specifications for the risk attitude information are possible and need to be explored. For example, the individual's perceived risk of a fatal accident on the job is compared with an approximate estimate of the actual risk. This latter variable can clearly be improved upon. Moreover, greater attention should be given to individuals reactions to differences between their risk perceptions and risk information. These reactions should be important to individuals' valuations of risk reductions. Overall, these findings are clearly supportive of the need for and potential payoff to further research with these restricted models. It seems reasonable to expect that this further analysis will need to incorporate explicitly adjustment for heteroscedasticity with the estimation of the model. Thus, application of a standard Tobit estimator would lead to inconsistent estimates. Indeed, there may be little basis for preferring this approach over GLS. Based on a much simpler model, Arabmazar and Schmidt [1981], for example, found that the severity of the impact of heteroscedasticity depended on the nature of the differences in error variances and the extent of censoring in the sample. Variance differences less than a factor of two and/or censoring of more than half of the sample are the thresholds that they suggest. As we observed earlier, our sample clearly falls within the range for censoring with 18 percent of the sample for the first risk change and a much smaller percentage of the pooled sample exhibiting a zero bid.*

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*The fraction declines with the pooled samples because of the questionnaire design. If individuals responded zero to the first risk change, they were not asked the second risk change as a change from level B to C but were asked instead for the complete change from A to C. These responses are analyzed differently in our summary statistics. Therefore, we add two observations for all positive responses and only one for the zero responses, reducing substantially the share of the sample that is zero response.

At present the GLS sample is composed primarily of nonzero responses because of the question sequence. Only zero responses to the second risk change were included. A zero response to the first risk change altered the questioning format. Further analysis will be necessary to determine whether these observations can be included in the pooled sample. Regardless of the treatment of the zero observations, heteroscedasticity seems to be a very important problem. The differences in the estimated sample variances are pronounced, greatly exceeding a factor of two. Nonetheless, with two responses per individual, it should be possible to develop a maximum likelihood estimator that accounts for the zero responses and the heteroscedasticity.

13.8 MODELING THE PAYMENT TO AVOID A RISK INCREASE

This section presents some initial results from an application of the model for describing the estimated marginal valuations of risk reductions to the request for payments to avoid risk increases. These increases were described using the same endpoints for the level of exposure probabilities as for the risk reductions. However, as described in Chapter 11, they were discussed in separate sections of the questionnaire. Individuals were informed that these were completely different situations.

The design of the questionnaire and the survey implies that all respondents--i.e., the full sample--were asked a question indicating that a medium-sized company was located in their town, 3 miles from their home. This company was described as producing hazardous wastes and disposing of them in a landfill on the site. Individuals were shown the risk card corresponding to the lowest level of risk in their design (card C for the contingent valuation questionnaires and card C for the contingent ranking questionnaires). A change in the volume of the wastes placed at the site was to be allowed. This change was described as providing the prospect of increasing risk to the highest level for the particular design point (card A). Individuals were then asked what they would be willing to pay to avoid the increase in risk. These responses are the valuations considered in the models presented in this section. Two further points should be noted, when the risk change was explained to respondents, it was described as being permitted by "the government" or "your town council." Recall that we discussed the implications of this distinction for the mean bids in Chapter 11. (The complete text of the question is available in Chapter 11.)

We did not attempt a detailed analysis of restricted models for the valuation responses for avoiding risk increases. Rather, we considered two issues: (1) did the semi-log specification with the exposure risk measure perform as well as with the responses to realized exposure risk decreases; and (2) were the estimated parameters in these two models comparable? To investigate these issues, we considered only the respondents to the contingent valuation questions. In further research we plan to consider the other component of the full sample.

Table 13-6 reports a sample of the estimated models. They conform to the simplest of the specifications used wtih the models based on the risk reduction questions and include the Acton town variable only because of the amount of activity related to hazardous wastes contamination in Acton. They also include a variable, GOVT, that identifies the individuals whose valuation question explained the increase in risk as due to "the government" (i.e, GOVT=1 in these cases) rather than "your town council" (i.e., GOVT=0 in these cases).

Income, the qualitative variable for the low-probability design points, and the qualitative variable for residents of Acton are statistically significant in all of the models considered. The four models in Table 13-6 illustrate the general nature of the findings. While exposure risk has a negative effect on the marginal valuation that declines in absolute magnitude with the level of the exposure risk as in the case of bids for risk reduction, neither exposure risk variable is significantly different from zero.

It is interesting to note that several of the estimated parameters in these models are approximately the same order of magnitude as the parameters estimated for the risk reduction models in Table 13-3. The only notable exceptions are the coefficients for the exposure risk squared (EXP^2) and the qualitative variable for the low-probability design points.

Under the assumption of independence, the Tiao-Goldberger [1962] test statistic was calculated to gauge whether each pair of these estimated coefficients would lead to a rejection of the null hypothesis of equality for the population parameters. Based on these findings the null hypothesis could not be rejected.

TABLE 13-6. MARGINAL VALUATION TO AVOID RISK INCREASES

Model variables and summary statistics	Model 1	Model 2	Model 3	Model 4
Intercept	-5.439	-5.584	-5.527	-5.641
	(-4.969)	(-5.127)	(-4.907)	(-5.036)
INCOME	0.076	0.069	0.076	0.070
	(6.823)	(6.081)	(6.820)	(6.072)
EXP	-0.106	-0.102	-0.107	-0.102
	(-0.960)	(-0.929)	(-0.959)	(-0.929)
EXP^2	0.002	0.003	0.002	0.003
	(1.036	(1.009)	(1.032)	(1.006)
VER78	2.123	2.141	2.114	2.135
	(1.962)	(1.991)	(1.949)	(1.981)
Acton	--	1.234	--	1.227
		(2.180)		(2.160)
GOVT	--	--	0.171	0.111
			(0.343)	(0.223)
R^2	0.192	0.206	0.193	0.206
F	16.31	14.18	13.03	11.78
n	278	278	278	278
s^2	17.184	16.951	17.239	17.010

Clearly, there are a number of additional issues that must be addressed with these valuation responses. The research to this point has not attempted to refine the models used for these valuation responses. It has not exploited the full sample or considered the full set of potential determinants of the marginal valuations for avoiding risk increases. Finally, as in the case of the models for the risk decrease bids, a Tobit estimator would be more appropriate for these models. However, in this case there is only one valuation response. Consequently, if this model is assumed to be different from the relationships describing the valuation responses for risk reductions, there is not sufficient information to take account of heteroscedasticity. Of course, based on the tests with the simple models considered to date, it would be desirable to consider further testing to determine whether responses for risk avoidance seem consistent with a pooling of all three responses.

13.9 INFLUENTIAL OBSERVATIONS, THE ROLE OF JUDGMENT IN SAMPLE SELECTION AND THICK-TAILED DISTRIBUTIONS

All of the statistical analyses of the valuation responses in this report have used the full sample excluding only the protest bids. The protest bids were eliminated because a separate set of questions was used to determine if a zero bid was intended as a "legitimate" zero bid--i.e., it was all the individual could afford or it was what he felt the "commodity" was worth. (See Chapter 11 for more details.) In this section we consider past practices used in evaluating contingent valuation responses to judge the individuals' acceptance of the contingent valuation questions and the corresponding definition of some observations as outliers, the treatment of outliers implied by the GLS estimation of our models for the estimated marginal valuations, and the results of several tests for the extent to which the contingent valuation bids appear to come from thick-tailed distributions. This last issue was included in our discussion of outliers because it clearly relates to the plausibility of some of the indexes used to judge these outlying observations, since symmetric distributions have been assumed to characterize the bids. Equally important, given the sensitivity of Tobit and related maximum likelihood estimators to the distributional assumptions used in characterizing the model's error (see Goldberger [1980] and Amemiya [1984]), the character of this distribution affects the potential for using Tobit (with an adjustment for heteroscedasticity) as an alternative to a sample selection process that eliminates some observations as outliers.

13.9.1 Past Practices in Screening Contingent Valuation Responses for Outliers

It has been common practice to reduce the samples derived from contingent valuation studies by deleting what are judged to be outlying observations. The difficulty with this process arises in establishing some basis for defining these outlying observations. There are two general approaches in the literature: (1) a purely statistical criteria that establishes a fixed bound for "legitimate" responses (e.g., the valuation responses would be judged as legitimate if they lie within k standard deviations of the mean, where k is a fixed constant), and (2) a criterion that combines statistical and economic considerations by focusing on the effect each observation has on the percentage change in an estimated parameter that is hypothesized, based on an economic model of the valuation process, to be an important determinant of the responses.

However, both approaches are ad hoc. They rely on analyst judgment. The first relies on an implicit assumption that the distributions of the valuation responses are symmetric and have finite variances. Presumably, the rationale for a fixed bound follows from an assumption that responses outside the interval realized 99 percent of the time by nearly all finite variance symmetric distributions cannot have been from individuals who understood or were willing to take seriously the contingent valuation questions.*

There are several problems with this approach. One of the most crucial is its focus on the valuation responses. By treating all bids as capable of being described by a constant mean distribution, the scheme ignores the role of other economic variables that we would expect to influence these bids. Income, for example, would be expected to influence the bids, leading to differing mean bids from households with differing incomes. Depending on the particular application, there are likely to be other variables as well. With the present study, measures of the character of the risk and the risk change would be expected on a priori grounds to influence the bids. This method

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*Examples of this approach include Randall, Ives, and Eastman [1974], Brookshire, Ives, and Schulze [1976], and Rowe, D'Arge, and Brookshire [1980].

has no systematic means for taking these influences into account. However, for a large value of k, the multiple of the standard deviation defining the interval for legitimate bids, it is possible to indirectly reflect the role of these other influences.

A value for k is easily established for finite variance symmetric distributions. Consider, for example, the normal distribution. If the threshold for legitimate responses is a 99-percent confidence interval, then k would be three. By increasing k beyond three (many of the past contingent valuation studies have used ten) the analyst implicitly allows for variation in the mean at the center of the interval. This variation could be the result of income or other variables that described the respondent or commodity that was being valued. Of course, the difficulty with this adjustment is that its effectiveness will depend on the influence of specific economic variables on these mean bids and the extent of variation in these variables in any particular sample. This would imply that it is not possible to define in advance a fixed criterion for the size of the interval as a constant multiple for the standard deviation about the mean.

The second approach proposes the use of regression diagnostics (see Belsley, Kuh, and Welsch [1980]) to gauge the influence of each observation by its percentage impact on the parameters of variables that can be specified, in advance, as potentially important determinants of the valuation responses. In the first application by Desvousges, Smith, and McGivney [1983], this was the estimated parameter for household income in a model for the option price bids for water quality improvements. A 30-percent change in the estimated parameter with the deletion of one observation was the criterion for identifying the outlying observations.

While this procedure is also ad hoc and to some extent arbitrary, it has some advantages over the first approach. First, it recognizes the potential for differing mean bids for individuals with differing incomes or other socioeconomic characteristics. Second, it expresses the objective of the screening process as one of identifying observations that do not appear to be consistent with or to have accepted the contingent market. This is accomplished by focusing on the observation's influence on an estimated parameter of an economic variable that would influence the bids if the respondents were providing their actual valuations of the commodity of interest. Finally, it evaluates influential observations within a framework that treats the bids as the sum of systematic and random components. The greater the size of the estimated residual's implied adjustment to the parameter, the larger will be the regression diagnostic. Large changes in the estimated parameters for important economic variables are treated as indications that these observations may not be drawn from the same model. In effect, they may not have accepted the terms of the contingent market on the same basis as the other respondents. Of course, defining a large change is purely a judgment. However, the first application of this approach by Desvousges, Smith, and McGivney [1983] did acknowledge the need to examine the features of the observations judged to be influential in order to determine if there were similarities in their economic or demographic characteristics.

Nonetheless, these advantages do not change the fact that the procedure is arbitrary. It uses an index of influence to determine observations that are judged to be inconsistent with the contingent valuation framework and clearly requires analyst judgment. Mendelsohn [1984] has recently criticized the approach on the grounds that an observation's influence on income is "only of passing interest" to the objectives of most contingent valuation studies. He argued that the central objective of the screening should be to remove observations that are incorrectly affecting the mean valuation. To meet this objective, he proposed using a set of variables associated with potential biases in the contingent valuation responses (e.g., qualitative variables for the interviewer, question format, and starting point, etc.) and relating them to the contingent valuation bids. Such models could then be used to predict what he referred to as the bias component of the contingent valuation responses. Of course, as he acknowledged, economic variables could also be associated with incentives to provide biased responses. Hence, it is entirely possible that one could not specify any model that would isolate biases (as distinct from legitimate economic influences) in contingent valuation responses.

In addition, his specific criticism of the Desvousges, Smith, and McGivney [1983] analysis apparently overlooked that all of the variables that Mendelsohn's bias analysis called for were included in the option price equation used for the regression diagnostics. Thus, the calculations of Desvousges, Smith, and

McGivney for indexes of influence were providing a set of gauges of the error in the valuation responses after taking account of specific sources of error, such as the interviewer effects and form of the question. Mendelsohn's other criticisms ignore the fact that the mean responses can be expected to change across respondents because of differences in their economic circumstances. Judgments on outliers that ignore this feature of the process face the same problems we outlined for the statistical approach.

13.9.2 Judging Influential Observations for the Present Study

The regression diagnostic framework requires that we be able to specify a model to explain the character of the valuation responses. In the present application, the role of important attributes of the contingent valuation commodity and of economic determinants of the responses was not clearcut on a priori grounds. Use of one model as a standard to gauge the influence of observations relies on the acceptability of the general form of that model even if the statistical fit to the particular equation is not necessarily good. Since we have not completed the process of model selection, it would be premature to evaluate the sample responses for outliers. Our most detailed model does not include variables for the inteviewers and will require further analysis, both from the perspective of considering new potential determinants of the marginal valuations and reformulations of some of the existing variables to better understand what they may be representing. This process is especially important where the estimated parameters are found to be sensitive to the specification of other determinants of the marginal valuations.

However, our findings implicitly take account of the observed differentials in respondents' understanding or acceptance of the contingent valuation questions. This is accomplished in the weighting of observations according to the estimated variances attributed to each respondent based on their bids (and the associated estimates of the marginal valuations) for the two risk changes. By pooling responses across questions, we imposed additional structure on the analysis of individuals who may not understand or accept the contingent valuation experiment. It is possible to judge two of their responses in relationship to the model used to describe the marginal valuations of risk changes.

This approach is consistent with the regression diagnostic format used in earlier studies, but does not eliminate observations. Rather, it gives them small weight in the estimation of the marginal valuation models. Indeed, Leamer [1984] recently used a GLS framework to characterize regression approaches that discard or reweight outlying observations. By defining the variance-covariance matrix as the sum of the conventional least squares weight (i.e., the identify matrix) plus a matrix that reflects the reweighting implied by informal approaches to treating outliers, he established that the corrected or reweighted estimates are adjustments to the OLS estimates of the parameters based on the judgmental criteria, the least squares residual for each specific observation, and values of the independent variables. Moreover, this approach can be shown to be closely related to the Belsley, Kuh, and Welsch [1980] regression diagnostics for the selection of given criteria for influential observations. Of course, it differs from the regression diagnostic/outlier approach in its treatment of the summary statistics describing contingent valuation responses. That is, in Leamer's case, these weights are used only in the regression models for the bids. They are not taken into account in calculating the estimated mean valuations reported in Chapter 11.

Nonetheless, this approach offers an alternative basis for judging outlying observations. Further research will be needed to judge the plausibility of using regression diagnostics based only on one of the risk changes with the estimated variances that reflect the weight of individual observations. In addition, it will be important to evaluate the sensitivity of both approaches to the specification of the model used to describe the estimated marginal valuations of risk changes. Finally, this further research must consider the economic and demographic features of the respondents whose valuations are judged to be outliers.*

13.9.3 Some Preliminary Tests for Thick-Tailed Distributions

A number of contingent valuation studies have found some evidence of bids coming from either skewed or thick-tailed distributions.† Distinguishing

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*If the detection of outliers can be done in a more systematic way, it should be possible to treat the problems it poses as analogous to the selectivity issues addressed in many recent econometric analyses of survey data.

†This was one of the observations made by the review panel for the state-of-the-arts assessment of contingent valuation methods (see Cummings et al. [1984] for more details.

the two features of distributions from sample information can be quite difficult. Both imply more weight in the tails of the distribution than one would expect for a symmetric distribution such as the normal. Skewness arises when one tail has more weight than another. By contrast, thick-tailed distributions can be symmetric but have a flatter density at the center than the normal.

The objective of this section is to report the results of several tests for the degree of thickness in the tails of the underlying distribution of valuations for risk reductions based on the sample responses. Our analysis has been conducted using the valuation responses and the transformed measure of the marginal valuation used in our restricted regression models of the determinants of the individual bids (i.e., $\log \frac{\Delta E}{\Delta R}$). Based on Monte Carlo studies comparing the power of five tests of normality against alternative distributions with either lighter or heavier tails, Smith [1975] found the kurtosis (K), U (Uthoff [1970]), and V statistics were more powerful in detecting heavy-tailed distributions. The three statistics are defined as follows:

$$K = \frac{\frac{\sum_{i=1}^{n} (X_i - \bar{X})^4}{n}}{\left[\frac{\sum_{i-1}^{n} (X_i - \bar{X})^2}{n}\right]^2}, \quad (13.6)$$

$$U = \frac{\left[\frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{n}\right]^{\frac{1}{2}}}{\frac{\sum_{i-1}^{n} \left| X_i - X_m \right|}{n}}, \quad (13.7)$$

$$V = \frac{\frac{1}{2}R}{\frac{\sum_{i=1}^{n} \left| X_i - X_m \right|}{n}}, \quad (13.8)$$

where

X_i = ith value of the relevant response (i.e., valuation or transformed estimate of marginal valuation - $\log(\frac{\Delta E}{\Delta R})$)

$\bar{X}$ = sample mean

X_m = sample median

R = sample range

n = sample size.

Table 13-7 presents the estimates for each statistic using the actual bids in response to the first and second risk reductions and for the case of avoiding risk increases. Using the empirical critical values reported in Smith [1975] for a 5-percent significance level and a sample size of 100 observations as approximations for the relevant critical values, all three statistics would reject normality in favor of a thick-tailed (or potentially skewed) alternative distribution for all three valuation responses.* These results should not be particularly surprising given that the valuation responses are truncated at zero and there is considerable heterogeneity in the character of the risk change that was presented to sample respondents. By contrast, when these tests are repeated using the transformed measures of the marginal valuations, the conclusions are not as clearcut. These results are reported in Table 13-8. With the marginal valuations for risk reductions, two of the three statistics (i.e., V and K) would not reject the null hypothesis of normality at the 5-percent level. Only the U statistic would call for a rejection. In the case of the valuation responses for avoiding risk increases, two of the three statistics (i.e., U and K) would call for rejection of the null hypothesis while V would not.

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*The specific values for the estimated critical values by significance level and sample size are:

	=0.05			=0.10		
	n=20	n=50	n=100	n=20	n=50	n=100
k	4.035	3.812	3.670	3.651	3.543	3.375
U	1.382	1.330	1.304	1.346	1.314	1.291
V	3.101	3.446	3.720	2.936	3.273	3.578

See Smith [1975], p. 665.

TABLE 13-7. TESTS FOR THICK-TAILED DISTRIBUTIONS WITH LEVELS OF VALUATION BIDS

Risk change	Test statistic U	V	K
First risk reduction (A to B)	1.87	7.11	15.90
Second risk reduction (B to C)	2.14	10.32	34.94
Avoiding risk increase (C to A)[a]	1.79	10.12	30.57

[a]These results relate to the sample of all respondents. For the subsample of individuals receiving the contingent valuation questionnaires, the results were: U = 1.93, V = 8.65, and K = 20.98.

TABLE 13-8. TESTS FOR THICK-TAILED DISTRIBUTIONS WITH TRANSFORMED ESTIMATES OF MARGINAL VALUATIONS[a]

Risk change	Test statistic U	V	K
First risk reduction (A to B)	1.58	2.48	3.34
Second risk reduction (B to C)	1.49	2.26	2.57
Avoiding risk increase (C to A)a	1.73	2.93	4.41

[a]These results are based on using $\log\left(\frac{\Delta E}{\Delta R}\right)$ as the transformed measure of the marginal valuation of each risk change.

There are several important qualifications to these findings. First, these tests are approximate and should be interpreted only as indicative of the presence of thick-tailed distributions. They are not definitive. Measuring skewness and the degree of flatness of a density near the center (or equivalently thickness in tails) is difficult. The two phenomena are easily confused by statistics intended to indicate their presence. Only a complete set of moments will determine a random variable's distribution exactly.

Second, as we noted earlier, substantial differences in the valuation responses in relation to the sample mean could be expected solely as a result of differences in respondents' income and the character of the risks asked of individuals. To avoid this inherent heterogeneity in what individuals responded to, it would have been necessary to calculate the indexes for each design point. While this would not control for individuals' characteristics, it would eliminate the problems posed by heterogeneity in the risk changes posed to individuals. Unfortunately, the sample sizes become quite small and the power of these tests correspondingly diminishes.*

Finally, we could have used the residuals from a model that relates the valuation responses to what has been asked and to the features of the individual. Since our research has not identified a final model, the results with the transformed marginal valuation represent an intermediate position. That is, the estimation of $\frac{\Delta E}{\Delta R}$ controls for the size of the risk change. The logarithmic transformation also serves to reduce the skewness in the distribution of bids.

Overall, these results seem to suggest that evidence of skewness and/or thick tails in the distribution of contingent valuation bids may well indicate the need to pay more specific attention to the determinants of valuation responses and to the specification of the functional form for the bid (in our case, option price) models. Based on these preliminary results, a thick-tailed distribution does not seem to be a likely characterization for the risk reduction responses. The results for valuations to avoid risk increases is more disparate. It may well be that these responses are more correctly modeled as arising from a non-normal distribution.

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*See the Monte Carlo results in Smith [1975] as one example.

Further research into the characteristics of the residuals from formal economic models for all responses will be necessary to complete a final evaluation of this issue.

13.10 IMPLICATIONS

The primary objective of this chapter has been to explore the implications of using restricted models to summarize the valuation responses for the exposure risk reduction questions on the questionnaire. These results were not intended to be final. Rather, our objective was to consider whether there would be a payoff to more restrictive modeling of the contingent valuation responses in terms of the increased understanding of the determinants of individual valuation of risk changes.

These restricted models were based on estimates of the marginal valuation of the risk changes. After examination of a number of specifications, they were developed using a semi-log form. Based on these preliminary findings, the answer to the question of potential payoff to further research appears to be clearly in the affirmative. Moreover, in the process of developing these estimates it has been possible to consider several additional issues.

One of the most important of these issues involves the pooling of valuation responses across the two risk reduction questions. Based on the estimates for all of the models applied to the valuation responses for risk changes individually, pooling appears to be acceptable. This implies that the two responses can be used to gauge the variance in the errors associated with each respondent. These variance estimates have several important uses. They permit the construction of a GLS estimator for the valuation models and may well provide a superior method for identifying respondents who reject the contingent valuation framework.

Our analysis also considered the potential relevance of the model to the valuation responses for avoiding risk increases. Here our preliminary work has been more limited. The initial results with the application of these models was less successful. While they appear to indicate that income and the risk measures play the same role in determining the marginal valuations (i.e., the null hypotheses of equality of their respective parameters could not be rejected), this finding must be interpreted cautiously. Further analysis with the full sample of these responses and more extensive model specifications is clearly warranted.

Another dimension of our analysis involved reconsideration of the procedures used for analyst intervention in deleting outlying contingent valuation responses, before analysis of the mean valuations or modeling and testing of the valuation responses in relation to other variables. After reviewing both approaches to this screening, including recent criticisms of the approach based on regression diagnostics, we used Leamer's [1984] recent work to argue that a GLS estimator and the diagnostic approach are closely related. Hence, the GLS weights may well be the most appropriate basis for judging respondents who have not understood or accepted the contingent valuation questions.

Finally, our preliminary analysis of the extent to which the valuation responses appear to have been generated by thick-tailed distributions suggests that this problem cannot be considered independent of the modeling of the behavioral function that explains the determinants of the valuation responses.

Further research with this information will require refining the econometric methods used to analyze the responses, explicitly taking account of the implications of zero bids for the selecting of probabilistic models of the data generating process as well as refining the character of the variables intended to measure the individual's attitude toward information on and perception of risks.

CHAPTER 14

THE USE OF CONTINGENT RANKING MODELS TO VALUE EXPOSURE RISK REDUCTIONS: PRELIMINARY RESULTS

14.1 INTRODUCTION

The purpose of this chapter is to describe the design and results from the contingent ranking component of our survey. The contingent ranking was used as an alternative means for eliciting individuals' preferences for reductions in the risk of exposure to hazardous wastes. This approach was first proposed in the economics literature by Beggs, Cardell, and Hausman [1981] as a method for measuring the demand for new commodities. Subsequently, Rae [1981a,b] used it as an alternative to contingent valuation for measuring the benefits associated with improving environmental amenities.*

Since its introduction to the literature, the approach has attracted considerable attention. However, to date, specific applications using contingent ranking for benefit estimation have been limited. Desvousges, Smith, and McGivney [1983] applied the method as part of their comparative evaluation of methods for estimating water quality benefits. More recently, the application of the method to valuing visibility improvements in Cincinnati have raised questions concerning both technical issues in the modeling and the estimation of contingent ranking utility functions and the sensitivity of the benefit estimates to the model selected to describe household rankings. Accordingly, there is a need for further research on both the performance of the contingent ranking method and, equally important, the consistency between independent applications of the contingent ranking and contingent valuation methodologies to value a specific amenity change.

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*There has been some controversy over the plausibility of the results derived from contingent ranking studies. Indeed, based on the sensitivity of the findings of the most recent effort to use the contingent ranking approach to model specification, the Electric Power Research Institute (EPRI) has sponsored a reevaluation of the contingent valuation and contingent ranking approaches for estimating the values of changes in environmental amenities.

Most contingent valuation studies have been structured to describe a hypothetical market to the individual in a way that places that individual in an active role in the market--as a bidder for a specific outcome. That is, the valuation questions have requested bids from individuals for stated changes in a carefully defined commodity. In effect, the individual is confronted with the propsect of being able to "purchase" the change (if it is a utility-enhancing increment) or pay to avoid it (if it will decrease utility).

In a few cases, notably Bishop and Heberlein [1979] and Bishop et al. [1984], the contingent valuation experiment has been structured so that the market outcome--a commodity (or change in a commodity)--and a price are presented to the individual; then he is requested to accept or reject the stated outcome. Contingent ranking can be viewed as an expansion on this second approach to describing the market. That is, several specific outcomes involving payments and changes in the commodity (or outcome) of interest are presented to the individual as possibilities. Rather than requesting a single choice or a yes-no decision on each, the interviewer asks the respondent to rank the choices from most to least preferred.* These types of responses may well be easier for individuals to answer and, as a consequence, may lead to more accurate information than attempts to directly elicit individuals' valuations.†

To date there has not been a direct comparison of the contingent valuation and contingent ranking methods using independent sample information.‡ As

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*All of the applications of the contingent ranking method have not allowed individuals to suggest that subsets of the options being ranked would tie in their preference ordering. Ties cannot be accommodated in the Beggs, Cardell, and Hausman [1981] formulation of the decision process. It is, however, possible to amend the framework to permit ties (see Cox [1972]). This is a potentially important addition to the method, because it appears that individuals undertake the rankings by first identifying the extreme alternatives--the most preferred and least preferred cases--and move to the choices that are most difficult to order in the middle. At present the method requires individuals to order all. This may introduce greater error in the center of the ranking relative to the extreme choices.

†See Hanemann [1984, 1985] for further discussion of the modeling of individuals' responses to valuation questions.

‡There was comparative information on the contingent valuation and contingent ranking approaches reported in the EPRI-sponsored Cincinnati study. However, this material is not in the public domain. Therefore, it cannot be reviewed at this time.

we noted earlier, in a study designed to estimate the option price for water quality improvements, Desvousges, Smith, and McGivney [1983] used both the contingent valuation and the contingent ranking approaches to elicit values for water quality changes. However, all individuals were asked both the contingent valuation and the contingent ranking questions. Consequently, we might expect that the responses to the first type of question asked would affect the responses given to the second. Indeed, the authors note that several individuals who refused to provide values for the water quality changes in a contingent valuation format (which was administered first in their interviews) also recognized the contingent ranking questions as eliciting the same type of information and refused them as well. While there was a high degree of consistency in the two sets of estimates reported in their study, the lack of independence in their administration makes this finding difficult to interpret. It may simply indicate that individuals attempted to be consistent in their responses.

Our survey design for the present study was structured to provide independent contingent valuation and contingent ranking estimates. By separating the sample into two groups, one group (approximately 60 percent of the sample) receiving the contingent valuation questionnaires and the second receiving the contingent ranking format, it was possible to develop independent estimates from each approach for individuals' valuation of exposure risk reductions.

This chapter reports the preliminary results from an analysis of these contingent ranking responses and a simple comparative assessment of the valuation estimates implied by these unrestricted contingent ranking models in relation to the contingent valuation responses. It is described as preliminary for several reasons. First, the models used to describe individuals' rankings of risk-payment combinations do not attempt to impose any theoretical restrictions on the functions estimated for the indirect utility functions. Second, our comparison of the valuation responses and estimates from the contingent ranking approach are designed as illustrative comparisons using the contingent ranking models to estimate the bids that are implied for the contingent valuation respondents. Our findings suggest that the relationship depends in important respects both on the benefit concept used and, especially, on the contingent ranking model selected for the comparison.

There are two aspects of these findings that should be noted. First, estimates of the mean (by town) changes in payment required to hold utility constant in the presence of a reduction in exposure risk, when positive, are generally larger than the contingent valuation responses for comparable risk changes. Second, in an evaluation of two of the estimated contingent ranking utility functions for two specified exposure risk reductions and four subsets of the contingent valuation sample, only two cases fail to reject the null hypothesis that would suggest contingent valuation bids and the corresponding predicted contingent ranking responses for the same individuals cluster about a 45° line. Of course, these results are based on fairly preliminary models for the random utility function that do not reflect the restrictions one might wish to impose based on theory. Nonetheless, they do permit standardization for individual respondents' characteristics through the process used to construct the estimates of the payment changes which hold utility constant.

Aside from this relative comparison of the contingent valuation and contingent ranking findings for consistency, the results do confirm the earlier Desvousges, Smith, and McGivney [1983] finding that the contingent ranking framework was easily understood by respondents. This finding was anticipated prior to the survey. The experience with the focus group sessions used to develop the questionnaire and in the pretest of the survey instrument both indicated that the ranking tasks were more easily accomplished by the individuals involved.

Section 14.2 begins the chapter with a brief review of the random utility model and the issues that arise in applying it under uncertainty. This section also provides a description of the maximum likelihood estimator based on a logit formulation for the random utility model. In the third section the form of the ranking questions is described together with the experimental design for the survey using the contingent ranking questionnaires. Section 14.4 presents the results. Beginning with some informal information on the patterns of rankings that emerged from the survey, this section describes the estimated models used to interpret the rankings and discusses their sensitivity to specification and version of the questionnaire used in the survey. Section 14.5 outlines the approach used to estimate the value of risk reductions from these models and provides some comparative information on the relationship between these estimates and the contingent valuation estimates for comparable risk changes. Section 14.6 summarizes the findings of the analysis and discusses their implications for further research.

14.2 THE RANDOM UTILITY MODEL

The random utility model has had the greatest application in modeling consumer behavior with respect to discrete choices. These choices are assumed to involve some degree of indivisibility, so that conventional marginal analysis in describing the incentives to consumer choice is not directly relevant. The individual is described as comparing a set of specific alternatives and selecting the one that yields the greatest total utility. In this framework the analyst is assumed to observe a set of individuals and their choices, but does not have full information on individual preferences. Behavioral observations are a set of trials, each one representing different individuals making choices. With assumptions concerning the distribution of types of individuals and information on the characteristics of the specific individuals who made particular selections, it is possible to describe the conditional probability of the choice of the commodities of interest.

To develop this framework in more specific terms, let Equation (14.1) describe individual i's utility function for commodity j. Individual i's characteristics are described by a vector X_i, and the attributes of the commodity by a vector C_j:

$$\mu(C_j, X_i) = v(C_j, X_i) + e(C_j, X_i) \quad , \qquad (14.1)$$

where

$\mu(.)$ is the total utility provided to an individual with X_i features from a commodity with C_j characteristics.

It has a deterministic component, v(.), and a stochastic component, e(.). To describe the conditional probability a commodity with attributes C_k will be selected by an individual with characteristics X_i, we must specify that the probability $\mu(C_k, X_i)$ will exceed all the possible alternatives as in Equation (14.2):

$$\mu(C_k, X_i) > \mu(C_n, X_i) \text{ for all } n \neq k \qquad (14.2)$$

or, substituting

$$v(C_k, X_i) + e(C_k, X_i) > v(C_n, X_i) + e(C_n, X_i) \ , \qquad (14.3)$$

Equation (14.3) can be rewritten as

$$v(C_k, X_i) - v(C_n, X_i) > e(C_n, X_i) - e(C_k, X_i) \ . \qquad (14.4)$$

By specifying a distribution for the stochastic component of utility, e(.), and specific set of determinants for v(.), Equation (14.4) can be transformed into a specific probability statement. For example, assuming that the e's follow independent, identically distributed Weibull distributions, then the probability expression for Equation (14.4) is given as follows:

$$\text{Prob } [\mu_k > \mu_n \text{ for all } n \neq k] = \frac{\exp\,(v(C_k, X_i))}{\sum_{n=1}^{T} \exp(v(C_n, X_i))} \ , \qquad (14.5)$$

where

T = all feasible alternatives including the kth.

All of this framework has been developed with little direct specification of how the v(.) functions relate to the conventional theory of consumer choice. While in many applications the connection has remained loose, it can also be argued that for conventional choice problems under certainty, that v(.) is simply an indirect utility function with the prices of commodities among the C_j and the individual's income among the X_i.

The form selected for v(.) has generally been linear in parameters. Nonetheless, as McFadden [1981] observed, it is possible to impose the theoretical properties of an indirect utility function on v(.) by appropriately defining the roles for C_j and X_i in the nonstochastic component of the utility function. Once this framework is used to model decisions under uncertainty, the same observation can hold. For example, we might consider the two state case where C_{1j} and C_{2j} correspond to the vectors of commodity specific variables in each state and π_j, the probability of the first state. v(.) would then be described as follows:

$$v(C_{1j}, C_{2j}, \pi_j, X_i) = \pi_j \ V_1(C_{1j}, X_i) + (1-\pi_j)V_2(C_{2j}, X_i) \ , \qquad (14.6)$$

where

$V_i(.)$ = state dependent, nonstochastic utility function.

In this form we are assuming that e(.) arises because of stochastic influences that are not associated with the uncertainty in the indivdiual's choice among the commodities in differing states of the world. e(.) represents uncertainty that is independent of the choice process among commodities. For the empirical analysis described in this chapter we have treated the exposure risk similar to any other commodity (or characteristic). Thus, we have not attempted to specify forms for the $V_i(.)$ functions and derive v(.) as a restricted function. To illustrate the distinction, consider the two alternative approaches to specifying v(.). In both cases suppose for simplicity the individual faces only two choices, one involves a stochastic outcome the second does not. They might be described as follows:

	Choice 1	Choice 2
Type 1 characteristic	π_1 of C_{11}	C_{21}
Type 2 characteristic	$1-\pi_1$ of C_{12}	0

With Choice 2, then the π_2 implied by the general definition given in Equation (14.6) is unity. We can assume C_{11}, C_{12}, and C_{21} can be either vectors of attributes or scalar quantities. The argument holds for either case. The unrestricted model implied by a linear specification for the nonstochastic component of utility might be Equation (14.7a) for choice one and Equation (14.7b) for two:

$$v(\bar{C}_1, X_i) = \alpha_0\pi_1 + \alpha_1 C_{11} + \alpha_2 C_{12} + \alpha_3 X_i \ , \qquad (14.7a)$$

where

$\bar{C}_1 = [C_{11}\ C_{12}]$;

$$v(\bar{C}_2, X_i) = \alpha_0 + \alpha_1\ C_{21} + \alpha_3\ X_i \ , \qquad (14.7b)$$

where

$\bar{C}_2 = [C_{21}\ 0]$.

In this case, the two values of the function differ only as a result of the substitution of the relevant values for each variable. It should also be noted that this example is deliberately simple. In practice we could not estimate the parameters for the X_i variables unless these variables were assumed to enter in an interactive format with the characteristics of the commodities being ranked. This is easily appreciated by substituting Equations (14.7a) and (14.7b) into (14.4). In a linear-in-parameters framework, the differences in the independent variables contributing to individual utility are what motivate the assignment of a relative standing. Without these interactions, individual characteristics cancel in determining an individual's ranking of the commodities.

Past research has addressed this issue in different ways. With a sufficient number of commodities being ranked separate functions can be estimated for each individual. This is one approach proposed by Beggs, Cardell, and Hausman [1981] and corresponds to what Rae designated the "individual" model. By contrast, one can consider defining interaction variables between the characteristics of the commodities being ranked and the attributes of the individuals doing the rankings. This is the approach used by Desvousges, Smith, and McGivney [1983] because there were not a sufficient number of choices being ranked. It amounts to a specification of how the parameters for the elements in C_j are expected to change with changes in individuals' attributes. To some extent it was treated arbitrarily by Desvousges, Smith, and McGivney. That is, each specification for the attributes of individuals thought to be important determinants of a ranking was interacted with each of the characteristics of the commodities being ranked and the findings compared. This simple example does serve to illustrate that it may be possible to improve on this practice using more information from our conceptual model of the decision process.

To consider how we might alter the specification of the random utility functions to more specifically reflect the conceptual framework, assume the state-dependent functions are linear in type one and two characterstics, but give each function different weights depending on the state of the world, as in Equations (14.8a) and (14.8b) below. Then we have Equations (14.9a) and (14.9b) as the "deterministic" utility functions corresponding to the two choices:

$$V_1(C_{11}, X_i) = a_0\ C_{11} + a_1\ X_i \tag{14.8a}$$

$$V_2(C_{12}, X_i) = b_0\ C_{12} + b_1\ X_i \tag{14.8b}$$

$$v(\bar{C}_1, X_i) = a_0\ \pi_1 C_{11} + b_0\ (1-\pi_1)C_{12} + a_1\ \pi_1 X_i + b_1\ (1-\pi_1)X_i \tag{14.9a}$$

$$v(\bar{C}_2, X_i) = a_0\ C_{21} + a_1\ X_i\ . \tag{14.9b}$$

The important distinction between the (14.7a) (14.7b) pair and the (14.9a), (14.9b) pair is the role assigned to the probability in the two formulations. It is also important to recognize that if we are willing to assume that certain variables have the same effect on each of the state dependent utility functions then the nature of the role of the probabilities as interaction variables changes with the events at risk. This possibility offers another set of potentially interesting testable hypotheses.

Clearly, these are simple examples. However, they do serve to illustrate that explicit consideration of the source of the state dependency, the form of the deterministic component of $\mu(.)$, as well as of the appropriate interaction between elements in C_j and X_i (such as would be implied by homogeneity of degree zero in income and prices), each offer the potential for introducing testable restrictions on $v(.)$. Indeed, without explicit consideration of some of these restrictions it will not be possible to argue that we have established a consistent theoretical basis for the valuation estimates derived from the estimated deterministic component of the utility function.

Estimation of the random utility model with ranked data and an assumption of independent Weibull distributions for the errors can be accomplished using a maximum likelihood estimator. Beggs, Cardell, and Hausman [1981] derive the likelihood function for this case as follows:

$$L = \prod_{i=1}^{N} \prod_{j=1}^{T} \left[\frac{\exp\ (v(C_j, X_i))}{\sum_{s=j}^{T} \exp(v(C_s, X_i))} \right], \tag{14.10}$$

where

T = number of alternatives ranked

N = number of individuals.

After specifying a functional relationship for v(.) and taking the logarithm of Equation (14.10), we have a globally concave, log-likelihood function. This function can be numerically optimized to derive the maximum likelihood estimates. Our estimator used a modified Davidon, Fletcher, Powell [1963] (DFP) algorithm with numerical derivatives.*

14.3 STRUCTURE OF THE CONTINGENT RANKING QUESTIONS AND EXPERIMENTAL DESIGN

The objective of the design of the questions used in the contingent ranking questionnaires was to maintain, as nearly as possible, complete consistency with the information described in the contingent valuation component of the survey. Consequently, the description of the problem as one associated with a medium-sized company disposing of hazardous wastes (on site) in a landfill, the explanation of exposure risk, and the identification of the conditional probability of death given exposure parallel those given for the contingent valuation questionnaires. (See Chapter 11 for a more complete description of this material.) Respondents were given experience with the use of the risk circle cards by asking them to consider the distance they felt that their home would have to be moved from its present location to experience a specific reduction in the risk of exposure.† This practice conforms to the procedure used with the contingent valuation questions asking for respondent valuations. Thus, in terms of the definition of the context of the task requested, the description of the risks involved, and the ways in which individuals pay for risk reductions, the contingent ranking and contingent valuation questionnaires were virtually identical.

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*The estimates were prepared using the GQOPT program developed by Richard Quandt at the Econometrics Section at Princeton University. More details on the program and convergence criteria used are available on request from the authors.

†See Chapter 15 for a more detailed discussion of this question and the results from it.

As in the contingent valuation component of the survey, the contingent ranking instruments elicit information on individuals' perceptions, attitudes, and valuations for different types of risks in two ways: (1) by asking several different questions to the same individual and (2) by asking different questions to different individuals. The first aspect of this process we have referred to as relating to the structure of the questionnaire and the second to the experimental design for the survey. With respect to the structure of the questionnaire received by respondents with the contingent ranking format, nearly all other dimensions of the questionnaire and tasks requested are identical between the contingent valuation and contingent ranking approaches. Thus, for example, use of a contingent ranking format to elicit valuation information associated with changes in the risk of exposure to hazardous wastes did not affect the questions concerning the distances an individual would select from hazardous facilities or the process used to investigate responses to job-related risks.

It did have effects on the questions designed to elicit the existence values for risks to the ecosystem as our discussion in Chapter 11 indicated. The reason is straightforward; the individual was assumed at the outset of this question to have bid for a risk change for his household. Therefore, based on the outcome of this process, he would have a postulated base exposure probability. We wanted to ask for an additional value for additional motives. Consequently, a contingent valuation question had to be introduced in the contingent ranking questionnaires before the existence value question. Since this was placed after the ranking tasks were completed it would not have influenced the rankings derived. Of course, it is possible that the responses to these contingent valuation questions were affected by the information provided in the rankings. This is one of the reasons these valuation responses were treated separately in Chapter 11.*

There were several other changes that were required by the use of the ranking format. The most important of these involves the logic of the task

*It is possible that the suggested payments used in the contingent ranking design points served as anchors for the valuation responses reported in these contingent valuation questions. We have a rather limited basis for investigating this issue because there are only two payment vectors. Nonetheless, it can be considered as part of a more detailed evaluation of bids to realize a level with no exposure risk, since this was the way these questions were posed.

requested of each respondent. With the contingent valuation questions each individual was presented two risk cards and asked his valuation of the reduction in the exposure risk associated with the changes from one card to the next. Consequently, the individual must compare the two cards to determine the "commodity" (i.e., the risk change) that is to be valued. By contrast, in the contingent ranking form, the individual was given four cards, each contains a risk level and a payment level. The payment level is explained to be required to realize the risk level. Figure 14-1 displays the four cards used for one of the design points (R-1) comparing the contingent ranking component of the survey.

A second difference in the ranking questionnaire arises from the approach used to evaluate how each respondent would react to the cause of death stemming from exposure to hazardous wastes. Recall that, in the contingent valuation questionnaires, each respondent was asked if they wished to change the reported valuation of the risk reduction when the event that could result from exposure was assumed to be one of two possibilities. In the ranking questionnaires these same effects were retained, but the question posed involved a revision to the earlier ranking with the proposed modification in health effect.

Since the experimental design used to alter the conditions presented to respondents affects the wording used to describe the ranking task requested of survey respondents, the features of this design must be reviewed first before proceeding to an overview of the questions used to elicit individuals' preference ordering. Approximately 40 percent of the survey respondents were given ranking questions.* Since the overall size of the sample for the ranking component of the survey was smaller than that devoted to the contingent valuation approach, the design selected was correspondingly simplified. It is a full-factorial design investigating the effect of the vector of exposure probabilities paired with a vector of proposed payments. Two variations in the vector of exposure probabilities and two in the payment vectors are considered. Thus, there were four different combinations of these two features of the conditions that were to be ranked. Figure 14-2 repeats one panel from Figure

*As we discussed in Chapter 9, all of the questionnaires were randomly ordered so that the effects of the questionnaire and interviewer on responses would not be confounded.

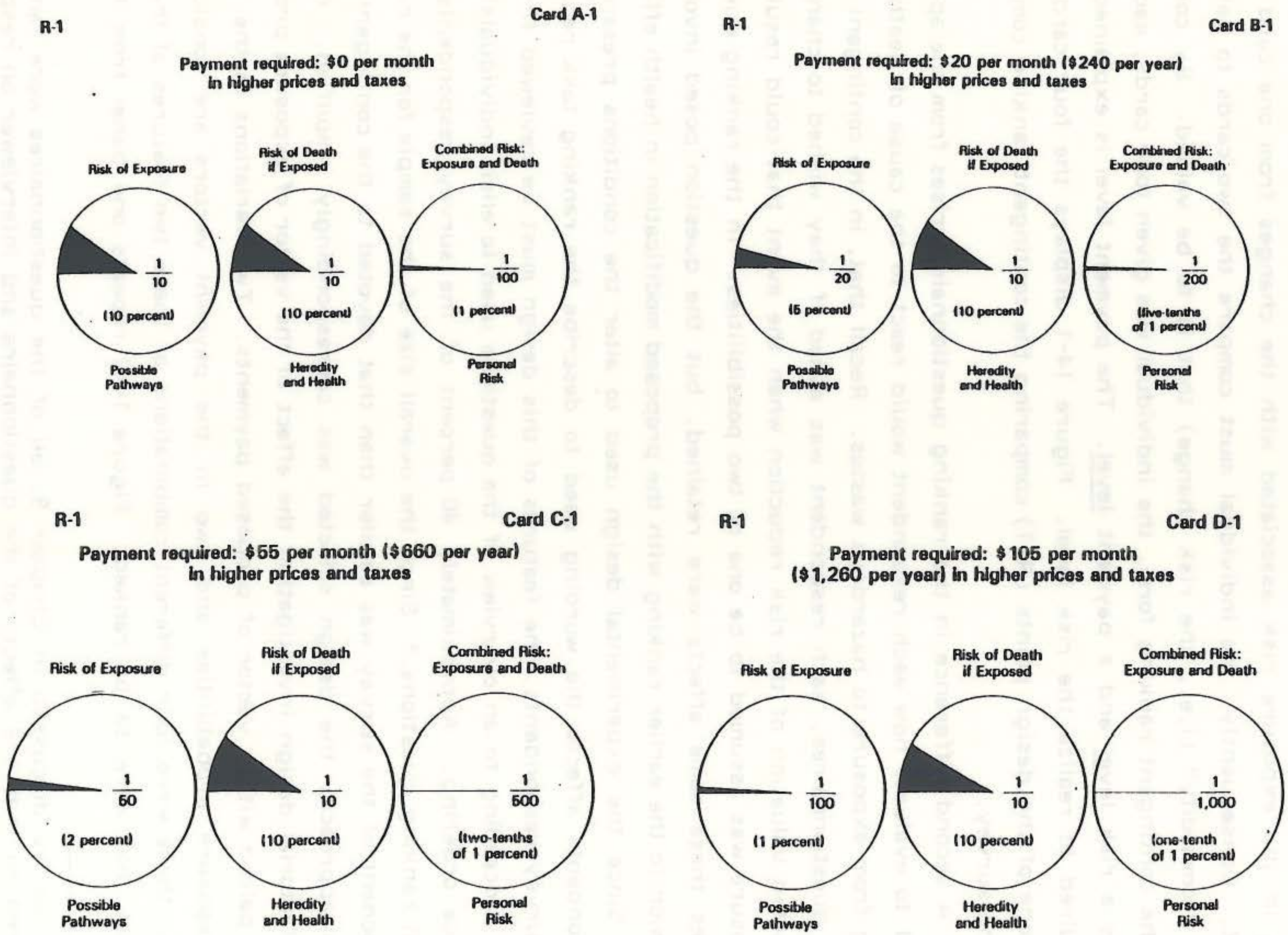

Figure 14-1. Modified risk cards for contingent ranking questons—design point R-1.

<table>
<tr><th colspan="11">Contingent Ranking Question Format (R)</th></tr>
<tr><th colspan="3">Levels of risk</th><th colspan="8">Amount of monthly payment</th></tr>
<tr><th rowspan="2">Vector</th><th rowspan="2">Risk of exposure</th><th rowspan="2">Risk of death, if exposed</th><th colspan="4">Vector A</th><th colspan="4">Vector B</th></tr>
<tr><th>$0</th><th>$20</th><th>$55</th><th>$150</th><th>$−20</th><th>$5</th><th>$40</th><th>$80</th></tr>
<tr><td>I</td><td>1/10
1/20
1/50
1/100</td><td>1/10</td><td colspan="4">R1</td><td colspan="4">R2</td></tr>
<tr><td>II</td><td>1/20
1/30
1/60
1/150</td><td>1/10</td><td colspan="4">R3</td><td colspan="4">R4</td></tr>
</table>

Figure 14-2. Outline of the design for the contingent ranking component of the survey.

7-4 in Chapter 7 defining the specific combinations associated with each design point.

Two aspects of these selections were important motivations for the design. The vector of exposure probabilities was selected to span approximately the same range as was used in the full-factorial component of the contingent valuation design (i.e., design points D1 through D6 in Figure 7-4). The distinction in the exposure risk vectors arises from differences in the level of starting and ending risks and differences in the rate of change over the four cases ranked. Exposure vector I postulates a reduction by a factor of ten in the exposure risk over the four cards ranked, while vector II has a reduction by a factor of seven and a half over the four. The rate at which these changes take place also varies between the two. In the first vector the rate is relatively constant--a reduction of a factor of two from Card A to Card B, then by two and a half from B to C, and then by two, again, from C to D. The second vector has an increasing percentage reduction from a factor of one and a half for A to B to a factor of two for B to C and then to a factor of two and a half for C to D.

The second motivation concerns the implicit assignment of property rights implied by the specification of the payment vectors. The first, payment vector, a, starts at an initial condition, comparable to the A risk card in designs D1 and D2 for the contingent valuation component of the survey. That is, the individual has the same exposure risk as in the initial state for designs D1 and D2 and makes no payment to receive this condition. Regulations are described as requiring more stringent containment technologies and thereby progressively reducing the exposure risk.

The payments along the top of the figure are the monthly additional costs associated with the new risk level. Thus, to calculate the implied payment increment for the risk reduction from Card B to Card C the individual must subtract the levels presented on each card. In the case of design points R1 and R3, for example, this increment would be $35.00 more per month for a reduction from 1/20 to 1/50 in the case of R1 and 1/30 to 1/60 for R2.

To provide an alternative implied set of property rights within the choices ranked, we introduced the possibility of a <u>negative</u> payment. In other words it was suggested that a reduction in taxes or the overall price level was possible as a result of a relaxation in the regulations governing the disposal of hazardous wastes. This is the case described with payment vector b.

In the process of using drafts of the questionnaire in focus groups and the pretest activities we found that individuals had difficulty in dealing with the negative payment as the first card presented. Moreover, it was difficult to control the reference position starting from this possibility. Consequently, we changed the ordering of the cards in presenting design points R2 and R4. The individual was introduced to the ranking task using Card B and then presented with Card A as a reflection of the possibility of receiving reduced taxes, but greater risk. Following this explanation of the possibility for increasing risk and reducing current taxes, the remaining cards with higher payments and lower risks were introduced. This process proved to be the most convenient method to control the context of the scenario described to the individuals and limited (in the pretest) the problems with respondents' understanding of the negative payments. However, as a result of this change in ordering the wording of the ranking task description is somewhat different for each of the two pairs of design points. The full text for the question with payment vector a (i.e., design points R1 and R3) is given as follows:

> Interviewer hands respondent Cards B and C <u>with</u> dollar amounts.*
>
> Now, think about these cards and about paying in higher prices and taxes. As you can see on the cards, the risk of exposure decreases from 1 chance in 20 on Card B, to 1 chance in 50 on Card C. The decrease means your <u>combined</u> risk of exposure and death gets smaller. The amounts you would pay in higher product prices and taxes increase while the risk of exposure decreases.
>
> Using a hypothetical situation, I'm going to ask you some questions about paying for different levels of exposure risk for you (and your household members).
>
> This is the hypothetical situation. A medium-size company that produces electronic parts is located 3 miles from your home. This company generates 2,000 gallons of hazardous wastes each day and disposes of them, using established industry-wide pratices, in a landfill right at the plant site. If you're exposed to a large enough amount of these wastes for a long enough period, there's a chance you will

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*The dollar amounts and probabilities mentioned in the text change with the design point for the questionnaire.

> die in 30 years. Under these circumstances, and if you didn't pay any more in higher product prices and taxes, your (and your household members') risk of exposure to these wastes would be at the level on Card A. This is a risk you could potentially face for all these years until the health effect is known.
>
> Now, suppose the government added regulations requiring the company to install special liners that would seal the landfill and monitoring systems that would detect leaks. These regulations would reduce the chances that the landfill would leak and your risk of exposure would be at the level on Card B. This would require a monthly payment of $20 in higher product prices and taxes.
>
> Suppose the government added more regulations requiring the company to remove the most toxic materials from the wastes before they're put into the lined and monitored landfill. This regulation would require a monthly payment of $55 in higher product prices and taxes, and your risk of exposure would be at the level on Card C.
>
> Suppose additional regulations would require the company to use more expensive ways to make its products. There would be a reduction in some of the most toxic wastes generated. These regulations would require a monthly payment of $105 in higher product prices and taxes, and your risk of exposure would be at the level on Card D.
>
> Look over the hypothetical situation on Card 7 [a card used by the interviewer to remind the respondent of the elements in the problem. It is given in Figure 14-3] once more. Now, thinking about your monthly income and what you spend it on in your budget, rank these cards. Place on top of the pile the card with the payment and risk combination you prefer the most and the card with the combination you like least on the bottom.

A substantial portion of the text does not change for the design points (R2 and R4) involving negative payments. The portion which changes begins in the fourth paragraph of the above discussion. The text for design points R2 and R4 is given as:

> This is the hypothetical situation. A medium-size company that produces electronic parts is located 3 miles from your home. This company generates 2,000 gallons of hazardous waste each day, and disposes of them, using established industry-wide practices, in a landfill right at the plant site. If you're exposed to a large enough amount of these wastes for a long enough period, there's a chance you will die in 30 years. Under these circumstances, your (and your household members') risk of exposure is a risk you could potentially face for all these years until the health effect is known.

Card 7

Exposure Risk Circumstances

- Electronic parts company
- Located 3 miles from your home
- Generates 2,000 gallons of hazardous waste each day
- Company disposes of the wastes in a landfill at company site
- If you are exposed, there is a chance you will die in 30 years

Figure 14-3. Description of hypothetical situation.

The government could introduce regulations which require the company to install special liners that will seal the landfill and monitoring systems that will detect leaks. These regulations would reduce the chances that the landfill could leak and your (and your household members') risk of exposure would be at the level on Card B. This would require a monthly payment of $5 in higher product prices and taxes.

If the government decides not to introduce regulations requiring special liners and monitoring systems, this could lead to a government cost savings, and the company would not raise its product prices as it would do with the regulations. If these regulations are not added, taxes could be reduced $20 per month. The risk of exposure for you (and your household members) would be at the level on Card A.

Alternatively, the government could add more regulations than described for Card B. These would require the company to remove the most toxic materials from the wastes before they are put into the lined and monitored landfill. Your risk of exposure would be at the level on Card C, and these regulations would require a monthly payment of $40 in higher product prices and taxes.

The balance of the explanation was not changed from that used with R1 and R3.

One final aspect of the contingent ranking design should be noted. It was not possible to consider the effects of changes in the conditional probability of death given exposure to hazardous wastes, so this probability was held constant at one-tenth.

14.4 EMPIRICAL FINDINGS

As we indicated in Chapter 9 the actual performance of the ranking questionnaires compares quite favorably with what was expected based on the sampling plan and experimental design. A total of 227 complete interviews with complete rankings were obtained, approximately 37 percent of the sample of completed interviews (including both contingent valuation and contingent ranking).

Our preliminary analysis of these data has focused on three tasks: (1) examining the responses to develop some insights as to the types of rankings provided and what these patterns might indicate, at a rather general level, about individual preferences; (2) testing the effects of the design variables on the rankings derived under the assumption that respondents can be treated as homogeneous; and (3) preliminary estimates of the random utility functions using the ranked logit framework and a largely unrestricted specification for the utility function assumed to describe the determinants of an ordering of exposure risk-payment combinations. We have not, at this stage of the research, attempted to analyze the revisions in the initial rankings provided in response to the proposed health effects resulting from exposure. In what follows we will summarize each dimension of the results of the analyses conducted with these initial rankings.

14.4.1 An Overview of the Nature of the Rankings Provided

Table 14-1 provides a summary of the frequency each of the cards describing a risk-payment combination was ranked first. In order to interpret the table some background on the labeling conventions used in this table and in the others which follow is necessary. The card labels--A, B, C, D--correspond to the paring of similarly positioned elements in the payment and exposure risk vectors. For example, referring back to Figure 14-2, Card A in design R1 would involve a pairing of the first payment, 0, with the first exposure risk 1/10. Card B relates to the second elements; C to the third and D to the fourth. This convention is maintained for all four design points. Equally important, we have used the term "Version" as synonymous with design point. Thus Version 1 corresponds to the set of respondents receiving the questionnaires associated with design point, R1.

Table 14-1 provides some interesting general information. First, in the cases where negative payments are used (Versions 2 and 4) the lower initial exposure risk associated with Version 4 does not increase its frequency of being selected as the first choice. Indeed, the cases involving the negative payments have the lowest frequency of selection as the most preferred alternative. If we assume individuals are homogeneous with no differences in constraints affecting their behavior (whether actual or in the context of a hypothetical situation such as posed here), then we would label the higher rates of ranking Card A first with Version 1 in comparison to 2 or Version 3 in comparison to 4 as irrational. In the case of 1 (3) they are receiving the same exposure risk as 2 (4), but the latter costs less. Indeed, it leads to a reduction in expenses and this may well be the source of the problem. Respondents simply may not believe this case would happen. As a consequence, they may well be-

TABLE 14-1. FREQUENCY OF CARD CHOSEN FIRST BY VERSION

	Card chosen first[a,b]				
Version	A	B	C	D	Total[c]
1	13 (5.73)	13 (5.73)	23 (10.13)	8 (3.52)	57 (25.11)
2	4 (1.76)	21 (9.25)	18 (7.93)	16 (7.05)	59 (25.99)
3	19 (8.37)	15 (6.61)	15 (6.61)	7 (3.08)	56 (24.67)
4	5 (2.20)	16 (7.05)	16 (7.05)	18 (7.93)	55 (24.23)
Total[a]	41 (18.06)	65 (28.63)	72 (31.92)	49 (21.59)	227 (100.00)

[a] Parentheses denote percentage of overall total.

[b] Includes only those respondents who had ranked all four cards.

[c] Row and column percentages may not add to 100 due to rounding.

lieve selection of this case would involve realizing the higher exposure risk but no corresponding reduction in taxes.

There are also examples consistent with a priori expectations in the table. For example, compare the first place rankings given to Card D with Versions 1 and 2 as well as 3 and 4. D in Version 1 yields the same risk level but higher payments than D in Version 2. Thus, we would expect with homogeneous individuals, D to be ranked first more frequently in 2 and 4 in comparison to 1 and 3, respectively. This is precisely the outcome realized. Another confirmation can be found with Card B in Versions 1 and 2. However, the remainder of the cases would appear to contradict a priori expectations based on simple assumptions, although none is as glaring an example as we observed for the case of Card A.

In Table 14-2, we present the frequency of all the potential types of rankings of all cards observed in our sample. Of the 24 possibilities, only 15 were observed. The frequencies for each by version are displayed in this table. Clearly, version does seem to affect the frequency with which these rankings are observed. Perhaps the most dramatic difference arises with the change in the frequency observed for the ranking ABCD and DCBA with designs involving negative payments versus those that do not.

14.4.2 Some Simple Tests for the Effects of Exposure and Payment Vectors

The first step in our more systematic analysis of these rankings is analogous to the tests involving samples means with the contingent valuation responses in Chapter 11. That is, we treated individuals as homogeneous so that the only factors that might affect their respective rankings of the combinations of payments and exposure vectors would be a change in either of these variables. Tables 14-3 and 14-4 present the results of chi square tests for hypotheses based on this simple view of the role of individual characteristics on the rankings.* In the first of these tables we report the results of four

---

*The chi-square statistic is defined as follows:

$$\sum_j \sum_i \frac{(O_{ij} - E_{ij})^2}{E_{ij}},$$

where

O_{ij} = observed frequency in the ijth cell

E_{ij} = expected frequency in the ijth cell.

TABLE 14-2. RANKING PERMUTATIONS CHOSEN, BY VERSION

Rank permutation[a]	Version[b]								Total	
	R1		R2		R3		R4			
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
ABCD	13	22.81	4	6.78	17	30.36	4	7.27	38	16.74
ACBD	0	0.00	0	0.00	1	1.79	1	1.82	2	0.88
ADBC	0	0.00	0	0.00	1	1.79	0	0.00	1	0.44
BACD	4	7.02	13	22.03	4	7.14	9	16.36	30	13.22
BADC	1	1.75	0	0.00	0	0.00	0	0.00	1	0.44
BCAD	0	0.00	3	5.08	5	8.93	2	3.64	10	4.41
BCDA	8	14.04	5	8.48	6	10.71	5	9.09	24	10.57
CABD	1	1.75	2	3.39	1	1.79	3	5.45	7	3.08
CBAD	5	8.77	3	5.08	4	7.14	2	3.63	14	6.17
CBDA	7	12.28	7	11.86	7	12.50	1	1.82	22	9.69
CDAB	0	0.00	1	1.69	0	0.00	1	1.82	2	0.88
CDBA	10	17.54	5	8.48	3	5.36	9	16.36	27	11.89
DBCA	0	0.00	1	1.69	0	0.00	0	0.00	1	0.44
DCAB	0	0.00	3	5.08	0	0.00	7	12.72	10	4.41
DCBA	8	14.04	12	20.34	7	12.50	11	20.00	38	16.74
Total	57	100.00	59	100.00	56	100.00	55	100.00	227	100.00

[a]Of the 24 possible permutations, only 15 were actually chosen.

[b]Percentages may not add to 100 due to rounding.

TABLE 14-3. TESTS CONCERNING THE INDEPENDENCE OF VERSION ADMINISTERED AND CARD CHOSEN FIRST

Null hypothesis	χ^2 statistic	Degrees of freedom	Critical value of χ^2 at the 0.05 level	Reject the null hypothesis at a 0.05 level
Version administered is independent of card chosen first (across all versions and first choices)	25.82	9	16.92	Yes
Payment vector given an exposure vector:				
Exposure vector 1/10, 1/20, 1/50, 1/100	9.88	3	7.81	Yes
Exposure vector 1/20, 1/50, 1/60, 1/150	9.65	3	7.81	Yes
Exposure vector given a payment vector:				
Payment vector 0, 20, 55, 105	2.90	3	7.81	No
Payment vector -20, 5, 40, 80	0.89	3	7.81	No

TABLE 14-4. TESTS CONCERNING THE UNDERLYING DISTRIBUTION OF CARD CHOSEN FIRST, BY VERSION

Null hypothesis	χ^2 statistic	Degrees of freedom	Critical value of χ^2 at the 0.05 level	Reject the null hypothesis at a 0.05 level
Card chosen first follows a uniform probability density function for:				
Version 1	10.82	3	7.81	Yes
Version 2	10.61	3	7.81	Yes
Version 3	5.20	3	7.81	No
Version 4	7.62	3	7.81	No

tests. First, we consider whether the combination of payment and exposure risk (or risk-payment card) ranked first is independent of the version considered. Clearly, the results call for a rejection of this null hypothesis. The next four tests refine this analysis to consider the attributes of a design point that would be expected to influence the selection of a risk-payment card first. The first two tests consider the effects of the payment vector holding exposure risk constant, and the last two reverse the process. As the decisions suggest, the payment vector appears to have an effect on the card ranked first for each exposure risk vector, while reversing their roles and reanalyzing the results suggests that we cannot reject the null hypothesis of independence for the card ranked first and the exposure risk vector.

Table 14-4 uses the chi-square test as a goodness of fit test. In this case we maintain that each risk-payment card is equally likely to be ranked first. Thus we would expect the frequencies to be uniformly distributed across the four cards. The first four rows of this table compare the observed frequencies of each card being ranked first with what would be implied by the uniform assumption by version. In Versions 1 and 2 we reject the null hypothesis of a uniform distribution, while in Versions 3 and 4 we do not at the 0.05 level. Of course, it should be acknowledged that this is a close decision for the case of Version 4.

14.4.3 <u>Preliminary Estimates of the Random Utility Models</u>

The estimation of models in terms of the attributes of the choices being ranked (i.e., the exposure risk-payment combinations) and the socioeconomic characteristics of respondents can be interpreted as a direct extension to the simple chi-square tests for independence of one component of the ranking (i.e., cards designated first and the attributes of the combinations ranked) reported earlier. In those cases we effectively assumed that the features of each respondent did not effect the conditional probability of selecting one alternative as first and tested whether the payment and exposure vectors did. Now we include additional information in the form of the specific assumptions for the functional form for the random utility models that were hypothesized at the outset of this chapter as providing the basis for individuals' rankings. These models include variables describing the features of individuals and the attributes of what they have been asked to rank.

Given the pronounced differences in the rankings by version we have developed these models in stages. The first stage results are based on a strategy that estimates a separate model using the responses to each version (i.e., design point). The specification of these models is maintained constant across all of the subsets of the sample and includes the payment and exposure risk measures, as well as the individual's age, sex, household income, years of education, and years of residence in the town. These variables related to each respondent are treated in two different ways. In one set of models, reported in Table 14-5, they are each interacted with the payment measure and in the second set, reported in Table 14-6, they are each interacted with the exposure risk measure.

The results from these simple models are remarkably good. The payment and exposure risks are usually statistically significant determinants of the index utility relevant to ordering risk-payment alternatives.* Both have a negative effect on the utility index as we would have expected a priori. The only exception to this sign pattern for the estimated parameters occurs in the case of the estimates based on the Version 2 sub-sample with the model involving individual characteristics interacted with exposure, and this parameter would not be judged to be significantly different from zero.

Several of the remaining variables would also be judged as statistically significant determinants of the preference indexes in some models. Moreover, there does appear to be a pattern across the versions and models considered in this simple case. Income is generally a positive influence when its parameter would be judged to be statistically significant in models involving interactions with payment, while the reverse sign arose for the significant parameter estimates in models with exposure interactions. Since these interaction variables modify the effect attributed to the attributes of the payment-risk cards being ranked, this would seem a plausible result. It suggests in the first case that, ceteris paribus, higher income leads payment increases to have a smaller negative effect on ranking a combination first. It is important to

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*These results must be cautiously interpreted because the tests are based on the asymptotic distributions for each test statistic. Nonetheless, our judgments can usually be based on generous margins over the conventional critical values used in testing the null hypotheses for parameter estimates.

TABLE 14-5. BASIC MODEL FOR THE RANDOM UTILITY MODEL WITH THE RANKED LOGIT ESTIMATOR, BY VERSION--INTERACTION WITH PAYMENT MEASURE

	Versions[a]											
	R1			R2			R3			R4		
		Interactive			Interactive			Interactive			Interactive	
Independent variables	Alternative specific	Payment	Exposure	Alternative specific	Payment	Exposure	Alternative specific	Payment	Exposure	Alternative specific	Payment	Exposure
Alternative specific												
Payment	-0.07 (-3.20)			-0.08 (-3.63)			-0.03 (-1.88)			-0.04 (-1.58)		
Exposure[b]	-0.04 (-6.57)			-0.04 (-5.97)			-0.13 (-5.57)			-1.32 (-4.68)		
Individual specific												
Age (X)		-4.8×10^{-4} (-1.99)			2.2×16^{-3} (0.86)			-9.5×10^{-4} (-3.32)			-7.8×10^{-5} (-0.23)	
Sex[c] (X)		-2.2×10^{-2} (-2.99)			8.9×10^{-3} (1.51)			1.0×10^{-2} (1.73)			-1.7×10^{-2} (-2.79)	
Income[d] (X)		2.8×10^{-4} (2.20)			-1.0×10^{-4} (-0.71)			4.6×10^{-4} (2.79)			2.4×10^{-2} (1.65)	
Education (X)		3.5×10^{-3} (2.51)			3.6×10^{-3} (2.33)			-8.9×10^{-4} (-0.84)			-4.35×10^{-4} (-0.31)	
Years in town (X)		9.4×10^{-4} (3.09)			-6.9×10^{-4} (-1.79)			4.8×10^{-4} (1.43)			-4.9×10^{-5} (-0.11)	
Initial likelihood value	-155.7			-153.5			-149.4			-155.7		
Number of iterations	17			16			15			13		
Final likelihood value	-115.2			-125.7			-119.6			-135.8		
Number of observations	49			48			47			49		

[a]Numbers in parentheses denote the ratio of the ML estimate of the coefficient to the asymptotic standard deviation.

[b]Exposure risk is scaled by 1,000 in these estimates (Exposure = actual probability × 1,000).

[c]Denotes a binary variable equal to one if male, zero otherwise.

[d]Household income in thousands of dollars.

TABLE 14-6. BASIC MODEL FOR THE RANDOM UTILITY MODEL WITH THE RANKED LOGIT ESTIMATOR, BY VERSION--INTERACTION WITH EXPOSURE RISK MEASURES

	Versions[a]											
	R1			R2			R3			R4		
	Alternative	Interactive		Alternative	Interactive		Alternative	Interactive		Alternative	Interactive	
Independent variables	specific	Payment	Exposure	specific	Payment	Exposure	specific	Payment	Exposure	specific	Payment	Exposure
Alternative specific												
Payment	-0.03 (-5.64)			-0.04 (-5.52)			-0.06 (-6.10)			-0.05 (-4.19)		
Exposure[b]	-0.02 (-0.78)			0.01 (0.26)			-0.20 (-4.31)			-0.16 (-2.53)		
Individual specific												
Age (X)			6.9×10^{-4} (2.11)			-4.7×10^{-6} (-0.01)			2.3×10^{-3} (3.89)			2.6×10^{-4} (0.36)
Sex[c] (X)			2.2×10^{-2} (2.84)			-8.7×10^{-3} (-1.30)			-2.6×10^{-2} (-1.87)			3.7×10^{-2} (2.63)
Income[d] (X)			-5.2×10^{-4} (-2.71)			4.2×10^{-5} (0.27)			-1.5×10^{-3} (-2.57)			-6.0×10^{-4} (-1.86)
Education (X)			-2.5×10^{-3} (-1.55)			-3.9×10^{-3} (-2.91)			1.7×10^{-3} (0.65)			9.2×10^{-4} (0.29)
Years in town (X)			-9.5×10^{-4} (-2.40)			3.8×10^{-4} (0.98)			-9.3×10^{-4} (-1.30)			3.4×10^{-5} (0.03)
Initial likelihood value	-155.7			-152.5			-149.6			-155.72		
Number of iterations	17			15			16			14		
Final likelihood value	-115.2			-124.9			-116.9			-136.19		
Number of observations	49			48			47			49		

[a]Numbers in parentheses denote the ratio of the ML estimate of the coefficient to the asymptotic standard deviation.

[b]Exposure risk is scaled by 1,000 in these estimates (Exposure = actual probability × 1,000).

[c]Denotes a binary variable equal to one if male, zero otherwise.

[d]Household income in thousands of dollars.

recognize that this interpretation not only holds other characteristics constant but the level of exposure risk. In the models where income was interacted with exposure risk, the parameters suggest higher income makes individuals less tolerant of exposure risk increases (for a given payment level). Hence the models would predict that these individuals would be willing to pay more for risk reductions in these cases.

These same sign reversals arise for all the other variables included in the basic model, when their estimated parameters would be judged as statistically significant. Age has a negative effect when interacted with payment and positive when interacted with exposure. Sex has the same pattern, while education and years in town resembles income with a positive effect when interacted with payment and negative with exposure risk.

Table 14-7 reports the estimates of these basic models (i.e., the same independent variables with the interactions with payment and exposure risk). The results parallel those obtained with the model applied to the subsets of the sample by design point. The payment and exposure risk measures have parameter estimates that would be judged to be statistically significant. Both have negative influences on the utility index. Income and age are also statistically significant determinants, with the sign pattern for the estimated parameters agreeing in each case with what was found with the models estimated for each version, provided we considered only the parameters judged to be statistically significant at approximately the 5 percent level.

Thus, on the basis of these findings, it seems clear that respondents' characteristics do matter. The nature of their effects on the utility index may help to explain some of the contradictory results found by examining the cards chosen first in isolation. That is, the collection of all ranks taken together do appear to be "explained" reasonably well by a very simple specification for the random utility function.

Of course, one might reasonably ask just how good is this explanation? One informal means of gauging this conclusion is to consider the within sample performance of the model in predicting the exposure risk-payment combinations that were selected by each respondent as their first choice. To illustrate what is involved, consider an example. Suppose we used each specification of the basic model (i.e., that using interactions with payment and with exposure risk

TABLE 14-7. BASIC MODEL FOR THE RANDOM UTILITY MODEL WITH THE RANKED LOGIT ESTIMATOR, USING THE FULL SAMPLE

Independent variables	Model 1			Model 2		
		Interaction with individual specific variables			Interaction with individual specific variables	
	Alternative specific	Payment	Exposure	Alternative specific	Payment	Exposure
Alternative specific						
Payment	-0.02 (-2.56)			-0.02 (-8.03)		
Exposure	-0.04 (-8.86)			-0.03 (-2.22)		
Individual specific						
Age (x)		-3.8×10^{-4} (-3.36)				6.4×10^{-4} (3.63)
Sex[b] (x)		-3.3×10^{-3} (-1.31)				6.3×10^{-3} (1.55)
Income[c] (x)		1.7×10^{-4} (2.79)				-2.7×10^{-4} (-2.68)
Education (x)		8.0×10^{-4} (1.55)				-1.7×10^{-3} (-2.05)
Years in town (x)		1.2×10^{-4} (0.93)				-3.5×10^{-4} (-1.72)
Summary statistics						
Chi-square[d]						
Version 1	4.91			1.02		
Version 2	1.67			2.07		
Version 3	1.05			1.15		
Version 4	10.39			15.38		
Initial likelihood	-616.54			-616.54		
Number of iterations	10			9		
Final likelihood value	-552.70			-550.58		
Number of observations	194			194		

[a]Parentheses below the parameter estimates denote asymptotic t-ratios for the null hypothesis of no association.

[b]Denotes a binary variable equal to one if the respondent was a male, zero otherwise.

[c]Household income in thousands of dollars.

[d]This statistic estimates the significance of the divergence between actual and predicted card chosen first with smaller χ^2 values denoting a small divergence. Chi-square values presented by version have 3 degrees of freedom and a critical value of 6.25 at the 10-percent level of significance.

and the full sample) to predict the average survey respondents' conditional probability of selecting each of two of the exposure risk-payment cards first. Table 14-8 reports these estimated probabilities for Cards A and D with each version for each of the two specifications of the basic model. These differences in estimated conditional probabilities illustrate the effect of design point and model on predictions for a single hypothetical individual. To gauge the effect for actual individuals we repeated the process using the respondents in our sample. Below the estimated equations in Table 14-7 we report the results of this exercise. It was undertaken for subsets of the sample corresponding to each design point (or version) using the random utility functions estimated from the full sample. These chi-square statistics test the null hypothesis of conformity between observed and expected frequencies (based on treating the first ranked card as the one with the largest of the conditional probabilities predicted from the estimated random utility models) for each card as the first choice of the respondents receiving each of the four versions.

Only in the case of Version 4 (the negative payment case with the lowest exposure risks), would the model be judged to be inconsistent with practice. Of course, this is simply an index of performance, not a test of the model. The predicted probabilities and corresponding designations for the first cards are a within-sample prediction.* Nonetheless, it does pinpoint the same combination that was a part of the problems observed in our general interpretation of the rankings.

Refinement of these models can proceed in a variety of directions. Since our analysis under this phase of the research was intended to be preliminary we have sought to consider model refinements for only three reasons:

1. Does refinement to these models, either through inclusion of other variables describing an individual's attitudes toward risk (or hazardous wastes), information, health, or family status change the overall conclusions based on these basic models? Moreover, would any of these models be judged unambiguously superior to the basic model?

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*It converts the predictions into categorical exact variables and will be sensitive to the procedure used to designate each outcome. Nonetheless, it is one simple way to gauge the conformity of the model with subsets of the sample.

TABLE 14-8. ESTIMATED CONDITIONAL PROBABILITY OF A PAYMENT-EXPOSURE RISK COMBINATION RANKING AS FIRST

Version	Payment-exposure risk combination[b]	Basic model[a] Payment interaction	Exposure risk interaction
1	A	0.054	0.130
	D	0.240	0.145
2	A	0.057	0.139
	D	0.277	0.176
3	A	0.227	0.325
	D	0.155	0.090
4	A	0.237	0.344
	D	0.179	0.107

[a] The basic model refers to the random utility model estimated using the full sample as given in Table 14-7.

[b] The A and D correspond to the risk cards used to describe the payment-exposure risk combination. A specifies the combination of the first elements in each vector and the combination of the last elements.

2. Does the inclusion of these additional variables improve the consistency of the estimated models for each subset (i.e., according to version)?

3. Do the results for a selected set of refinements in the economic variables, changing their respective roles to provide somewhat more consistency with what would be expected from economic theory improve the results? And, therefore, do these modifications help to identify directions for further research?

Tables 14-9 through 14-13 begin the process of addressing these questions. Rather than review the specific results in detail, we will attempt to summarize the general responses to these three questions that seem to be implied by the findings to date.

First, while several of the knowledge, attitude, and risk preference measures would be judged to be significant determinants in some models for particular subsets of the sample, overall patterns are difficult to discern. The inclusion of these variables does not appear to affect the importance and sign patterns observed for the variables in the basic models presented earlier. In drawing this conclusion, it is important to note that the income and payment variables have been entered in a different format in these models. That is, the term income is followed by $(\div)^{-1}$. This is intended to suggest that the ratio of payment to income has entered the model.

Finally the results do not provide clear patterns as to how to proceed in model development. It does appear that the theoretical arguments sketched outlined may in this chapter help to improve upon the task associated with model selection. That is, it should be possible to use state dependent specifications for the deterministic component of the utility model to develop a set of interaction variables that would follow from theory. Moreover, by considering the variables that might be expected to lead to state dependency in preferences, it should be possible to reduce the set of potential models and to formulate specific expectations for the variables that are included in them.

14.5 COMPARING CONTINGENT VALUATION AND CONTINGENT RANKING ESTIMATES OF THE VALUE OF RISK REDUCTIONS

The objective of this section is to report a preliminary comparison of a set of valuation estimates implied by the estimated utility functions derived

TABLE 14-9. SELECTED RESULTS FOR THE RANDOM UTILITY MODEL WITH THE RANKED LOGIT ESTIMATOR BY VERSION

	Versions[a]											
	R1			R2			R3			R4		
		Interaction with individual specific variables			Interaction with individual specific variables			Interaction with individual specific variables			Interaction with individual specific variables	
Independent variables	Alternative specific	Payment	Exposure	Alternative specific	Payment	Exposure	Alternative specific	Payment	Exposure	Alternative specific	Payment	Exposure
Alternative specific												
Payment	-0.10 (-3.67)			-0.04 (-1.42)			-0.01 (-0.02)			-0.01 (-0.01)		
Exposure	-0.04 (-4.85)			-0.05 (-5.57)			-0.12 (-0.68)			-0.14 (-4.79)		
Individual specific[b]												
Age (x)		-4.8×10^{-4} (-1.63)			-1.1×10^{-4} (-0.39)			-8.4×10^{-4} (-3.04)			4.4×10^{-5} (0.15)	
Sex[c] (x)		-1.8×10^{-2} (-2.57)			7.7×10^{-3} (1.22)			6.6×10^{-3} (1.14)			-1.6×10^{-2} (-2.50)	
Income[d] $(\div)^{-1}$		9.6×10^{-2} (1.19)			-4.5×10^{-2} (-1.00)			-2.8×10^{-1} (-6.16)			-2.1×10^{-1} (-2.31)	
Education (x)		5.6×10^{-3} (3.23)			1.5×10^{-3} (1.15)			-1.1×10^{-3} (-1.06)			-1.6×10^{-3} (-1.11)	
Risk[e] (x)			-1.5×10^{-2} (-1.77)			1.0×10^{-2} (1.37)			9.1×10^{-3} (0.66)			9.4×10^{-3} (0.63)
Years lived in town (x)		5.5×10^{-4} (1.63)			-6.9×10^{-4} (-1.57)			5.2×10^{-4} (1.68)			-2.4×10^{-4} (-0.57)	
Specific reason for given rank[f] (x)		7.7×10^{-3} (1.23)			-1.1×10^{-2} (-1.72)			3.9×10^{-3} (0.66)			-6.5×10^{-3} (-1.07)	
Number of children less than 18 (x)		5.0×10^{-3} (1.09)			-1.1×10^{-2} (-3.02)			-2.4×10^{-4} (-0.08)			2.9×10^{-3} (0.14)	
Home ownership[g] (x)		2.1×10^{-2} (2.71)			7.2×10^{-4} (0.09)			-4.0×10^{-3} (-0.59)			8.6×10^{-3} (1.18)	
Summary statistics												
Initial likelihood value	-152.54			-155.72			-146.19			-162.08		
Number of iterations	16			15			20			15		
Final likelihood value	-108.27			-123.28			-112.03			-137.31		
Number of observations	48			49			46			51		

[a] Parentheses below the parameter estimates denote asymptotic t-ratios for the null hypothesis of no association.

[b] Parentheses to the right of each individual specific variable denote the form of the interaction with payment or exposure.

[c] Denotes a binary variable equal to one if the respondent was a male, zero otherwise.

[d] Household income in thousands of dollars.

[e] Denotes a binary variable equal to one if the individual stated a preference for risky situations, zero otherwise. This variable is based on responses to question K5.

[f] Denotes a binary variable equal to one if the respondent stated a specific illness for their ranking, zero otherwise.

[g] Denotes a binary variable equal to one if the respondent owned their home, zero otherwise.

TABLE 14-10. SELECTED RESULTS FOR THE RANDOM UTILITY MODEL WITH THE RANKED LOGIT ESTIMATOR BY VERSION

Independent variables	Versions[a] R1 Alternative specific	R1 Interaction with individual specific variables: Payment	R1 Exposure	R2 Alternative specific	R2 Interaction with individual specific variables: Payment	R2 Exposure	R3 Alternative specific	R3 Interaction with individual specific variables: Payment	R3 Exposure	R4 Alternative specific	R4 Interaction with individual specific variables: Payment	R4 Exposure
Alternative specific												
Payment	-0.10 (-3.57)			-0.06 (-2.47)			-0.01 (-0.45)			-0.01 (-0.30)		
Exposure	-0.04 (-4.99)			-0.05 (-5.81)			-0.13 (-7.22)			-0.14 (-4.87)		
Individual specific[b]												
Age (x)		-2.9×10^{-4} (-1.10)			-2.97×10^{-4} (-1.31)			5.7×10^{-4} (2.80)			-6.6×10^{-6} (-0.03)	
Sex[c] (x)		-1.9×10^{-2} (-2.92)			6.2×10^{-3} (1.02)			4.0×10^{-3} (0.76)			-1.8×10^{-2} (-2.86)	
Income[d] (÷)$^{-1}$		1.1×10^{-1} (1.59)			-5.4×10^{-2} (-1.23)			-2.7×10^{-1} (-6.86)			-2.4×10^{-1} (-2.49)	
Education (x)		4.7×10^{-3} (2.92)			2.8×10^{-3} (2.41)			-8.6×10^{-4} (-8.49)			-1.9×10^{-3} (-1.30)	
Risk[e] (x)			-1.5×10^{-2} (-1.72)			4.7×10^{-3} (0.72)			1.4×10^{-2} (11.06)			5.1×10^{-3} (0.37)
Number of children less than 18 (x)		5.2×10^{-3} (1.16)			-1.0×10^{-2} (-2.86)			2.7×10^{-4} (0.09)			-1.8×10^{-4} (-0.09)	
Home ownership[f] (x)		2.4×10^{-2} (3.25)			-2.9×10^{-3} (-0.41)			-2.2×10^{-3} (-0.34)			5.2×10^{-3} (0.75)	
Summary statistics												
Initial likelihood value	-152.55			-155.72			-146.19			-162.08		
Number of iterations	13			12			13			12		
Final likelihood value	-110.54			-125.83			-113.35			-137.95		
Number of observations	48			49			46			51		

[a]Parentheses below the parameter estimates denote asymptotic t-ratios for the null hypothesis of no association.

[b]Parentheses to the right of each individual specific variable denote the form of the interaction with payment or exposure.

[c]Denotes a binary variable equal to one if the respondent was a male, zero otherwise.

[d]Household income in thousands of dollars.

[e]Denotes a binary variable equal to one if the individual stated a preference for risky situations, zero otherwise. This variable is based on responses to question K5.

[f]Denotes a binary variable equal to one if the respondent owned their home, zero otherwise.

TABLE 14-11. SELECTED RESULTS FOR THE RANDOM UTILITY MODEL WITH THE RANKED LOGIT ESTIMATOR BY VERSION

	Versions[a]											
	R1			R2			R3			R4		
		Interaction with individual specific variables			Interaction with individual specific variables			Interaction with individual specific variables			Interaction with individual specific variables	
Independent variables	Alternative specific	Payment	Exposure	Alternative specific	Payment	Exposure	Alternative specific	Payment	Exposure	Alternative specific	Payment	Exposure
Alternative specific												
Payment	-0.07 (-2.96)			-0.07 (-3.03)			-0.01 (-0.59)			-0.02 (-0.61)		
Exposure	-0.04 (-3.87)			-0.04 (-4.04)			-0.09 (-3.59)			-0.11 (-3.47)		
Individual specific[b]												
Age (x)		-2.9×10^{-4} (-1.18)			8.2×10^{-5} (0.33)			-9.2×10^{-4} (-4.28)			2.7×10^{-4} (1.03)	
Sex[c] (x)		-2.2×10^{-2} (-3.36)			6.1×10^{-3} (1.02)			5.0×10^{-3} (0.89)			-2.1×10^{-2} (-3.31)	
Income[d] $(\div)^{-1}$		-4.9×10^{-2} (-0.67)			-2.2×10^{-2} (-0.52)			-2.5×10^{-1} (-5.97)			-2.7×10^{-1} (-2.81)	
Education (x)		3.8×10^{-3} (2.49)			2.5×10^{-3} (2.13)			-3.5×10^{-4} (-0.35)			-1.4×10^{-3} (-0.97)	
Years lived in town (x)		8.8×10^{-4} (2.80)			-6.2×10^{-4} (-1.68)			4.8×10^{-4} (1.92)			-6.5×10^{-5} (-0.16)	
Concerned about hazardous waste[e] (x)			-3.4×10^{-3} (-0.33)			-7.0×10^{-3} (-0.92)			-4.2×10^{-2} (-2.39)			-4.2×10^{-4} (-0.02)
Hazardous waste pollution is harmful[f] (x)			-1.5×10^{-2} (-1.69)			-7.5×10^{-3} (-0.89)			-9.5×10^{-3} (-0.69)			-3.4×10^{-2} (-2.24)
Risk of dying from hazardous waste[g] (x)			-9.1×10^{-3} (-0.22)			7.7×10^{-3} (1.43)			-2.3×10^{-2} (-1.63)			-2.5×10^{-1} (-5.96)
Summary statistics												
Initial likelihood value	-152.55			-155.72			-146.19			-162.08		
Number of iterations	15			13			16			18		
Final likelihood value	-112.64			-128.14			-107.17			-130.87		
Number of observations	48			49			46			51		

[a]Parentheses below the parameter estimates denote asymptotic t-ratios for the null hypothesis of no association.

[b]Parentheses to the right of each individual specific variable denote the form of the interaction with payment or exposure.

[c]Denotes a binary variable equal to one if the respondent was a male, zero otherwise.

[d]Household income in thousands of dollars.

[e]Denotes a binary variable equal to one if the respondent stated a concern about hazardous waste, zero otherwise. This variable is based on responses to question K4.

[f]Denotes a binary variable equal to one if the respondent considered hazardous waste pollution as harmful.

[g]Respondents evaluation of the risk of dying from hazardous waste given the risk ladder.

TABLE 14-12. SELECTED RESULTS FOR THE RANDOM UTILITY MODEL WITH THE RANKED LOGIT ESTIMATOR BY VERSION

Independent variables	Versions[a]											
	R1			R2			R3			R4		
	Alternative specific	Interaction with individual specific variables		Alternative specific	Interaction with individual specific variables		Alternative specific	Interaction with individual specific variables		Alternative specific	Interaction with individual specific variables	
		Payment	Exposure		Payment	Exposure		Payment	Exposure		Payment	Exposure
Alternative specific												
Payment	-0.02			-0.03			-0.04			-0.02		
	(-1.63)			(-1.86)			(-2.53)			(-1.21)		
Exposure	0.02			-0.01			-0.24			-0.18		
	(0.93)			(-0.49)			(-4.76)			(-3.35)		
Individual specific[b]												
Age (x)		-6.8×10^{-5}			-1.7×10^{-4}			-3.5×10^{-4}			-1.5×10^{-4}	
		(-0.26)			(-.060)			(-1.23)			(-0.51)	
Sex[c] (x)		-1.8×10^{-2}			6.3×10^{-3}			1.0×10^{-2}			-2.6×10^{-2}	
		(-2.73)			(1.05)			(1.57)			(-3.79)	
Income per person[d] $(\div)^{-1}$		-1.3×10^{-2}			-3.3×10^{-2}			-1.3×10^{-1}			-7.7×10^{-2}	
		(-0.47)			(-0.78)			(-2.92)			(-2.64)	
Education (x)			-4.8×10^{-3}			-3.9×10^{-3}			2.9×10^{-3}			6.1×10^{-3}
			(-3.13)			(-2.65)			(0.98)			(1.91)
Years in town (x)			-7.0×10^{-4}			7.5×10^{-5}			4.0×10^{-4}			-2.6×10^{-4}
			(-1.75)			(0.17)			(0.59)			(-0.26)
Acton[e] (x)			-7.7×10^{-5}			-3.7×10^{-3}			-1.7×10^{-2}			-4.1×10^{-2}
			(-0.01)			(-0.44)			(-0.93)			(-2.53)
Comparative health[f] (x)			-1.9×10^{-4}			-2.1×10^{-3}			2.7×10^{-2}			-3.5×10^{-2}
			(-0.03)			(-0.29)			(1.70)			(-2.63)
Years smoked[g] (x)			3.4×10^{-4}			-4.3×10^{-4}			1.8×10^{-3}			-5.2×10^{-4}
			(1.44)			(-1.27)			(2.95)			(-0.86)
Summary statistics												
Initial likelihood value	-155.72			-155.72			-149.36			-162.08		
Number of iterations	13			13			14			13		
Final likelihood value	-117.97			-127.23			-113.00			-132.64		
Number of observations	49			49			47			51		

[a]Parentheses below the parameter estimates denote asymptotic t-ratios for the null hypothesis of no association.

[b]Parentheses to the right of each individual specific variable denote the form of the interaction with payment or exposure.

[c]Denotes a binary variable equal to one if the respondent was a male, zero otherwise.

[d]Household income in thousands of dollars divided by number of people in household.

[e]Denotes a binary variable equal to one if the respondent lived in Acton, zero otherwise.

[f]Denotes a binary variable equal to one if the respondent rated their health better than others of the same age, zero otherwise. This variable is based on responses to question J1.

[g]Number of years respondent smoked tobacco. For respondents who have not smoked this value is set to zero.

TABLE 14-13. SELECTED RESULTS FOR THE RANDOM UTILITY MODEL WITH THE RANKED LOGIT ESTIMATOR, FULL SAMPLE

	Model-specific sample[a]					
	Model 1			Model 2		
		Interaction with individual specific variables			Interaction with individual specific variables	
Independent variables	Alternative specific	Payment	Exposure	Alternative specific	Payment	Exposure
Alternative specific						
Payment	-0.02 (-1.66)			-0.01 (-1.56)		
Exposure	-0.04 (-9.66)			-0.03 (-5.02)		
Individual specific						
Age		-3.6×10^{-4} (-3.02)			-3.2×10^{-4} (-2.81)	
Sex[b]		-3.4×10^{-3} (-1.33)			-4.7×10^{-3} (-1.81)	
Income[c] $(\div)^{-1}$		-8.3×10^{-2} (-2.91)			-1.0×10^{-1} (-3.62)	
Education (x)		6.9×10^{-4} (1.31)			7.6×10^{-4} (1.48)	
Risk[d] (x)			6.8×10^{-3} (1.45)			
Years in town (x)		3.8×10^{-5} (0.25)			1.6×10^{-4} (1.16)	
Reason for rank[e] (x)		-6.9×10^{-4} (-0.25)				
Number of children less than 18 (x)		7.8×10^{-4} (0.58)				
Home ownership (x)		7.1×10^{-3} (2.22)				
Attitudes toward hazardous wastes[f] (x)						-9.7×10^{-3} (-1.90)
Consider hazardous waste a serious problem[g] (x)						-1.3×10^{-2} (-2.74)
Risk of dying from hazardous waste[h] (x)						2.3×10^{-3} (0.42)

See footnotes at end of table. (continued)

TABLE 14-13 (continued)

Independent variables	Model-specific sample[a] Model 1 Alternative specific	Interaction with individual specific variables Payment	Exposure	Model 2 Alternative specific	Interaction with individual specific variables Payment	Exposure
Summary statistics						
Chi-square[i]						
Version 1	5.09			9.82		
Version 2	1.55			3.34		
Version 3	0.98			1.78		
Version 4	10.96			5.90		
Initial likelihood	-616.54			-616.54		
Number of iterations	15			14		
Final likelihood value	-546.06			-542.12		
Number of observations	194			194		

[a]Parentheses below the parameter estimates denote asymptotic t-ratios for the null hypothesis of no association.

[b]Denotes a binary variable equal to one if the respondent was a male, zero otherwise.

[c]Household income in thousands of dollars.

[d]Denotes a binary variable to denote combined risk of dying from: auto accident, heart disease, air pollution, or hazardous wastes.

[e]Denotes a binary variable equal to one if the respondent had a particular illness in mind when the cards were ranked, zero otherwise. This variable was based on responses to question F7.

[f]Denotes a binary variable equal to one if the respondent was concerned about hazardous waste, zero otherwise. This variable was based on responses to question K4.

[g]Denotes a binary variable equal to one if the respondent considered hazardous waste as a serious problem, zero otherwise.

[h]Denotes a binary variable equal to one if the respondent claimed there was a relatively large risk of dying from hazardous waste pollution, zero otherwise.

[i]This statistic estimates the significance of the divergence between actual and predicted card chosen first with smaller χ^2 values denoting a small divergence. Chi-square values presented by version have 3 degrees of freedom and a critical value of 6.25 at the 10-percent level of significance.

from the contingent ranking models in comparison with the contingent valuation resutls. It should be acknowledged that since we have not imposed specific theoretical restrictions on the estimated utility functions, we do not have an explicit theoretical interpretation for the valuation estimates that are derived. This problem was first identified in Desvousges, Smith, and McGivney [1983]. It arises because theory would suggest restrictions on the nature of the relationship between income and the proposed payment for an exposure risk level. Of course, the exact nature of these restrictions depends on how these payments are defined. Without these restrictions, different valuation estimates can be derived depending on whether they are defined as changes in the payments to maintain constant utility in the presence of a change in exposure risk, or changes in income to offset the change in exposure risk.

For the present purposes, we will confine our attention to calculating the changes in the proposed payments that would be required to maintain a constant level for the utility index when the exposure risk changes. With the simple models, the payment changes can be defined for each of the two specifications of the basic model. Consider, for example, the specification involving interactions between the payment and the independent variables describing the characteristics of the individual. A general statement of this model is given in Equation (14.11):

$$v = a_0P + a_1R + P \cdot \sum_{j=1}^{M} b_jX_j \ , \qquad (14.11)$$

where

P = payment

R = exposure risk

X_j = jth characteristic of the individual.

Totally differentiating Equation (14.11) with respect to the arguments that are assumed to change, we have Equation (14.12):

$$dv = a_0dP + a_1dR + dP \sum_{j=1}^{M} b_jX_j \ . \qquad (14.12)$$

Holding total utility constant implies the dv=0. Thus, solving Equation (14.12) for dP, we have:

$$dP = \frac{-a_1 dR}{(a_0 + \sum_{j=1}^{M} b_j X_j)} . \qquad (14.13)$$

The same basic logic can be applied to the case of a model where the interactions are with the exposure risk variable, as defined in Equation (14.14):

$$\bar{v} = C_0 P + C_1 R + R \sum_{j=1}^{M} d_j X_j . \qquad (14.14)$$

Repeating the same process, the payment increment, dP, in this case would be given as follows:

$$dP = \frac{-(C_1 + \sum_{j=1}^{M} d_j X_j) dR}{C_0} . \qquad (14.15)$$

To implement this approach to estimating the valuation of a risk change, we must select one or more of the estimated random utility models. As we acknowledged earlier, our refined models add little to the simple basic model we used to start the process of trying to interpret the role of respondent characteristics in explaining the observed rankings. Nonetheless, this conclusion is at this stage purely a judgment based on rather casual comparison of the estimates. Moreover, it is also clear that we can improve on the information used in forming this judgment. For example, we can consider using adaptations to the Hausman [1978] specification error test (see also Hausman and McFadden [1984]) to evaluate our models. These are direct avenues for future research in improving our preliminary estimates. However, it should be acknowledged that these tests will not provide information on the overall importance of the selection of a model for the valuation estimates. That is, if our objective in estimating these models is exclusively one of estimating the representative individual's valuation of a reduction in the risk of exposure to hazardous waste, and if Equations (14.13) and (14.15) are accepted as the appropriate valuation measures, then our interest lies in the sensitivity of these results to the model used. It may well be, for example, that we cannot judge a particular model as "best", but that the selection from a set of close competitors does not matter for the implied benefit estimates.

We can provide a simple illustration of the problem by comparing the implied valuation estimates for all versions of the basic model in some specific scenarios. For example, consider the task of predicting the valuation of the risk changes posed in the contingent valuation questions by the respondents receiving the ranking questionnaire. This is one potential valuation scenario. Table 14-14 reports the average valuations derived from these calculations by town for each of the three exposure risk reductions within the range of probabilities posed in the contingent ranking questionnaires. All ten of the possible versions of the basic model have been used (i.e., 5 based on sample × 2 based on interaction variables used).

While this is a detailed table, a few general patterns do emerge. Models estimated from subsets of the sample routinely have more negative predictions for what are improvements in the respondents' circumstances. There are also a very wide range of estimates for these payment increments over the various models and towns. Of the set of models reported, it appears that the basic model estimated using the full sample offers the most consistent results. There are no negative predictions and there is also a more modest set of estimates for the valuation increments. Based on these findings alone, it seems clear that the selection of a model for valuation estimates from this set can make a substantial difference in the results derived. Moreover, even on the basis of a rather limited set of models and the maintenance of parallel specifications in models used, the problem of devising a set of criteria for refining model selection does appear quite relevant to this application.

Since developing a proposed resolution to this issue was beyond the scope of the Phase I research activities, we have developed two illustrative comparisons of the contingent valuation and contingent ranking valuation estimates. The first of these relies on mean valuation responses from the contingent valuation component of the sample and the mean estimated valuation response using each of the estimated utility models with the respondents to the contingent ranking questionnaires. Table 14-15 reports these results for each of the three exposure risk changes falling within the range of risks used in the rankings.

TABLE 14-14. AVERAGE VALUATION OF EXPOSURE RISK CHANGE BY TOWN[a]

		1/30 to 1/60										1/10 to 1/20									
		Version 1		Version 2		Version 3		Version 4		Version 5		Version 1		Version 2		Version 3		Version 4		Version 5	
Town	Income	P	E	P	E	P	E	P	E	P	E	P	E	P	E	P	E	P	E	P	E
Abington	25.8	26.4	26.2	NV	11.5	35.8	NV	NV	51.2	32.7	28.8	79.3	78.5	NV	34.4	107.3	NV	NV	154.6	98.2	86.3
Acton	45.6	61.6	28.6	NV	20.8	43.1	NV	NV	48.1	48.2	35.5	184.8	85.4	NV	62.5	129.2	NV	NV	144.2	144.6	106.4
Arlington	30.0	16.1	17.6	NV	17.1	41.0	NV	NV	38.7	28.6	25.4	48.2	52.9	NV	51.4	122.9	NV	NV	116.2	85.8	76.2
Belmont	50.8	NV	35.0	NV	14.7	45.1	NV	NV	55.7	93.9	36.8	NV	105.1	NV	44.1	135.3	NV	NV	167.0	281.6	110.4
Beverly	25.6	46.4	20.7	NV	19.5	32.8	NV	NV	44.6	36.6	25.6	139.1	62.1	NV	58.4	98.4	NV	NV	133.8	109.6	76.8
Braintree	45.5	23.1	22.8	NV	16.5	41.3	NV	NV	49.6	39.8	28.8	69.4	68.4	NV	49.4	124.0	NV	NV	148.7	119.4	86.3
Brookline	44.2	NV	21.2	NV	18.1	30.4	NV	NV	51.7	49.1	21.0	NV	63.6	NV	54.2	91.2	NV	NV	155.0	147.2	63.1
Cambridge	19.5	29.8	24.0	NV	17.0	38.8	NV	NV	46.1	37.0	32.2	89.4	72.1	NV	50.9	116.4	NV	NV	138.2	111.1	96.7
Canton	29.2	20.8	22.3	NV	8.2	44.1	NV	NV	47.8	37.7	24.3	62.5	66.9	NV	24.5	132.4	NV	NV	143.4	113.2	73.0
Carlisle	67.5	22.9	30.6	NV	24.0	72.8	15.3	NV	47.1	68.0	42.7	68.5	91.7	NV	72.1	218.3	46.0	NV	141.2	204.0	128.2
Chelsea	22.5	30.6	23.4	NV	18.7	37.5	NV	NV	41.1	32.4	29.9	91.9	70.3	NV	56.1	112.5	NV	NV	123.4	97.1	89.6
Cohasset	27.5	37.2	30.6	NV	20.5	34.4	NV	NV	50.7	43.1	36.4	111.5	91.9	NV	61.4	103.3	NV	NV	152.2	129.2	109.2
Everett	11.3	15.4	13.7	1.3	9.8	32.3	NV	610.9	45.2	25.1	18.2	46.3	41.0	3.8	29.3	97.0	NV	1832.7	135.7	75.3	54.5
Framington	36.9	14.8	25.5	NV	17.4	40.1	NV	NV	45.4	34.7	30.3	44.4	76.3	NV	52.2	120.4	NV	NV	136.1	104.2	90.9
Franklin	47.5	58.8	34.2	NV	16.9	43.3	NV	NV	55.5	56.5	38.9	158.3	102.7	NV	50.6	129.9	NV	NV	166.4	169.6	116.6
Hill	5.8	17.6	12.6	NV	14.3	28.8	NV	109.6	42.0	26.6	17.5	52.7	37.9	NV	42.8	86.5	NV	328.9	125.9	79.9	52.4
Holbrook	27.5	21.2	26.4	NV	14.6	41.1	NV	NV	52.8	42.3	34.4	63.7	79.3	NV	43.8	123.3	NV	NV	158.4	127.0	103.1
Kingston	7.5	9.8	NV	NV	11.6	24.6	NV	NV	32.3	16.3	1.1	29.2	NV	NV	34.9	73.9	NV	NV	96.9	48.9	3.2
Lexington	57.5	10.4	34.5	NV	20.6	42.2	NV	NV	49.6	48.9	37.4	31.2	103.6	NV	61.7	126.7	NV	NV	148.8	146.7	112.3
Lynn	17.5	18.4	9.7	NV	15.3	35.3	NV	NV	41.0	32.2	18.7	55.1	29.2	NV	45.9	105.8	NV	NV	123.0	96.5	56.2
Malden	38.5	1.8	26.9	NV	15.9	36.9	NV	NV	49.9	50.2	29.3	120.5	80.7	NV	47.6	110.8	NV	NV	149.7	150.6	87.9
Marblehead	17.5	NV	36.7	NV	12.7	24.7	NV	NV	44.1	23.0	24.0	NV	110.0	NV	38.0	74.1	NV	NV	132.3	69.1	71.9
Marshfield	17.5	14.4	11.6	NV	16.3	32.4	NV	NV	43.0	26.1	20.5	43.2	34.8	NV	48.9	97.2	NV	NV	129.1	78.2	61.4
Medford	29.2	28.1	23.1	NV	17.1	35.7	NV	NV	49.0	35.8	28.4	84.2	69.4	NV	51.3	107.2	NV	NV	147.0	107.3	85.1
Melrose	42.5	55.6	31.2	NV	20.2	40.5	NV	NV	48.6	47.5	34.9	166.6	93.5	NV	60.5	121.4	NV	NV	146.0	142.4	104.6
Millis	35.0	14.8	18.6	NV	14.0	42.0	NV	NV	47.4	31.8	26.8	44.3	55.8	NV	42.1	125.9	NV	NV	142.0	95.3	80.4
Milton	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Natick	45.0	92.0	36.3	NV	23.2	57.7	5.8	NV	48.7	75.9	45.5	276.0	109.0	NV	69.6	173.0	17.4	NV	146.0	227.7	136.4
Needham	17.5	15.2	19.1	NV	17.0	61.2	5.1	NV	39.0	40.1	33.8	45.6	57.4	NV	50.8	183.6	15.3	NV	117.1	120.3	101.3
Newton	50.5	52.1	33.0	NV	19.8	39.7	NV	NV	49.1	45.8	35.4	156.2	99.0	NV	59.4	119.1	NV	NV	147.3	137.3	106.3
Norwell	47.5	31.2	32.2	NV	17.0	47.2	NV	NV	50.9	47.7	36.9	93.6	96.7	NV	50.9	141.6	NV	NV	152.8	143.1	110.8
Norwood	32.5	26.9	23.0	NV	17.7	41.1	NV	NV	46.1	44.8	30.9	80.8	69.1	NV	53.2	123.3	NV	NV	138.3	134.3	92.8
Peabody	45.8	29.9	26.4	NV	16.0	38.1	NV	NV	49.8	36.5	29.4	89.8	79.1	NV	47.8	114.4	NV	NV	149.4	109.4	88.2
Quincy	19.5	25.4	22.8	NV	16.2	38.6	NV	NV	44.7	33.9	29.3	76.3	68.3	NV	48.6	115.9	NV	NV	134.1	101.6	87.8
Revere	7.5	16.8	14.9	NV	12.5	24.2	NV	NV	45.4	21.3	14.8	50.4	44.7	NV	37.4	72.7	NV	NV	136.2	63.9	44.4
Salem	22.5	21.0	22.1	NV	12.1	28.4	NV	NV	48.9	25.3	21.7	63.1	66.2	NV	36.1	85.2	NV	NV	146.8	76.0	65.0
Saugus	32.5	20.9	25.4	NV	13.9	36.2	NV	NV	52.7	35.1	30.3	62.5	76.2	NV	41.7	108.5	NV	NV	158.1	105.4	90.8
Scituate	22.5	19.1	17.5	NV	26.2	31.3	NV	NV	35.2	28.3	26.1	57.2	52.4	NV	78.6	93.8	NV	NV	105.7	85.0	78.4
Sherborn	82.5	NV	47.0	NV	17.8	47.5	4.8	NV	60.4	65.8	44.5	NV	140.9	NV	53.4	142.5	14.5	NV	181.2	197.3	133.6
Somerville	20.8	NV	25.5	NV	19.7	39.1	NV	NV	40.9	35.6	32.3	NV	76.4	NV	59.1	117.3	NV	NV	122.6	106.8	96.8
Stoneham	27.5	17.5	16.5	NV	18.5	43.6	NV	NV	38.6	35.8	26.2	52.4	49.4	NV	55.5	130.8	NV	NV	115.7	107.5	78.6
Stoughton	25.0	16.2	15.2	NV	15.7	28.1	NV	NV	42.5	23.1	17.7	48.6	45.5	NV	47.1	84.4	NV	NV	127.4	69.5	53.0
Swampscott	47.5	44.2	35.1	NV	13.9	46.5	0.2	NV	55.8	49.1	38.5	132.6	105.4	NV	41.6	139.6	0.4	NV	167.4	147.4	115.3
Topsfield	67.5	19.8	25.8	NV	18.2	38.4	NV	NV	51.4	33.8	29.0	59.3	77.4	NV	54.7	115.1	NV	NV	154.1	101.4	87.1
Wakefield	42.5	32.9	33.2	NV	12.1	42.1	NV	NV	54.5	40.5	34.9	98.7	99.5	NV	36.4	126.3	NV	NV	163.5	121.5	104.7
Walpole	27.5	30.0	25.0	NV	13.9	37.8	NV	NV	45.2	32.3	26.9	90.1	75.0	NV	41.6	113.5	NV	.NV	135.8	97.0	80.6
Waltham	27.5	13.2	12.5	NV	21.3	38.6	NV	NV	38.7	31.3	25.1	39.7	37.4	NV	63.9	115.8	NV	NV	116.0	93.8	75.4
Watertown	33.5	24.9	20.6	NV	15.5	42.4	NV	NV	44.0	35.9	24.5	74.7	61.7	NV	46.6	127.3	NV	NV	132.0	107.6	73.5
Westwood	67.5	84.6	37.8	NV	22.4	47.0	2.6	NV	43.4	41.0	38.1	253.8	113.4	NV	67.3	140.9	7.8	NV	130.2	123.0	114.2
Weymouth	22.5	42.7	30.3	NV	24.4	31.9	NV	NV	49.3	44.9	37.5	128.0	90.8	NV	73.3	95.6	NV	NV	147.8	134.8	112.4
Wilmington	47.5	19.2	24.6	NV	19.1	52.3	4.3	NV	42.6	38.3	33.3	57.5	73.9	NV	57.2	152.0	12.8	NV	127.7	114.8	99.9
Winthrop	45.0	26.8	26.1	NV	18.7	38.3	NV	NV	47.5	35.6	31.3	80.3	78.4	NV	56.0	114.9	NV	NV	142.4	106.7	93.4
Woburn	34.2	16.6	19.2	NV	16.0	41.3	NV	NV	44.2	32.8	26.6	49.9	57.6	NV	47.9	124.0	NV	NV	132.7	98.5	79.8

NOTES: P = Payment; E = Exposure; NV designates a negative value for the estimated payment corresponding to the utility change.

[a]These estimates are constructed using the full sample to estimate the change in the payment that would maintain a constant level for the estimated indirect function with the specified change in the exposure risk.

TABLE 14-15. AVERAGE VALUATION ESTIMATES FOR RISK REDUCTIONS USING CONTINGENT VALUATION AND CONTINGENT RANKING ESTIMATES[a]

Valuation framework		Change in exposure risk 1/5 to 1/10		n	1/10 to 1/20		n	1/30 to 1/60		n
I. Contingent valuation										
Conditional risk 1/10			14.19 (19.89)	42		13.85 (20.56)	47		19.19 (25.92)	48
Conditional risk 1/20			26.20 (42.39)	46		31.02 (48.34)	46		19.73 (42.95)	45
II. Contingent ranking[b]										
Version 1	P	N[c]	155.42 (928.81)	206	N	77.71 (464.41)	206	N	25.90 (154.80)	206
	E	R	152.15 (67.28)		R	76.68 (33.64)		R	25.36 (11.21)	
Version 2	P	R	-115.17 (316.83)	206	R	-57.58 (158.42)	206	R	-19.19 (52.81)	206
	E	R	107.48 (33.93)		R	53.74 (16.97)		N	17.91 (5.65)	
Version 3	P	R	240.98 (64.09)	206	R	120.49 (32.04)	206	R	40.16 (10.68)	206
	E	R	-48.48 (76.64)		R	-24.24 (38.32)		R	-8.08 (12.77)	
Version 4	P	N	-455.76 (2,882.36)	206	N	-227.89 (1,441.18)	206	N	-75.96 (480.39)	206
	E	R	282.36 (44.71)		R	141.18 (22.35)		R	47.06 (7.45)	
Version 5	P	R	250.18 (136.06)	206	R	125.09 (68.03)	206	R	41.70 (22.68)	206
	E	R	184.88 (65.42)	206	R	92.44 (32.71)	206	R	30.81 (10.90)	206

[a]Numbers in parentheses below the means are the estimated sample standard deviations. n is the sample size involved in each case.

[b]P refers to the model using the payment interaction, and E the exposure risk interaction.

[c]N designates the failure to reject the null hypothesis of equality of means and R indicates rejection. The t-statistic used for these calculations was

$$t = \frac{\bar{X}_1 - \bar{X}_2}{sp}$$

$$sp = \sqrt{\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1 + n_2 - 2}\left(\frac{n_1 + n_2}{n_1 \cdot n_2}\right)}$$

There are two ways of interpreting these results. First, since the means were developed independently, we might suggest the application of a test for the null hypothesis of equality of means for the relevant exposure risk reductions using each of the potential contingent ranking models. This is not the correct interpretation of the contingent ranking valuations. Each estimate involves a nonlinear combination of random variables (see Equations (14.13) and (14.15)). There will be a different mean and variance for each individual by the assumptions of the model. Thus, to use these calculated values is equivalent to ignoring this information. Nonetheless, it is a practice that closely parallels the types of comparisons in valuation estimates reported in earlier studies. Consequenlty, we have reported it to provide an approximate gauge of the relationship between the average estimates derived from the two methods. When the conventional t test for difference in means is applied as an index of disparity in the two estimates, there are only seven cases where the null hypothesis of equality would not be rejected at the 5 percent level. These cases are identified in Table 14-15 with an N prior to sample mean (R designates rejection of the null hypothesis). In each case the test involved a comparison of the mean of the calculated contingent ranking valuations with the relevant contingent valuation mean. Since the contingent ranking design points held the conditional risk constant at 1/10, this implies the tests involve only the first row of the table.

It is difficult to isolate features that distinguish the cases where we would be led to a judgment that the null hypothesis could not be rejected in relationship to the remainder where it is. Clearly, the differences can arise from substantial differences in the underlying distributions for these random variables, making the use of the test statistic as a crude index of disparity a poor discriminator. Equally important, differences in the composition of the individuals in each contingent valuation subsample versus respondents receiving the contingent ranking questionnaires who were used for these calculations could be another factor in these pronounced differences.

One approach to avoid these criticisms is to assume we can only focus on the mean estimates from each method and apply instead the Cummings, Brookshire, and Schulze [1984] reference accuracy criteria. Here we can find several cases with overlapping intervals implied by taking ±50 percent of their respective estimated values. The cases of consistency as judged by this approach are confined to those with the smallest risks (i.e., the change from 1/30 to 1/60).

A second approach for developing a comparison of the contingent valuation and contingent ranking estimates does so at the individual level. To illustrate how it would proceed we have selected two contingent ranking based models--the basic specification applied to the full sample using the payment (P) and the exposure risk (E) formulations. With these estimated models it is possible to calculate for the contingent valuation respondents a valuation for the risk changes they are asked. Moreover, these estimates can be developed taking account of each individual's characteristics (to the extent they are included as determinants of the contingent ranking utility functions). Table 14-16 reports a summary of these results for two smaller risk changes that overlap the contingent ranking design risks. This table reports regression models following Theil's [1961] proposed approach for evaluating the predictive performance of economic models. In this case the contingent valuation for these specified risk changes have been regressed on the estimated payment change to maintain constant total utility in the presence of that risk reduction that was calculated for each individual using each of two of the random utility models estimated with the contingent ranking responses. Each of the four contingent valuation design points involving these two risk changes is considered separately, because we would expect that the level of the conditional risk, which cannot be reflected in the contingent ranking models, would affect the consistency between the two approaches to estimating the valuation.

These results confirm the findings using the Cummings et al. reference accuracy criteria in that the contingent valuation and contingent ranking estimates appear more consistent at the lower risks (i.e., the case of a change from 1/30 to 1/60). The correspondence does not appear to be affected by the level of the conditional risk. Indeed, the results are approximately comparable for the two levels. Finally, the model using interactions with exposure risk is more compatible than that involving interactions with payments.

Overall, while these models are preliminary and the comparisons limited to the two basic models estimated using the full sample of contingent ranking responses, it does appear that contingent valuation and contingent ranking can provide comparable valuation estimates. Of course, the selection of the

TABLE 14-16. COMPARISON OF CONTINGENT VALUATION AND CONTINGENT RANKING VALUATION ESTIMATES USING INDIVIDUAL RESPONSES[a]

Independent variables	1/10 to 1/20				1/30 to 1/60			
	D1		D2		D5		D6	
	P	E	P	E	P	E	P	E
Intercept	-4.24 (-0.87)	-5.15 (-0.79)	27.97 (2.29)	-8.56 (-0.38)	6.60 (0.53)	2.26 (0.20)	-42.60 (-3.18)	-32.85 (-1.28)
CR payment	0.15 (5.11) (-29.31)[b]	0.25 (3.73) (-11.19)	0.06 (1.08) (-17.09)	0.48 (2.167) (-2.34)	0.33 (1.06) (-2.17)	0.56 (1.59) (-1.25)	1.45 (5.91) (1.83)	1.83 (2.47) (1.12)
R^2	0.42	0.28	0.03	0.13	0.63	0.06	0.56	0.19
F	26.13	13.87	1.17	4.70	1.12	2.51	34.97	6.12
n	37	37	34	34	38	38	38	28

[a] The numbers in parentheses immediately below the estimated coefficients are t statistics for the null hypothesis of no association.

[b] The second set of numbers in parentheses test the null hypothesis of unity for the slope parameter.

model used to organize the contingent ranking responses and range for the risk change are the key variables in this conclusion. The consistency exists for only one model over a limited range of the risk change. This may reflect inadequacies in our preliminary models for the contingent ranking results or ranges where the two may not be expected to perform consistently.

14.6 SUMMARY

This chapter has summarized the preliminary results from the analysis of the contingent ranking component of our survey. These results seem promising. Simple versions of the random utility model appeared to do reasonably well in "explaining" the rankings provided by the survey respondents. The role of the basic influences (i.e., the payment, exposure risk, and income variables) on the utility indexes seems quite stable. Nonetheless, the initial efforts to enhance the model specification suggest that there may be scope for incorporating information on risk perceptions, information, and the nature of the individual's circumstances in the description of the determinants of these rankings. However, the development and a selection from among candidate models appears difficult without a fairly specific theoretical structure to guide the specification.

Finally, to consider the issues involved in developing a comparison of contingent valuation and contingent ranking estimates, we developed two simple comparative appraisals using the basic model. These suggested some consistency in the two valuation estimates. However, this conclusion was found to be sensitive to both the contingent ranking model used and the range selected for the exposure risks.

CHAPTER 15

A COMPARISON OF CONTINGENT VALUATION AND HEDONIC PROPERTY VALUE MODELS FOR RISK AVOIDANCE

15.1 INTRODUCTION

This chapter presents a comparative evaluation of the contingent valuation and hedonic property value approaches for valuing risk avoidance. This evaluation focuses specifically on measures of risk-avoidance actions taken by households in response to the location of industrial facilities that have hazardous waste landfills. Risk avoidance differs from risk reductions in the sense that the risks of exposure to hazardous wastes from the facilities are not reduced; only the household can control the size of these exposure risks. It can reduce these risks by some action it takes to avoid them. Thus, our evaluation focuses on household location decisions as an action for reducing the risks of exposure to hazardous wastes.

Our evaluation differs from most previous comparative evaluations of the approaches for estimating benefits associated with environmental resources. It does not compare values or benefits. Instead, it uses an entirely different standard to gauge the relative or "reference" accuracy of contingent valuation and hedonic property value models. Specifically, we compare the "predicted" distance that an "average" household, in each of 54 survey-area towns, would choose to locate from the facilities that have hazardous waste landfills. To develop these predictions we have proposed a combined framework--one that uses both the hedonic property value model and a "demand for distance" model developed from the contingent valuation survey together. Each framework provides an element in the information required to develop these predictions. Thus, we would expect that if they are mutually consistent descriptions of the decision process, their combined predictions would be consistent with the performance of other economic models for location decisions. This argument implies that the mutual consistency of the models can be judged by how these predictions compare with the average of the actual distances households have selected from these types of facilities. Therefore, this approach offers a new standard for gauging reference (or relative) accuracy. Previous comparisons compared two estimates, with the actual, or "true," values unknown.

Despite the alternative perspective provided by this comparison, however, it does have disadvantages. Specifically because we use the two approaches jointly to make the predictions, we cannot attribute any inaccuracies exclusively to one approach or the other. In addition, for our specific comparative evaluation, it should be acknowledged that it is very preliminary. It is based on initial models for both approaches that are more exploratory than final. Indeed, we view this chapter as structuring an agenda for further research rather than as a report on the final results of an exhaustive comparison.*

15.2 GUIDE TO THE CHAPTER

Section 15.3 of this chapter summarizes past comparative evaluations of contingent valuation and indirect methods for estimating the benefits associated with changes in some aspect of environmental quality. Section 15.4 highlights some of the conceptual issues associated with comparing hedonic models intended to reflect households' responses to risk and contingent valuation surveys. Section 15.5 details the elements in the questionnaire and adjustments made to the structure of the experimental design so that comparative information could be elicited. Section 15.6 summarizes the data and features of the hedonic property value model used in our comparison. Although our comparative evaluation was based on an initial version of the model developed by Harrison [1983], our review includes a discussion of the relationship between this variant of the model relative to a revised formulation recently proposed by Harrison and Stock [1984]. Section 15.7 describes the ability of the survey respondents, to use distance as a mechanism to obtain risk reductions. Section 15.8 reports the demand-for-distance results derived from the survey responses

*Our recent findings with refined versions of the generalized travel cost model (Smith, Desvousges, and McGivney [1983]) used to value water quality improvements (see Smith, Desvousges, and Fisher [1984]) suggest that this caution is indeed warranted. In the presence of incomplete plausibility and sensitivity analyses of the specific models derived from each method, the comparative analysis can easily reflect specification or other modeling errors with each method's candidate. They need not be the result of inconsistency in the underlying methodologies' "true" results.

and how these are merged with information from the Harrison hedonic model to predict the distance selected by the "average" household for each town in the survey area. Section 15.9 reports a comparison of these findings with the average distances selected by households in each town based on the reported sales in the Harrison data set. Finally, Section 15.10 discusses the limitations of the analysis and the potential implications of these findings for further research.

15.3 THE ROLE OF JUDGMENT IN COMPARATIVE STUDIES

This section discusses the role of judgment in past efforts to compare alternative benefits estimation approaches. Our purpose here is to provide an additional perspective on these comparative efforts and to indicate how the comparison in this chapter differs from them. (See Cummings, Brookshire, and Schulze [1984] for a detailed overview and evaluation of the majority of past efforts to compare contingent valuation and indirect methods' estimates of individuals' valuations of environmental resources.)

Cummings, Brookshire, and Schulze [1984] concluded their recent evaluation of comparative studies by observing that, with the exception of one estimate in Desvousges, Smith, and McGivney [1983], all comparisons yielded estimates that were within their reference accuracy bounds of ±50 percent.* That is, ±50 percent intervals defined using the contingent valuation estimates generally overlapped those defined using the indirect method's estimate by ±50 percent. With one other exception, these studies all sought to compare estimates of the representative individual's valuation of some environmentally related good or service--i.e., services of recreation sites, hunting permits, water quality levels at water-based recreation sites, air quality levels, and earthquake hazard information. (See Table 6-12 in Cummings, Brookshire, and Schulze [1984] for a summary.) The only exception involves a comparison of the estimated elasticity of substitution between wages and the services of the social infrastructure in New Mexico communities. In this case, a hedonic wage model and a contingent valuation survey's estimates of this elasticity were com-

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*This one estimate in Desvousges, Smith, and McGivney [1983] was for the loss of the area and was identified in the study as likely to be subject to error because of the generalized travel cost model's treatment of substitute sites.

pared and found to provide consistent results. Cummings, Brookshire, and Schulze [1984] also noted that, while the true values individuals place on commodities can never be known, all of the empirical evidence available at the time of their assessment indicated that contingent valuation estimates are indistinguishable from those available from indirect methods in order of magnitude terms. Moreover, in most cases (and especially where the Cummings, Brookshire, and Schulze reference operating conditions are satisfied), the contingent valuation estimates are within ±50 percent of the estimates derived using other methods. Consequently, the authors closed their summary with a positive evaluation of the accomplishments of contingent valuation and of the prospects for further advances.

One element discussed by Cummings, Brookshire, and Schulze [1984] but not specifically considered in evaluating the results of the various comparisons is the role of the analyst's judgment in the construction of each method's benefit estimates. For example, subsequent analysis of the Desvousges, Smith, and McGivney [1983] comparative results has highlighted the important role such judgments can play in shaping each method's results and, in turn, the conclusions that are derived from comparative assessments. Although this point has generally been recognized as an important component of most contingent valuation research, it has not been specifically made for the indirect methods' results.*

The Smith, Desvousges, and Fisher [1984] reevaluation of the comparison reported in Desvousges, Smith, and McGivney [1983] indicates that an analyst's judgment can have a direct and important effect on the numerical results reported for benefit comparisons involving the valuation of water quality changes with the travel cost model. Table 15-1 presents revised estimates of the recreation benefits from water quality improvements for both travel cost and contingent valuation approaches, using the average of the two iterative bidding question formats to be comparable with the estimates presented in Cummings, Brookshire, and Schulze [1984]. The revised travel cost estimates resulted

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*This is simply a question of relative emphasis. Cummings, Brookshire, and Schulze [1984] do clearly discuss the problems with selecting specifications for the econometric models used in indirect methods and cite recent evidence by Coursey and Nyquist [1983] on the sensitivity of demand functions to the assumptions made concerning the stochastic error as one example.

TABLE 15-1. RESULTS OF THE REVISED DESVOUSGES, SMITH, AND MCGIVNEY COMPARATIVE STUDY

	Water quality change		
Approach	Loss of area	Boatable to game fishing	Boatable to swimmable
Contingent valuation[a]	20.14	11.48	28.00
Original[b] travel cost	82.65	7.01	14.71
Revised[c] travel cost	3.53	7.16	28.86
Contingent valuation ±50%	10.07 to 30.21	5.74 to 17.22	14.00 to 42.00
Revised travel cost ±50%	1.77 to 5.30	3.58 to 10.74	14.43 to 43.29

[a] These estimates are slightly different from those reported in Cummings, Brookshire, and Schulze [1984]. They reflect the different number of observations associated with the two iterative bidding estimates and compute a grand mean taking these differences into account.

[b] See Desvousges, Smith, and McGivney [1983] for more details.

[c] These travel cost estimates are based on a simple travel cost model estimated using the responses of survey respondents who used sites along the Monongahela River (the study area). See Smith, Desvousges, and Fisher [1984] for discussion of the specific model.

from efforts to refine the earlier generalized travel cost model. However, they are from a simple travel cost model and not the generalized model or its antecedents. This model was selected after extensive evaluation of the plausibility of a number of alternative models. Applying the reference accuracy criteria of Cummings, Brookshire, and Schulze [1984], two of the three ±50 percent intervals for the revised travel cost estimates for water quality changes overlap the corresponding intervals for the "average" contingent valuation estimates. The third estimate remains inconsistent, yet is now much lower than the contingent valuation estimate. When the first model's estimates were used in this comparison, the travel cost estimate for this case (i.e., a water quality deterioration leading to the loss of the recreational use of the site) was clearly larger than the subsequent estimates. Thus, this reevaluation illustrates the important role the analysts' judgments can play in the benefit estimates derived from each method as well as in any comparative evaluations of different methods based on such estimates.

The effect of the analysts' judgments is especially important to the interpretation of the findings reported in this chapter. As we noted at the outset of the chapter, our objective is to compare the average distances from industrial facilities with onsite hazardous waste landfills selected by households with the distances that are predicted as the "average" household's selections based on a "demand for distance" model. This demand model was derived from the responses in our contingent valuation survey. To calculate these predicted distances, we used an early version of Harrison's analysis of the housing sales in suburban Boston to estimate the implicit price of distance from an industrial site with hazardous wastes. In a subsequent analysis (see Harrison and Stock [1984]), completed too late to be included in further comparative analyses, a new specification was reported for a hedonic property value model based on the same sales data. This new analysis uses a substantially different measure of the hazardous-waste-related attribute that households are assumed to be selecting in their site location decisions. Given the differences in the two models (described further in Section 15.4), it is reasonable to expect that comparative evaluations of the contingent-valuation results based on the second hedonic model could well differ from those using the first specification. Judgment is required to determine which model is the most appropriate basis for estimating a household's marginal willingness to pay for distance (as a component of the site attributes describing the disamenities associated with hazardous waste disposal sites). Such an evaluation is beyond the scope of this chapter and the research activities associated with the first phase of this project. However, it will be important to the development of a final comparative assessment of contingent-valuation and property-value estimates of the risk-avoidance activities of households.

15.4 CONCEPTUAL DIMENSIONS OF THE DISTANCE-RISK RELATIONSHIP

We have argued throughout the conceptual and empirical analyses in this report that hazardous waste disposal regulations (if effective) should be treated as providing individuals with reductions in the risks of being exposed to hazardous wastes. Consequently, our analysis has focused on estimating individuals' valuations of exposure risk reductions. Before we can evaluate the relationship between these results and other approaches to the problem, it is important to consider how other approaches treat "the outputs" delivered to households from increased regulations of land-based disposal of hazardous wastes.* To apply a hedonic property value model to estimate the values relevant to a household for hazardous waste regulations, it is important to know how the household can respond to hazardous waste disposal practices. While there are a variety of possibilities, the most direct, and likely most compatible with the hedonic framework, is to select a distance from a disposal site. In effect, this distance is a proxy for a service delivered to the household. By increasing the distance between its residence and a landfill with hazardous wastes, the household is assumed to be receiving some services that enhance its utility.

The nature of services received are important to understanding the role of distance in the hedonic framework. For example, increased distance from the disposal site can serve to reduce risk by reducing the number of pathways through which an exposure can occur. That is, with increased distance, exposure to airborne hazardous substances disposed at the site becomes less likely. Alternatively, to the extent the household gets its water from a private

*This analysis need not apply only to land-based disposal regulations. It is general enough to apply to most hazardous waste regulations.

well and therefore relies on groundwater, distance may also reduce the chance of an exposure through contamination of the household's water supply. However, the precise outcome would depend on the relationship between the source of the well water and the location of the disposal site. It would also be affected by the character of the disposal practices, the nature of the soil, the wastes involved in the disposal site, and the time horizon for the analysis. Clearly, the services provided by increased distance from a hazardous waste site can be very complicated.

Despite these complications, we have assumed (as has Harrison) that increased distance is a mechanism for reducing risk. This is why we have referred to these distance selections as risk-avoidance actions. In effect, greater distances enable the household to avoid or reduce the risk of exposure to hazardous wastes. Linking distance and risk avoidance is a crucial assumption because it affects our ability to connect the results of any contingent valuation survey designed to estimate the option prices that would be paid for reductions in the risk of exposure with comparable valuation measures derived from hedonic property value models (see Smith [1985b]). What is at issue is the nature of the transfer function that individuals perceive is connecting their risk of exposure to hazardous substances with the distance of their homes from a hazardous waste disposal site. To use the results of a hedonic model based on these distances (or functions of them, as in the case of Harrison and Stock [1984]) to estimate the representative individual's marginal value (i.e., incremental option price) of risk reductions, we must assume that there is an accepted, and commonly understood, transfer function between distance and exposure risk. Since the technical factors governing this relationship are imperfectly understood by experts on the processes governing contamination of groundwater as a result of land-based disposal of these substances, it seems unreasonable to expect consistency in the judgments made by the layperson.*

*This uncertainty played an important role in the design of the Burness et al. [1983] contingent valuation study. Their effort sought to use contingent valuation to estimate individuals' valuations of a regulation given uncertainty as to the effects of hazardous wastes. It was argued, because of the lack of clear consistency, that the presentation of specific risks would not be treated as credible information by survey respondents otherwise.

However, this consistency in risk-perception-distance relationships across individuals is not required if it is possible to acquire the information necessary to understand the factors that determine how different individuals form their perceptions of this relationship. Unfortunately, this possibility was explored in several focus group sessions (see Desvousges et al. [1984a]) without success. Thus, our a priori expectations for acquiring the desired information as part of the contingent valuation survey were not optimistic. Nonetheless, our questionnaire was structured to include one approach for eliciting information on this risk perception-distance relationship.

15.5 ALTERNATIVE AVENUES FOR COMPARISON

This section discusses the two alternatives considered within our research design for comparing the contingent-valuation-based estimates of individuals' responses to risks of exposure to hazardous wastes with those available from a hedonic property value model. The first alternative involves comparing the valuation responses derived from contingent valuation on a per unit of risk basis with the marginal valuations estimated from a hedonic property value model. The second uses the two methods to develop a joint prediction of the distance a specified (or hypothetical) household would select to locate in relationship to a hazardous waste site. Each alternative requires different types of information. The first requires an estimate of distance-risk transfer function described in the preceding section and, as a result, calls for information on the distance equivalent to risk reductions. The second requires a description of the behavioral responses of households in the presence of different prices of risk avoidance activities and consequently requires information consistent with a demand for distance model.

15.5.1 Eliciting the Distances Considered to be Required for Risk Reductions

The first alternative for comparison involves eliciting each respondent's perceived transfer function between distance and exposure risk reduction. If it is possible to acquire this information, then the contingent valuation responses can be "translated" into point estimates for the incremental option prices that would be paid for increases in the distance between an individual's home in relationship to a land-based hazardous waste disposal site.

A simple comparison between these estimates and those implied by a hedonic property value model with this distance measure would then provide one basis for comparing point estimates of approximately consistent benefit concepts. However, an exceptionally large number of qualifying assumptions are required to establish a general correspondence between the two sets of estimates.* For example, the hedonic estimates are estimates of a point on the individual's incremental option price-risk schedule (see Smith [1985]). The estimation of the option prices that would be paid for discrete risk changes (i.e., increases in distance) would face modeling and estimation problems analogous to those facing conventional uses of the hedonic model (see Bartik and Smith [forthcoming] for further discussion).

In addition, the assumptions needed to use contingent valuation responses to derive implied valuations of distance changes are equally limiting. Perhaps the most stringent assumption required is that the function relating the respondent's option price bid to the change in his exposure risk must be combined, in some fashion, with his transfer function for distance and exposure risk changes. Combining these functional relationships is complicated not only by conceptual issues, but also by the need to know the functional form. Moreover, it must be estimated based on a limited range of empirical evidence for

*To some extent, this is also true of the other comparative analyses as well. However, because the results have tended to support the conclusion of consistency between the contingent valuation and particular indirect method findings, the required assumptions have been given less attention.

Equally important, in our case, the "commodity" involved in the contingent valuation analysis is a risk change. Based on the Cummings, Brookshire, and Schulze [1984] analysis, this could be considered a case where the application did not satisfy their reference operating conditions (ROCs). These conditions are

- Subjects (or participants in the contingent valuation) must understand and be familiar with the commodity to be valued
- Subjects must have had or be allowed to obtain prior valuation and choice experience with respect to consumption levels of the commodity
- There must be little uncertainty
- Willingness to pay and not willingness to accept valuation measures should be elicited.

That is, depending on one's own interpretation of the ROCs, this case could contradict three of the four reference operating conditions.

these relationships. Thus, even with the ability to successfully elicit information on the relationship between distance and perceived risk, the connection between estimates from both methods using this comparison is crude.

However, some of these same types of problems were present with the past comparisons of contingent valuation with an indirect method. Generally, they were avoided by assuming that the connection between physical measures of air or water quality and the perceived consequences of these amenities was known by individuals. This approach may not be unwarranted, but it seems a more reasonable assumption for many environmental amenities compared to the case for relationships involving risk. For example, the whole issue of risk perception has been controversial,* which has provoked criticism of the expected utility hypothesis, as we acknowledged in Chapter 3. Consequently, it is prudent to consider evaluating the plausibility of the distance-risk change responses before using them in a comparison of contingent valuation and hedonic property model findings.

Such a comparison need not be concerned with whether the individuals know the "true," underlying relationship beween exposure risk and distance. Rather, the objective is to determine what each individual perceives that relationship to be. An evaluation of plausibility is then an appraisal of the consistency of the responses with what would be derived if respondents understood what was asked. Since the focus group sessions indicated that this level of understanding might not be realized, we incorporated a different set of distance-related questions used earlier by Mitchell [1982] to gauge individuals' aversions to the siting of undesirable facilities. Mitchell used the distance at which an individual would be willing to have a new facility built before desiring to relocate his home.† This aversion presumably reflects the same motives

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*For a good discussion of the problems in understanding the risk perception process from the psychologists' perspective, see Slovic, Fischhoff, and Lichtenstein [1982].

†The specific text of Mitchell's question is given as follows:

> Finding new places to build new industrial and power plants is sometimes difficult these days. I'm going to mention five types of buildings or sites. Assuming that they would be built and operated according to government environmental and safety regu-

(continued)

hypothesized to govern location decisions within the hedonic property value model. It is, of course, less carefully controlled. "Desiring to move or protest an action" are activities that require more precise specification if they are to be associated with the tangible actions underlying the hedonic property value model. Nonetheless, Mitchell's results indicated that individuals could readily understand these types of questions. Our focus group sessions confirmed his appraisal. In using them as a gauge of the plausibility of the risk perception responses we are implicitly assuming that our questions based on the Mitchell approach request distances that correspond to minimally acceptable levels of perceived risk (in our case, implicitly recognizing the costs of moving). By contrast, our distance-risk reduction question developed for the comparison requests increments in distance that would yield a specified risk change. Nonetheless, it seems plausible to expect a reasonable proximity between the two with the former potentially providing an upper bound to the latter.*

(continued)

> lations, you might or might not feel strongly about living close to them. For each type of plant please tell me the closest such a plant could be built from your home before you would want to move to another place or to actively protest, or whether it wouldn't matter to you one way or another how close it was?

The specific facilities mentioned were:

- A ten-story office building
- A power plant that uses coal for fuel
- A nuclear power plant
- A large industrial plant or factory
- A disposal site for hazardous waste chemicals (if the government said disposal could be done safely and that the site would be inspected regularly for possible problems).

*This is a conjecture and not a conclusion that could be demonstrated. The exact relationship depends on what individuals take into account in formulating their responses to the Mitchell distance questions. In particular, the level of risk that would be regarded as acceptable (given the perceived cost of the action moving) in comparison with the risk changes asked about would likely be the key determinants of the relationship between these responses.

15.5.2 Eliciting Demand-for-Distance Information

The second approach for developing comparative information does not require individuals to formally calculate distance-risk change. Rather, it assumes that proximity is a relevant measure of the perceived risk experienced by the individual (and of any other disamenities associated with these facilities). The process is straightforward. A price increment per mile of distance between the individual's home and an industrial site that has a landfill with hazardous substances is suggested to the individual. This is described as the increase in the purchase price of the home, holding all other structural, site, and neighborhood characteristics constant. In effect, the demand-for-distance approach constructs a hypothetical, partial equilibrium single market for proximity with a constant marginal price for that proximity. It implicitly assumes that the individual is capable of separating distance from all other attributes. As explained in Chapter 7, our design asked different individuals different marginal prices.

Nevertheless, our second approach assumes that a specific relationship exists between the individual's demand for distance and his demands for other site attributes. These other demands influence the demand for distance through the overall price of housing. There are no specific substitution or complementarity relationships between attributes of the structure, site, or neighborhood and the proximity. To investigate them would require comparably detailed information on the decisions with respect to any other characteristics hypothesized to be associated with distance. Equally important, this approach assumes a constant marginal price for distance to facilitate asking the questions of respondents. This assumption stands at variance with the role of most housing and site attributes in hedonic models. Indeed, it is the nonconstancy of these marginal prices that poses problems with the use of hedonic property value models to characterize individuals' preferences for site attributes (see Quigley [1982] and Bartik and Smith [forthcoming]).

15.6 STRUCTURE OF THE QUESTIONS AND DESIGN FOR COMPARATIVE INFORMATION

There are three important features of the structure used to elicit information for a comparison of contingent valuation estimates of an individual's risk valuation and avoidance activities. The first of these involves the experimental design. Our two approaches--i.e., eliciting distances required to realize risk reductions versus distances selected at constant marginal prices per mile from a disposal site--were considered to be independent in the experimental design. That is, the risk change posed in the first type question was selected independently of the marginal price for the second. We have effectively assumed that the two responses are made independently. Based on the pretest and other experience with the questionnaire, this assumption seemed quite reasonable. The two types of information are requested in different parts of the questionnaire, separated by a substantial number of other questions that elicit a wide variety of additional information. Moreover, different scenario descriptions were used for each approach.

The second feature of the process of obtaining this information involves the selection of the risk changes used for eliciting a distance-risk change function. Specifically, these were tied to the endpoints of the exposure risk vectors used in the contingent valuation questions (see Chapter 7, Figure 7-2). In effect, the starting exposure probability and the ending exposure probability were used for the distance-risk change question. There were several reasons for this tied design. First, and most important, if these distances could be elicited successfully, they would correspond to the precise risk change for which the individual expressed a valuation response. Further assumptions concerning the functional form of the transfer function between distance and risk would not be required to translate the bids for risk reductions to valuations of distance.

Second, the risk circles described in Chapter 8 as the basic vehicle for explaining the commodity, a risk change, to the individual were discussed at the outset of the questions requesting distance-risk change information. This permitted the respondent to gain familiarity with the vehicle and helped to highlight the risk postulated to be capable of being controlled--the exposure risk (or shaded portion of the first circle on the cards, see Figure 8-6 in Chapter 8).

The last feature of this dimension of the questionnaire was the selection of marginal prices for distance. Each respondent was given one of four values--$250, $600, $1,000 and $1,300. These figures were described as increases to the purchase price of the house for each mile it was located away from the disposal site. The specific values were selected based on an initial review of an early version of the Harrison property value model, on experience with this type of question in focus groups, and on the results of other hedonic property value studies in which distance measures from other types of undesirable facilities were included as site attributes.

After explaining the concept of risk and the features of the risk circles, the question requesting the distance-risk change information proceeded in two parts. The first part asked if the individual thought moving would affect the risk of exposure to a hazardous chemical in the drinking water supply. If he answered "yes," the distance was requested. The specific text of the questions was as follows:

> Please look at Cards A and C. The risk of exposure decreases from 1 chance in 300, or thirty-three hundredths of 1 percent chance, on Card A to 1 chance in 1,500, or seven-hundredths of 1 percent chance, on Card C. Since your heredity doesn't change, the middle circles don't change. This also means the combined risk decreases from 1 chance in 30,000 to 1 chance in 150,000, or from thirty-three ten-thousandths of 1 percent to seven ten-thousandths of 1 percent.
>
> Now think about a hypothetical situation using Cards A and C. Suppose that Card A shows your risk of exposure from a hazardous chemical in your drinking water supply. Do you think that by moving you could reduce your risk of exposure to the level shown on Card C? I am not asking would you actually move, but is it possible that by moving you could reduce your risk to the level on Card C?
>
> For a positive response then:
>
> How far do you think you would need to move to lower your risk to the exposure level on Card C?

Of course, the precise size of the probabilities explained in the introductory text varied with the specific design point (see Figure 7-2 in Chapter 7).

The second question used for comparative information occurred after all risk valuation information had been requested of respondents to separate it from the distance-risk change responses and, equally important, to avoid the potential of the marginal prices of distance serving as informational "anchors" and thereby affecting the individual's valuation responses for the postulated risk changes. This question first elicited information on the average cost of a house in the respondent's neighborhood. If the individual could not provide an estimate, the interviewer suggested a value based on estimates for the 1980

Census for each town.* Immediately following this question, the respondent was told that he could select a location for his home in relationship to a manufacturing plant that disposes of hazardous wastes in a landfill at the site. Once the distance was given, the interviewer calculated the revised cost of the home and asked if this was what the individual had intended. The specific text of the two questions is given below:

> I want you to think about another, completely different situation. This is about distance from a plant or factory site with hazardous waste and how it might affect your choice of where to buy a house. But first, what would you say is the average cost of a house in your neighborhood?
>
> Now, suppose you could choose between two almost identical homes like those in this neighborhood. That is, they have the same number and types of rooms and all their other features are the same; and your children would go to similar schools. The only difference between them is their distance from a manufacturing plant that disposes of its hazardous waste in a landfill at the plant site. Suppose you could pick any distance you would want from the hazardous waste site, except that for each mile between your house and the site, you would pay $250 more than for the same house you could get next to the site. For example, suppose the price of a house next to the site was (READ AVERAGE COST FROM ABOVE); then the same house 1 mile away would cost (READ AVERAGE COST) plus $250. At an additional cost of $250 per mile, how many miles away from the plant site would you choose to be?

The last component of the information used in the comparative analysis was a replication of the Mitchell [1982] distance question. The basic concept of the question was retained, but the action was recast as an individual moving rather than desiring to move. The specific set of facilities described to respondents had several categories that overlapped with those of Mitchell's analysis and some new types of facilities. The specific question was as follows:

> Finding places to build new industrial or power plants, businesses or commercial buildings, or public facilities is sometimes difficult. I am going to name some different types of facilities. Suppose that each of the things I name would definitely be built and would be operated according to government environmental and safety laws.

---

*Appendix G reports the specific values that were made available to interviewers. However, for the sample of homeowners, the respondents were able to provide an estimate of the average value of homes in their neighborhood.

Tell me the closest distance to your home that each facility could be built before you would move. If you wouldn't move no matter how close it was built, please tell me.

	DISTANCE IN MILES	DON'T KNOW
Ten-story office building..............	______	*
Large industrial plant without hazardous wastes........................	______	*
Coal-fired power plant..................	______	*
Nuclear power plant.....................	______	*
Four-lane interstate highway..........	______	*
Gasoline station/convenience store...	______	*
Large industrial plant with a hazardous waste landfill...............	______	*

* = response code for does not know the answer.

One final aspect of the process of eliciting information for the survey should be acknowledged. The sample size available for analysis is larger with this information because these questions were included on both the contingent valuation and the contingent ranking variants of the questionnaire.* In what follows, the analysis focuses on only the homeowners in the sample because this is the group considered in the hedonic property value analysis. Moreover, it seemed reasonable to expect that they would be more capable of responding to the second of the two comparative questions. This restriction yields a basic sample of 391 observations (before adjustments for nonresponses and the associated missing information associated with each model specification).

15.7 THE HARRISON HEDONIC PROPERTY VALUE MODEL

The property value model that forms the basis of the indirect method for estimating the extent of risk avoidance on the part of households was developed by Harrison [1983]. It is based on the sales of over 2,000 single-family housing units in 83 towns in suburban Boston. The study included extensive information on both the characteristics of these housing units and on the attributes of their neighborhoods, including indexes of air quality, access to the

*See Chapters 7 and 9 for a more detailed discussion of the rationale for and specific details of the experimental design underlying the survey.

central business district, crime, the property tax rate, a measure of school quality, and detailed information on the location of industrial sites, landfills, and land-based disposal sites for hazardous wastes. Ten of the eighty-three towns included landfills with hazardous wastes disposed in them. These were industrial sites with landfills containing hazardous wastes on their premises. A total of 11 such sites was identified in the suburban Boston area, with two sites in Woburn. The Harrison data include information on the distances of each property to the closest site, the type of site, and detailed information on the sources of water for each town. Table 15-2 provides a description of the variables used in the Harrison model.

The housing prices are sales prices for transactions between November 1977 and March 1981, with most of the sales taking place toward the end of the period. Prices were measured in constant dollar (1977) terms in the first analysis of these data (Harrison [1983]). Although a variety of models were considered, our attention will focus on the log-linear specification of the model. The proxy measure assumed to reflect the disamenity influence of the hazardous waste site was represented by two distance variables. The first of these measures the distance of the house to the closest industrial site, whether or not hazardous wastes were actually disposed of in a landfill at the site. The second is an interaction variable--the product of a qualitative variable, which was unity if the site had a landfill with hazardous waste (zero otherwise), and the minimum distance measure. This format was selected in an attempt to separate a disamenity effect for industrial sites and a separate, additive effect (i.e., a shift of the slope coefficient for the distance measure) that was associated with whether hazardous wastes were actually disposed of in the landfill at the site.

Table 15-3 lists the hazardous waste sites involved. Figure 15-1 shows these sites in the sample-area towns, with shaded triangles indicating the location of the hazardous waste landfill. Table 15-4 reports the hedonic function reported in the first Harrison [1983] analysis of these data. This model formed the basis for our comparative evaluation.

In subsequent analysis, Harrison and Stock [1984] have respecified the model, adding new potential determinants of housing prices and--more significant for our comparative analysis--changing the definition of the measure of the disamenity (i.e., the measure of the perceived exposure risk) due to the

TABLE 15-2. DESCRIPTION OF SELECTED VARIABLES IN HARRISON PROPERTY VALUE DATA SET

Variable name	Description
MINDISTT	Distance to nearest hazardous waste site
MINDISTI	Distance to nearest industrial site
LOT	Lot size
STORIES	Number of stories of house
YRBLT	Year house was built
HEAT (FORCED AIR)	Type of heating system, variable = 1, then forced air, 0 otherwise
HEAT (HOT WATER)	Type of heating system, variable = 1, then hot water, 0 otherwise
HEAT (STEAM)	Type of heating system, variable = 1, then steam, 0 otherwise[a]
CONST	An index of the quality of construction, variable is: 0 = poor, 5 = excellent
COND	An index of the present condition, variable is: 0 = poor, 5 = excellent
LOT	Lot size in square feet
BATH	Number of full bathrooms
SPACE	Living area in square feet
ROOMS	Number of rooms
BASE	Percentage of basement that was finished
FIREP	Number of fireplaces
COVPARK	Qualitative variable for covered parking, variable = 1 for covered parking, = 0 otherwise
CRIME	Crime rate
TAX	Full value tax rate

(continued)

TABLE 15-2 (continued)

Variable name	Description
PTRATIO	Pupil to teacher ratio
STAT	Fraction of low status in tract population
TOXIC	Area of nearest hazardous waste site
ACC	Index of access to employment centers
NOXO	1980 air pollution measure in the Census tract
RAD	Index of access to radial highways
CHAS	Qualitative variable, variable = 1, indicating tract borders the Charles River, = 0 otherwise
THREAT	Qualitative variable on whether municipality's water supply has been threatened by a hazardous waste site, variable = 1 if threatened, = 0 otherwise
FILL	Area of nearest landfill
D	Distance to nearest industrial or hazardous waste site
DW	Interaction variable between D and a qualitative variable = 1 if site contains hazardous wastes and = 0 otherwise

[a] The omitted category is described as "other" heating systems.

TABLE 15-3. HAZARDOUS WASTE SITES IN THE BOSTON SMSA IDENTIFIED BEFORE 1982

Town	Name	Approximate land area (acres)	Date of discovery
Acton	W. R. Grace Company	400	Dec 1978
Ashland	Nyanza, Inc.	30	1967
Bedford	BSAF Industries	5	May 1978
Bellingham	Benzenoid Organics	4	Oct 1980
Cambridge	W. R. Grace Company	10	Mar 1979
Canton	Indian Line Farm	25	Dec 1980
Kingston	Marty's GMC	1	Apr 1980
Salem	Salem Acres, Inc.	180	Sept 1980
Weymouth	Agrico	10	May 1980
Woburn	Industriplex 128	300	June 1979
Woburn	Wells G and H	200 (plume) 0.005 (wells)	Sept 1979

Source: Harrison and Stock [1984].

Figure 15-1. Map of survey area showing industrial sites with landfills containing hazardous wastes.

TABLE 15-4. HEDONIC PROPERTY VALUE FUNCTION: INITIAL VERSION

Variable	Coefficient	t-statistic
Dependent: Log (HV)		
Constant	7.677	22.12
STORIES	-0.006	-0.61
HEAT (FORCED AIR)	0.048	3.26
HEAT (HOT WATER)	0.098	6.39
HEAT (STEAM)	0.068	3.40
CONST	0.056	9.23
COND	0.034	6.91
YRBLT	-0.002	-3.03
YRBLT2	0.00006	6.21
log (LOT)	0.073	9.42
log (BATH)	0.088	5.29
log (SPACE)	0.338	18.49
BASE	0.0004	1.92
FIREP	0.096	13.79
COVPARK	0.085	8.64
log (TAX)	-0.336	-12.23
log (PTRATIO)	-0.264	-6.10
log (STAT)	-0.006	-3.25
log (ACC)	-0.204	-13.43
log (NOXO)	-0.575	-6.78
log (RAD)	0.059	6.18
CHAS	0.079	2.94
THREAT	0.031	1.07
FILL	-0.0007	-4.59
D	0.013	1.59
DW	0.054	3.17

Adjusted R2 = .72

Total degrees of freedom = 2186

Source: Harrison [1983].

location of the hazardous waste landfills in relationship to private homes. In their revised analysis, Harrison and Stock considered two indexes of perceived risk of exposure to hazardous wastes. These indexes are based on functions of the inverse of the square of the distance of each of the 11 sites to the house. The first index is simply the sum of these inverses across all sites. The second weights these inverses of the squared distances by the area of the site as a proxy for the volume of the chemicals at the site. The rationale for their specification is based on a simple physical model of the exposure process. Under the assumption of a uniform dispersion through a homogeneous medium, the concentration of contaminants at any house's location will decline with the inverse of the square of the distance of the contamination source from the house.*

It is important to note that this framework may not be relevant to exposure through an individual's water supply if the houses are served through municipal water supplies. In that case, the relevant measure would relate to the location of the source in relation to the wells providing each town's water. Harrison and Stock acknowledge this possibility, but argue that the effects of risks of this type cannot be distinguished from the "town effect" measures for each town represented by qualitative variables in their revised model. These variables were also not part of the original Harrison specification. In addition, two further modifications were introduced. Since the sales took place over a period in which interest rates and other financial factors changed substantially, with corresponding influences on both housing prices and sales activity, the authors introduced qualitative variables for the quarter in which the sale took place. Finally, a variable to reflect "income effects" was included in the hedonic price function. They explain their rationale as follows:

> Our formulation implies that the willingness to pay to avoid the risks of living near a hazardous waste site would depend on income. To account for such a relationship, we included interaction terms in which the two hazardous waste variables [the risk measures described earlier] were multiplied by the predicted price obtained from an initial regression [i.e., hedonic price function]. We anticipated that the interaction term would be negative to reflect an increasing marginal value of waste cleanup as income (and hence predicted house price) rises. (Harrison and Stock [1984], pp. 18-19).

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*This explanation paraphrases the Harrison-Stock [1984] explanation. They also used the number of industrial sites, within various concentric circles around each housing location, to measure disamenity effects.

This additional variable seems somewhat controversial. Based on the authors' explanation, their specific rationale for including it is not clear. The hedonic price function should not reflect the buyer's income as a measure of willingness to pay. The hedonic function is an equilibrium relationship describing the locus of market equilibria for a differentiated product. It may well be that the authors intended to postulate segmented markets by income level, similar to Thaler and Rosen's [1975] suggestion of differentiated implicit markets for risk in their hedonic wage model. In that case, one might still wish to question their proxy variable because of its construction.

Nevertheless, the revised model does not yield statistically significant estimates of the parameters for the risk terms. That is, based on a simple examination of the estimates, some of the specification changes do not appear to be clear improvements in the earlier format. Consequently, further comparative evaluation of the two models will be necessary before it is possible to unambiguously conclude that the revised model is a superior basis for describing household risk-avoidance activities.

However, a detailed evaluation of the two models is beyond the scope of this report; the first has been accepted as the initial basis of performing an initial comparison and describing the factors that may be important to the results of such an evaluation.

15.8 RISK CHANGE AND DISTANCE

Table 15-5 reports the mean responses for our version of Mitchell's distance questions by town for two types of facilities--a large industrial plant without hazardous wastes and one with a landfill containing hazardous wastes. These responses are reported in the second and third columns of the table with the estimated standard deviation in parentheses below the mean. The fourth column provides the average distance reported for the risk change from the exposure level associated with Card A to that of Card C. Consequently, this mean is based on distances for quite different risk changes. That is, as we noted earlier, this risk change was specifically tied to the experimental design for the valuation changes measured with the contingent valuation method. This implies that we are adding together the distance response perceptions for quite different risk changes, depending upon the composition of the design points that happen to be contained in each town.

TABLE 15-5. AVERAGE DISTANCE RESPONSES, DISTANCE RISK CHANGE RESPONSES, AND ACTUAL DISTANCES BY TOWN[a]

Town	Number of obser-vations	Distance from industrial plant, mi: Plant without hazardous wastes	Distance from industrial plant, mi: Plant with hazardous wastes	Distance for risk change, mi[b]	Number of sales	Actual distance from industrial plant (minimum), mi: Plant without hazardous wastes	Actual distance from industrial plant (minimum), mi: Plant with hazardous wastes
Abington	7	2.71	24.50	2.00	13	4.96	8.36
		(1.98)	(22.60)			(1.09)	(1.65)
Acton	114	3.64	16.02	100.66	31	2.03	1.94
		(9.80)	(21.07)	(134.15)		(0.99)	(0.96)
Arlington	2	3.00	39.67	100.00	58	2.31	2.32
		(3.00)	(51.38)			(0.67)	(0.66)
Belmont	6	6.67	58.29	50.00	63	1.91	1.83
		(2.58)	(40.99)			(0.49)	(0.48)
Beverly	10	16.80	24.90	200.00	21	2.54	13.12
		(46.83)	(29.98)	(267.71)		(1.35)	(3.53)
Braintree	6	2.67	9.33	83.33	43	2.25	5.53
		(2.58)	(7.79)	(28.87)		(1.16)	(1.79)
Brookline	5	2.20	7.20	70.00	32	4.44	4.36
		(1.64)	(4.09)	(51.96)		(0.90)	(0.89)
Cambridge	4	2.00	17.25		53	1.95	2.06
		(2.00)	(21.99)			(0.71)	(1.23)
Canton	5	1.40	16.60	310.00	9	1.41	9.64
		(2.07)	(10.38)	(410.12)		(0.80)	(1.51)
Carlisle	8	6.25	26.88		5	6.31	4.58
		(2.55)	(22.98)			(1.00)	(0.42)
Cohasset	4	6.25	16.25	26.67	9	6.36	15.28
		(4.79)	(11.09)	(17.56)		(0.66)	(2.59)
Framingham	12	25.13	25.31	320.00	74	2.48	4.27
		(79.20)	(35.16)	(391.46)		(0.92)	(1.14)
Franklin	5	1.40	14.00	68.78	34	2.12	8.49
		(1.14)	(20.36)	(89.29)		(0.72)	(3.52)
Holbrook	1	10.00	20.00		18	5.46	6.30
						(0.55)	(0.55)

(continued)

TABLE 15-5 (continued)

Town	Number of obser- vations	Distance from industrial plant, mi: Plant without hazardous wastes	Distance from industrial plant, mi: Plant with hazardous wastes	Distance for risk change, mi[b]	Number of sales	Actual distance from industrial plant (minimum), mi: Plant without hazardous wastes	Actual distance from industrial plant (minimum), mi: Plant with hazardous wastes
Kingston		3.00 (2.83)	5.00 (5.00)	10.00	32	2.77 (1.56)	17.25 (5.05)
Lexington	11	5.58 (5.43)	10.83 (8.26)	126.25 (134.45)	33	5.26 (0.98)	3.99 (0.94)
Lynn	1	1.50 (2.18)	17.50 (17.68)	50.00	202	2.96 (0.63)	8.34 (2.59)
Malden	10	2.75 (3.16)	24.20 (15.98)	130.00 (185.90)	18	2.19 (0.58)	4.84 (0.68)
Marblehead	1	0.00	0.00		9	2.17 (0.39)	13.55 (0.80)
Marshfield	2	1.00 (1.41)	1.50 (2.12)	30.00	31	8.60 (1.38)	15.81 (2.89)
Medford	1	7.50 (3.54)	15.00 (7.07)		18	2.03 (0.40)	2.28 (0.61)
Melrose	6	2.38 (3.79)	7.67 (4.97)	183.33 (28.87)	19	3.03 (0.37)	4.88 (0.63)
Millis	1	2.00	10.00		12	4.39 (0.65)	8.50 (0.65)
Milton	2	6.00 (5.66)	22.50 (3.54)	100.00	54	4.27 (0.58)	6.29 (0.91)
Natick	3	2.00 (1.73)	7.00 (7.21)	75.00 (43.30)	51	3.29 (0.84)	6.48 (1.13)
Needham	2	0.00 (0.00)	1.00 (1.41)		19	7.76 (0.29)	9.50 (0.69)
Newton	6	3.67 (3.78)	178.84 (402.35)	268.75 (124.79)	48	5.78 (1.00)	5.76 (1.08)
Norwell	6	8.50 (7.97)	23.50 (21.39)	157.00 (158.10)	28	4.62 (1.80)	12.21 (2.89)

(continued)

TABLE 15-5 (continued)

Town	Number of obser- vations	Distance from industrial plant, mi: Plant without hazardous wastes	Distance from industrial plant, mi: Plant with hazardous wastes	Distance for risk change, mi[b]	Number of sales	Actual distance from industrial plant (minimum), mi: Plant without hazardous wastes	Actual distance from industrial plant (minimum), mi: Plant with hazardous wastes
Norwood	1	5.50	6.50		22	1.74	11.51
		(6.36)	(4.95)			(0.50)	(2.19)
Peabody	5	6.83	30.17	40.00	66	1.60	8.16
		(8.01)	(38.33)	(14.14)		(1.00)	(2.17)
Quincy	6	3.42	9.17	100.00	162	2.36	6.67
		(5.10)	(9.17)			(1.00)	(1.66)
Reading	3	2.00	21.67	78.33	33	0.93	2.04
		(1.00)	(12.58)	(105.63)		(0.45)	(0.74)
Revere	2	0.15	1.50		6	1.73	7.88
		(0.21)	(0.71)			(1.18)	(0.92)
Salem	9	18.56	52.89	68.50	8	0.67	11.65
		(31.78)	(44.76)	(89.72)		(0.48)	(1.01)
Saugus	6	3.17	17.00	28.33	16	3.84	6.62
		(2.79)	(19.34)	(20.21)		(0.57)	(0.83)
Scituate	4	1.75	30.00	200.00	46	8.56	14.80
		(2.36)	(46.90)			(1.28)	(2.62)
Sherborn	4	25.20	56.80	100.50	4	3.07	5.52
		(42.54)	(41.52)	(140.71)		(1.00)	(1.28)
Somerville	3	2.33	20.67		38	1.47	1.90
		(2.52)	(25.72)			(0.47)	(0.72)
Stoneham	1	1.00	10.00	20.00	16	1.19	2.76
						(0.43)	(0.71)
Stoughton	5	2.00	7.50	35.00	20	2.85	9.95
		(2.45)	(11.61)	(13.23)		(0.89)	(1.85)
Swampscott	6	168.00	32.00	100.00	5	2.44	11.29
		(407.60)	(37.80)			(0.22)	(0.33)
Topsfield	5	2.80	22.80	600.00	7	2.87	13.25
		(2.28)	(16.71)	(0.00)		(0.41)	(0.35)

(continued)

TABLE 15-5 (continued)

Town	Number of observations	Distance from industrial plant, mi: Plant without hazardous wastes	Distance from industrial plant, mi: Plant with hazardous wastes	Distance for risk change, mi[b]	Number of sales	Actual distance from industrial plant (minimum), mi: Plant without hazardous wastes	Actual distance from industrial plant (minimum), mi: Plant with hazardous wastes
Wakefield	4	1.75 (2.22)	56.25 (95.86)	160.00 (121.66)	13	2.01 (0.75)	3.54 (0.77)
Walpole	5	0.92 (0.66)	35.00 (40.62)	80.00 (98.99)	13	1.82 (0.82)	12.61 (2.01)
Waltham	4	3.75 (2.22)	26.25 (23.58)	30.00 (28.28)	21	4.99 (0.89)	4.98 (0.97)
Watertown	6	3.08 (3.93)	35.00 (23.24)	106.00 (92.63)	16	2.82 (0.64)	2.71 (0.64)
Wayland	1	1.00	1.00		18	1.88 (0.72)	7.41 (0.95)
Wellesley	3	3.33 (2.08)	11.00 (12.29)	95.00 (77.78)	27	5.10 (0.98)	9.04 (0.66)
Westwood	8	4.00 (2.20)	30.63 (39.11)	31.75 (45.60)	8	3.24 (0.71)	11.55 (1.02)
Weymouth					79	1.57 (0.74)	7.29 (2.88)
Wilmington	5	5.00 (3.54)	57.00 (41.77)	203.33 (260.83)	17	1.87 (0.88)	3.63 (1.17)
Winchester	1	15.00	50.00		14	2.13 (1.01)	3.50 (0.39)
Winthrop	8	4.31 (3.84)	134.50 (349.79)	100.00	3	2.74 (0.39)	8.99 (0.83)
Woburn	8	1.00 (1.69)	23.50 (32.54)	33.00 (36.98)	21	1.79 (1.21)	2.49 (1.19)

[a]The first four columns relate to the survey responses; the last three are based on the Harrison property value data sample. The numbers in parentheses below the sample means are the sample standard deviations.

[b]In those cases where no standard deviation is reported, there was only one respondent to the question.

To compare the distance for a risk change with the distance responses to our Mitchell questions, it is necessary to consider the variation in the distance responses according to the risk change described. Table 15-6 reports the mean distances perceived for the exposure risk changes corresponding to each design point in the sample (including both the contingent valuation and the contingent ranking formats). With the exception of the subset associated with the third design point under the contingent ranking format (given in the third row of the table), the means for our Mitchell-distance questions calculated with these subsamples are of the same general order of magnitude as the means estimated using the town-specific subsamples. The presence of hazardous wastes at an industrial site's landfill yields a consistent increase in the distance individuals would require (the third design point is again the only exception to this conclusion and results from outlying observations). The distance increase ranges from 2 to over 25 times larger than the minimum "acceptable" distance from an industrial plant without hazardous wastes in landfills at the site.

The responses on the distance/risk change questions are more difficult to understand. When one considers the means across subsamples, there does not appear to be a consistent relationship between the size of the risk change and the distance response. In some cases equal percentage changes, regardless of the initial level of the exposure probability, yielded distance responses in fairly close proximity. However, this was not uniformly true. Indeed, there are several important exceptions. For example, the first two design points of the contingent ranking imply the same percentage risk change as the first two with contingent valuation question format, yet the distance responses are quite different. Even within a question format type there are a couple of exceptions to the assumption that individuals focus on the percentage change in the odds and not the size of the actual risk change. Thus, it appears that either the sample respondents did not understand or they were unable to formulate a consistent perceived relationship between distance to a hazardous waste site and the associated risk changes. This conclusion is reinforced by the fairly close proximity between the average distance responses to the Mitchell questions and the average of actual distances from sites for houses involved in sales in each town, shown in Table 15-5. The results are

TABLE 15-6. MEAN DISTANCE RESPONSES GROUPED BY THE SIZE OF THE RISK CHANGE[a]

	Exposure risk change[c]			Minimum distance from industrial plant, mi	
Version[b]	Scenario	Change	Average distance for risk change, mi	Plant without hazardous wastes	Plant with hazardous wastes
Ranking	1/10 to 1/50	0.08	156.05 (159.69)	17.29 (37.71)	33.35 (35.85)
Ranking	1/10 to 1/50	0.08	154.12 (163.48)	7.96 (22.21)	24.50 (30.73)
Ranking	1/20 to 1/60	0.03	126.50 (155.12)	64.24 (224.04)	28.20 (31.12)
Ranking	1/20 to 1/60	0.03	137.05 (208.04)	3.94 (3.48)	14.91 (13.68)
Direct question	1/10 to 1/50	0.08	99.87 (126.37)	3.03 (4.61)	80.12 (238.80)
Direct question	1/10 to 1/50	0.08	61.83 (50.84)	2.95 (4.50)	20.72 (25.39)
Direct question	1/5 to 1/25	0.16	61.00 (53.21)	3.33 (2.53)	22.33 (32.83)
Direct question	1/5 to 1/25	0.16	155.00 (319.33)	1.92 (1.38)	16.92 (25.70)
Direct question	1/30 to 1/150	0.023	83.21 (135.10)	3.27 (4.18)	84.73 (253.68)
Direct question	1/30 to 1/150	0.023	153.85 (147.49)	4.64 (6.36)	13.49 (13.88)
Direct question	1/300 to 1/1,500	0.0023	97.43 (165.65)	3.61 (3.54)	27.06 (47.29)
Direct question	1/300 to 1/1,500	0.0023	72.40 (98.80)	5.10 (7.92)	24.69 (35.37)

[a] The numbers in parentheses below the sample means are the estimated standard deviations.

[b] Ranking designates the contingent ranking versions of the questionnaire, and direct question refers to the remaining versions used in the research design.

[c] There are multiple replications of the same exposure risk change reported because they correspond to cases where there was another reason (i.e., variable that changed) to distinguish the design point. However, these other changes were not intended to affect the distance questions used for these results.

also consistent with our focus group experiences, which led us to develop the alternative demand-for-distance approach.

Finally, the mean distances for subsamples organized by town seem implausible. They are generally a good deal larger than both the averages of the actual distances and the averages for the Mitchell questions. Thus, all the available informal evidence suggests that the use of these responses either in translating the contingent valuation responses to a valuation per unit of distance or in the estimation of a distance-risk change function based on them is not likely to provide an adequate basis for comparing the contingent valuation responses with estimates from the Harrison hedonic property value model.

15.9 THE DEMAND FOR DISTANCE FOR RISK AVOIDANCE

Given the unsuccessful nature of our attempt to elicit the perceived distance-risk change function of our sample respondents, the questions requesting information consistent with a partial equilibrium demand-for-distance function formed the basis for our comparison of the survey and the hedonic models.

Table 15-7 reports the results of the statistical analysis of these responses with three different functional forms for the demand function--linear, semi-log (with the log of distance as the dependent variable), and double-log. The basic specification included the housing price reported by respondents for the average house in their respective neighborhoods, the postulated marginal price of distance, and the household income. The results clearly favor the nonlinear specifications with both the semi-log and the double-log forms exhibiting statistically significant parameter estimates. In all cases, the signs of the basic model's parameter estimates agree with a priori expectations.

There are a wide variety of other determinants that might be considered in attempting to improve the fit of these models as well as our understanding of the household responses. Indeed, the design of the questionnaire provides a reasonably wide range of variables that should be considered potential determinants of these responses--including measures of the individual's attitude toward risk; his socioeconomic characteristics; the number of children in his household; the years he has been living in the home; and, based on the recent experience in this area, the town in which he lived. This analysis is clearly warranted for further research. However, it is not relevant to this compari-

TABLE 15-7. DEMAND-FOR-DISTANCE MODELS[a]

Independent variables	Basic model			Selected alternative specifications					
	Linear	Semi-log	Double-log	Semi-log	Semi-log	Semi-log	Double-log	Double-log	Double-log
Intercept	-0.169 (-0.014)	2.003 (12.114)	1.180 (1.554)	2.181 (10.732)	2.054 (5.528)	1.904 (4.880)	1.629 (1.980)	2.026 (1.751)	1.775 (1.509)
Housing price[b]	0.087 (0.930)	0.003 (2.294)	0.416 (2.774)	0.003 (1.989)	0.003 (2.219)	0.003 (2.003)	0.411 (2.640)	0.433 (2.851)	0.407 (2.654)
Marginal price of distance	-0.008 (-0.884)	-0.0003 (-2.815)	-0.193 (-2.506)	-0.0004 (-2.784)	-0.0004 (-3.158)	-0.0004 (-3.217)	-0.204 (-2.523)	-0.216 (-2.834)	-0.220 (-2.880)
Income[c]	0.306 (1.626)	0.005 (1.924)	0.124 (1.474)	0.005 (1.687)	0.002 (0.648)	0.002 (0.709)	0.094 (1.056)	-0.001 (-0.011)	0.001 (0.014)
Education	-	-	-	-	0.037 (1.754)	0.039 (1.878)	-	0.441 (1.720)	0.466 (1.810)
Age	-	-	-	-	-0.008 (-2.334)	-0.006 (-1.647)	-	-0.391 (-2.338)	-0.317 (-1.777)
Children <17 years	-	-	-	-	-	0.059 (1.237)	-	-	0.054 (1.150)
Years[d]	-	-	-	-0.008 (-1.810)	-	-	-0.105 (-1.839)	-	-
R^2	0.028	0.089	0.085	0.101	0.122	0.126	0.096	0.116	0.120
F	2.827*	9.579**	9.011**	7.647**	8.078**	6.999**	7.167**	7.605**	6.565**
s	58.121	0.826	0.828	0.829	0.813	0.813	0.831	0.816	0.816
n[e]	296	296	296	275	296	296	275	296	296

[a]The numbers in parentheses below the estimated coefficients are t-ratios for the null hypothesis of no association.

[b]The housing price is measured in thousands of dollars.

[c]Income is measured in thousands of dollars of family income.

[d]Number of years at this address.

[e]The number of observations reflects the deletion of respondents with incomplete information on one or more of the variables involved in the model.

**Significant at the 0.01 level.

*Significant at the 0.05 level.

son, because independent measures of these potential determinants are not available in the Harrison data set and could not be acquired from other sources such as the 1980 Census. At best, the census reported income, race, education, and family composition measures that can be developed at the census tract level to consolidate to the town level for use with Harrison's information.*

Thus, what is important for the objectives of this research is whether the omission of these variables seriously biases the parameter estimates for the variables on which independent information is available. To address this issue, we report in the second half of Table 15-7 a selected set of the expanded specifications for the semi-log and double-log models. The principal interest in these models is the sensitivity of the estimated parameters for the price of housing, income, and the marginal price of distance to the inclusion of additional variables. For the most part, it is fairly limited with the semi-log specification. The estimated parameters for the variables that can be measured for our comparative analysis are quite stable across any of the three specifications reported here and, indeed, more generally over several others that have been considered as part of our preliminary analysis of these responses. The results are somewhat less encouraging with the double-log model. In this case, the estimated parameter for income is quite unstable. In one case, the estimated coefficient is negative but insignificant.

Clearly, such informal comparisons cannot establish whether there will be substantial biases associated with omitted variables when our comparison is forced to rely on the basic model with a limited specification. Nonetheless, they do suggest that the judgments that must be made in selecting a final specification for the demand for distance model are, in the case of the semi-log specification, less likely to be important to the "accepted" parameter estimates for what are clearly among the most important of the economic variables determining these distance responses. Moreover, this interpretation is consistent with James-Stein [1961] type estimators, which have influenced much of the recent work on pretesting and model selection. The James-Stein approach

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*It is important to distinguish the information used to estimate the Harrison [1983] and Harrison and Stock [1984] hedonic functions from that used in our comparison. The former are data on individual sales transactions. The latter is simply a summary of these results providing the mean of the individual records for each town.

develops estimates as weighted averages of the results of restricted and unrestricted estimators. The restrictions involved can be the exclusion restrictions associated with differing model specifications. If the estimated parameters do not vary greatly with alternative treatments of other potential determinants of the distance responses, the results derived for the weighted estimator will be approximately the same as the basic model's estimates. This approach also seems to be in the spirit of Leamer's [1983] proposals for reforming the practices used in reporting econometric results.

Unfortunately, the same conclusions cannot be drawn in the case of the double-log model. In this case, the results are much more sensitive to the specification selected. However, this may not be crucial to our further analysis. If one were required to select a final model, then, based on conventional criteria of minimum standard error of estimate (see Theil [1957]), the semi-log would appear to have a slight advantage over the double-log models with the comparable specifications. Accordingly, while the comparison in the next section reports the results for both models in a variety of alternative prediction forms, our primary focus will be on the results with the semi-log specification.

Before turning to those results it is important to acknowledge the encouraging findings from this simple and preliminary analysis of distance responses. The results clearly indicate the types of tradeoffs implied by the hedonic models that assume distance will serve as a proxy for the disamenity effects (including the perceived risk) associated with proximity to hazardous waste sites.

15.10 A COMPARATIVE EVALUATION OF THE CONTINGENT VALUATION AND HEDONIC MODELS

As we acknowledged at the outset of this chapter, the primary results reported in this section are not a comparative evaluation of estimated values from the contingent valuation and hedonic approaches to benefit estimation. Instead, we propose to judge the consistency or compatibility of the methods by using them together to predict the distances that the "average" (or representative) household in each of 54 towns would select from an industrial site with a landfill containing hazardous wastes. These predictions can then be compared with the averages of the actual distances selected in these towns. Our application of the two methods accepts as a maintained hypothesis the assumption that households treat distance as a proxy for the disamenity effects of these sites (including, but not necessarily limited to, their perceived risks of exposure to these hazardous wastes). Therefore, a close correspondence between the actual levels of distance and the predictions from a framework that uses both methods to derive the predictions would yield indirect evidence of the relative compatibility of each framework's description of the decision process. It is not a validation of the methods. Moreover, it faces many of the problems of past comparisons in that a finding of incompatibility of actual and predicted distances does not provide insight as to which aspect of either method is at fault.

The specific details of the prediction begin with the basic specifications estimated for the demand for distance models based on the responses given in the contingent valuation survey. With these models and information on the determinants of these distance demands it is possible to project the distance that the "average" individual would select. These projections are based on a constructed average household in each of 54 towns in suburban Boston. This household is assumed to have a housing demand that corresponds to the average sales price (in 1984 dollars) experienced with the homes in the Harrison data set. The household income level corresponds to the average of the family incomes reported for the census tracts in each of these towns for the 1980 Census (using the consumer price index to convert it to 1984 dollars). The marginal price is calculated from the Harrison hedonic price function as the derivative of the function with respect to distance. The marginal price for the specification of the Harrison model given in Table 15-4 is given in Equation (15.1) below:

$$\frac{\partial P}{\partial D} = (\alpha_D + \alpha_{DW})\ P\ , \qquad (15.1)$$

where

- α_D = estimated parameter for distance to the nearest industrial site regardless of whether it included a landfill with hazardous wastes
- α_{DW} = estimated parameter for the interaction variable of distance and a dummy variable identifying the site as containing hazardous waste
- P = the average price of the houses sold in a town in 1984 dollars.

There are several aspects of this calculation that are important to the interpretation of the results. First, we have included both the disamenity effects of an industrial site (as reflected in α_D) and the differential effects per mile of the presence of hazardous wastes in the calculation of the marginal price for distance. This specification was selected because of the description of the scenario used in our question (as reported above in Section 15.4).

Second, there are at least two options for the value of the housing price used in these calculations including the average of the actual sales prices (converted to 1984 dollars) and the predicted price based on the average characteristics of houses sold in each town. There are a number of reasons why these two measures will be different and will imply quite different assumptions. Use of the second measure, for example, constructs a housing type with the average characteristics of houses that sold in the town in the Harrison data set. A specific house with those features may not exist. With a nonlinear hedonic price schedule this will not correspond to the average price. However, if we assume that the hedonic model is correctly specified, it does reflect only the factors considered to be important to housing prices. It omits other factors that might have influenced the sale prices in a particular town at a specific time that would more reasonably be considered random error. Therefore, it uses the model more specifically than the first strategy.

However, this specificity is a mixed blessing. Since the hedonic price function is nonlinear with the log of the price, a function of the levels of some variables, and the logs of others, we can expect that estimates of the price based on it will be biased (i.e., by Jensen's inequality). There are some adjustments that reduce the extent of or eliminate the bias for some cases (see Goldberger [1968]), but the information required for these calculations was not available for our estimates of these prices.

Finally, the hedonic price function by its specification implies a marginal price schedule rather than a constant marginal price as implied by our formulation of the demand for distance survey question. It also does not necessarily imply that decisions will correspond to the partial equilibrium framework underlying the description of the survey questions.

Some of these problems must, by design, be treated as maintained hypotheses. Others can be investigated in development of the comparison. The postulated structure of the decision process and approximate constancy of the marginal price are maintained hypotheses. To deal with the effects of the procedures used to estimate the marginal price, we consider two separate estimates--one based on the average of the actual prices and one using the predicted price using the average characteristics.

Table 15-8 compares the marginal prices implied by the two approaches with MP1 being the prediction based on the average characteristics of homes sold in each town and MP2 using the average of the actual prices. This table also compares these calculated marginal prices with the average of the design marginal prices that were asked of the survey respondents in each town (column 4 in the table). Clearly, the calculated marginal prices are uniformly larger than the average of our design prices and fall outside the range of the prices used. This is unfortunate because it implies that the demand for distance models estimated from the survey responses are less likely to be relevant to these cases.

The table also reports the survey respondents' estimate of the average price of homes in their neighborhood in comparison with the average prices of sales in that town in the Harrison data set (in 1984 dollars). These prices are generally consistent, though there are a few notable exceptions, as, for example, the case of the town of Brookline. The discrepancies are in both directions and should not be interpreted as reflecting on the ability of respondents to gauge housing values. Our sample is a representative sample of the population in suburban Boston, not each town. Moreover, even a representative sample of each town's homeowners would not necessarily be representative of the prices and characteristics of houses that were selling in any given period.

The last component of the table is the average distance selected by respondents as their answers to the distance demand question in comparison to the actual distances of the homes selling in these towns. With the exception of the distance response for Belmont and Lexington, these two distance measures are comparable in order of magnitude terms. Of course, this does not represent a confirmation of either modeling framework. Rather, at best, it can be interpreted as one indication that respondents understood the features of the contingent valuation question.

TABLE 15-8. A COMPARISON OF THE REGION I SURVEY RESPONSES AND HARRISON DATA BY TOWN

Town	Survey responses: Number of observations	Average price of house, $	Distance selected, mi	Average marginal price, $	Average price of house, $[a]	MP1	MP2	Average of minimum distance to hazardous waste site, mi
Abington	7	51,625	6.29	669	62,832	7,779	4,210	8.36
Acton	114	120,102	12.72	788	125,884	8,239	8,434	1.95
Arlington	3	93,000	5.67	950	108,455	6,308	7,267	2.32
Belmont	5	124,375	53.00	706	147,820	8,073	9,904	1.83
Beverly	8	90,000	8.50	795	85,044	12,005	5,698	13.12
Braintree	6	87,500	18.67	900	77,349	7,052	5,182	5.53
Brookline	6	240,833	11.50	633	98,593	5,874	6,605	4.37
Cambridge	4	171,250	12.50	888	109,845	4,916	7,360	2.06
Canton	5	71,000	6.20	700	123,563	13,809	8,279	9.64
Carlisle	7	179,285	21.57	681	132,201	11,686	8,858	4.58
Cohasset	3	78,750	11.67	813	130,157	19,065	8,721	15.28
Framingham	14	117,153	22.43	673	102,416	7,472	6,862	4.27
Franklin	5	84,200	14.60	920	79,727	10,601	5,342	8.49
Holbrook	1	65,000	10.00	1,300	67,980	6,599	4,555	6.30
Kingston	3	56,333	3.33	983	77,277	15,785	5,178	17.25
Lexington	10	158,792	112.00	929	145,315	9,073	9,736	3.99
Lynn	3	43,333	8.33	983	54,931	6,023	3,680	8.34
Malden	10	73,111	15.50	625	66,870	5,843	4,480	4.84
Marblehead	1	80,000	0.00	650	145,299	14,506	9,735	13.55
Marshfield	2	66,000	1.50	1,150	83,627	14,271	5,602	15.81
Medford	2	65,000	10.00	825	81,512	6,165	5,461	2.29
Melrose	6	92,500	7.83	1,142	86,357	6,658	5,786	4.88
Millis	1	60,000	10.00	650	94,347	9,745	6,321	8.50
Milton	2	145,000	6.00	1,300	105,003	9,898	7,035	6.29
Natick	4	73,333	6.50	975	91,596	8,245	6,137	6.48
Needham	3	126,667	10.67	600	119,540	12,677	8,009	9.50
Newton	6	159,714	25.00	929	142,091	8,534	9,520	5.76

(continued)

TABLE 15-8 (continued)

Town	Survey responses: Number of observations	Average price of house, $	Distance selected, mi	Average marginal price, $	Average price of house, $[a]	MP1	MP2	Average of minimum distance to hazardous waste site, mi
Norwell	6	92,500	15.00	925	104,511	13,878	7,002	12.21
Norwood	2	75,000	5.50	625	89,983	11,743	6,029	11.58
Peabody	6	83,333	7.83	875	84,328	8,127	5,650	8.17
Quincy	6	70,000	10.83	517	69,862	6,234	4,681	6.67
Reading	3	90,000	14.67	950	97,727	6,504	6,547	2.04
Revere	2	90,000	8.00	250	68,320	6,118	4,578	7.88
Salem	8	76,667	9.63	750	68,236	8,003	4,572	11.65
Saugus	6	80,833	7.83	875	72,368	7,660	4,848	6.62
Scituate	3	115,000	20.00	713	93,179	12,742	6,243	14.80
Sherborn	5	188,000	11.40	560	176,398	10,237	11,819	5.52
Somerville	2	122,500	13.50	600	65,184	4,356	4,367	1.90
Stoneham	1	75,000	10.00	1,000	88,928	6,146	5,958	2.76
Stoughton	6	58,333	9.00	725	69,713	9,211	4,671	9.95
Swampscott	6	62,166	12.50	817	111,119	11,143	7,445	11.29
Topsfield	5	146,000	12.00	820	150,596	20,103	10,000	13.25
Wakefield	4	101,250	7.50	625	84,259	6,497	5,645	3.54
Walpole	5	72,083	21.40	725	87,669	13,486	5,874	12.61
Waltham	4	85,000	10.00	800	84,828	7,036	5,684	4.98
Watertown	5	99,250	12.00	683	117,052	6,856	7,843	2.71
Wayland	1	200,000	20.00	1,300	128,823	10,916	8,631	7.41
Wellesley	3	166,667	11.67	517	154,742	14,939	10,368	9.04
Westwood	8	102,500	12.50	838	116,017	17,378	7,773	11.55
Wilmington	4	82,000	38.50	920	14,207	5,935	4,972	3.63
Winchester	1	137,500	20.00	1,150	140,456	7,676	9,411	3.50
Winthrop	8	100,000	9.50	869	67,304	8,728	4,509	8.99
Woburn	8	68,625	8.00	706	84,652	6,801	5,671	2.49

[a] These prices are averages of the sale prices from November 1977 to March 1981. Harrison provided the mean price by town in 1977 dollars. These have been converted to 1984 dollars (the year of the survey) using the total shelter component of the housing component of the consumer price index for 1977 and June 1984.

Table 15-9 presents the predicted distances implied by each of the two basic models (the semi-log and double-log specifications in Table 15-7) with each measure of the marginal price and with a correction to adjust for the bias induced by using the semi-log and double-log functions to predict the level of distance.* The specific features defining each type of prediction in Table 15-9 are given in Table 15-10. Several overall observations can be made based on casual inspection of these results. First, the predictions from the semi-log specifications (i.e., D3, D4, D7, and D8), our preferred módel, are uniformly less than those with the double-log model. Moreover, they are usually less than the average of the minimum distances for the houses in each town in the Harrison data set (i.e., what we are interpreting as the actual distances selected). Both the use of the actual sales price and the adjustment to reduce the bias in each model's estimates of distance tend to increase the predicted distance. While the selection of the actual price for housing as the price component in Equation (15.1) does not always increase the marginal price estimates, it does increase the majority of the estimates for both the semi-log and the double-log models.

Comparing the estimates with the average of the actual distances for the houses in Harrison's sample is difficult. In somewhat less than half the cases (20 of the 54 towns), our range of estimates considering all three of the factors that distinguish them--model, housing price, and bias adjustment--does not include the average of the actual distances to the nearest disposal site containing hazardous wastes. Since these ranges are quite large, greater in many

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*The specific correction involves using Goldberger's [1968] suggestion for reducing the bias by predicting distance, D, with the conditional expectation:

$$D_k = \exp\ (X_k \beta) \cdot \exp\ (\frac{1}{2}\ \sigma^2)\ ,$$

where

D_k = the predicted distance for the kth town

X_k = 1×N vector of the determinants of distance demand (in linear form for the semi-log model and log form for the double-log specification)

β = N×1 parameter vector

σ^2 = variance in the error for the distance demand function.

TABLE 15-9. PREDICTED AND ACTUAL DISTANCE TO HAZARDOUS WASTE SITES BY TOWN

Town	Predicted distance, mi D1	D2	D3	D4	D5	D6	D7	D8	Actual distance, mi: Average minimum distance, industrial	Average minimum distance, hazardous waste
Abington	4.91	5.53	1.02	2.96	6.92	7.79	1.43	4.17	4.96	8.36
Acton	6.75	6.72	1.14	1.08	9.51	9.47	1.60	1.51	2.04	1.95
Arlington	6.49	6.32	1.84	1.38	9.14	8.90	2.59	1.94	2.31	2.32
Belmont	7.20	6.92	1.27	0.73	10.14	9.75	1.79	1.03	1.91	1.83
Beverly	5.15	5.94	0.31	2.04	7.25	8.36	0.43	2.87	2.54	13.12
Braintree	5.53	5.87	1.35	2.36	7.79	8.26	1.90	3.32	2.25	5.53
Brookline	6.21	6.07	2.05	1.65	8.75	8.55	2.89	2.32	4.44	4.37
Cambridge	6.25	5.78	2.60	1.25	8.80	8.14	3.65	1.75	1.95	2.06
Canton	5.97	6.59	0.21	1.09	8.40	9.28	0.29	1.54	1.41	9.64
Carlisle	6.70	7.07	0.44	1.03	9.44	9.95	0.62	1.45	6.31	4.58
Cohasset	5.90	6.86	0.05	1.03	8.31	9.66	0.06	1.44	6.36	15.28
Framingham	6.18	6.28	1.29	1.55	8.71	8.85	1.81	2.18	2.48	4.27
Franklin	5.19	5.92	0.47	2.25	7.31	8.34	0.65	3.17	2.12	8.49
Holbrook	5.26	5.65	1.47	2.72	7.40	7.95	2.07	3.83	5.46	6.30
Kingston	4.62	5.72	0.10	2.29	6.50	8.06	0.13	3.22	2.77	17.25
Lexington	7.12	7.03	0.97	0.79	10.03	9.90	1.36	1.11	5.26	3.99
Lynn	4.73	5.21	1.63	3.29	6.67	7.33	2.29	4.62	2.96	8.34
Malden	5.24	5.51	1.81	2.72	7.37	7.76	2:54	3.82	2.19	4.84
Marblehead	6.42	6.93	0.18	0.77	9.04	9.76	0.26	1.08	2.17	13.55
Marshfield	4.87	5.83	0.15	2.08	6.85	8.21	0.22	2.93	8.60	15.81
Medford	5.65	5.79	1.73	2.13	7.96	8.15	2.43	3.00	2.03	2.29
Melrose	5.88	6.04	1.56	2.03	8.28	8.50	2.20	2.86	3.03	4.88
Millis	5.67	6.16	0.63	1.76	7.98	8.68	0.89	2.48	4.39	8.50
Milton	5.98	6.39	0.64	1.52	8.42	9.00	0.91	2.14	4.27	6.30
Natick	5.80	6.13	0.99	1.86	8.16	8.64	1.39	2.62	3.29	6.48
Needham	6.17	6.74	0.30	1.22	8.68	9.49	0.42	1.72	7.76	9.50
Newton	7.09	6.94	1.11	0.83	9.98	9.78	1.57	1.16	5.78	5.76
Norwell	5.57	6.36	0.19	1.53	7.85	8.96	0.27	2.15	4.62	12.21
Norwood	5.35	6.08	0.34	1.90	7.54	8.57	0.48	2.67	1.74	11.58
Peabody	5.53	5.93	0.98	2.07	7.78	8.35	1.38	2.91	1.60	8.17
Quincy	5.28	5.58	1.63	2.60	7.43	7.86	2.29	3.66	2.36	6.67
Reading	6.28	6.28	1.72	1.70	8.85	8.84	2.42	2.39	0.93	2.04
Revere	5.19	5.49	1.65	2.62	7.31	7.73	2.32	3.69	1.73	7.88
Salem	5.01	5.58	0.95	2.66	7.05	7.86	1.34	3.74	0.67	11.65
Saugus	5.27	5.76	1.09	2.54	7.43	8.11	1.54	3.57	3.84	6.61
Scituate	5.37	6.16	0.26	1.83	7.56	8.67	0.37	2.58	8.56	14.80
Sherborn	7.68	7.47	0.78	0.49	10.82	10.52	1.10	0.69	3.07	5.52
Somerville	5.38	5.38	2.76	2.75	7.58	7.57	3.88	3.87	1.47	1.90
Stoneham	6.01	6.05	1.83	1.93	8.47	8.52	2.57	2.72	1.19	2.76
Stoughton	4.98	5.67	0.68	2.64	7.01	7.99	0.96	3.72	2.85	9.95
Swampscott	6.06	6.55	0.45	1.37	8.53	9.22	0.64	1.93	2.44	11.29
Topsfield	6.20	7.08	0.04	0.72	8.74	9.98	0.05	1.01	2.87	13.25
Wakefield	5.78	5.94	1.61	2.08	8.14	8.36	2.26	2.92	2.01	3.54
Walpole	5.23	6.14	0.21	2.02	7.37	8.65	0.29	2.84	1.83	12.61
Waltham	5.68	5.92	1.36	2.04	8.00	8.33	1.91	2.87	4.99	4.98
Watertown	6.48	6.31	1.57	1.17	9.12	8.89	2.21	1.64	2.82	2.71
Wayland	6.60	6.91	0.54	1.07	9.30	9.73	0.76	1.51	1.88	7.41
Wellesley	6.74	7.23	0.18	0.70	9.49	10.18	0.25	0.98	5.11	9.04
Westwood	5.66	6.61	0.07	1.28	7.97	9.30	0.10	1.81	3.24	11.55
Weymouth	5.24	5.72	1.12	2.55	7.38	8.05	1.57	3.58	1.58	7.29
Wilmington	5.70	5.90	1.91	2.55	8.03	8.31	2.69	3.59	1.87	3.63
Winchester	7.18	6.91	1.43	0.85	10.12	9.73	2.02	1.20	2.13	3.50
Winthrop	4.92	5.58	0.77	2.74	6.92	7.86	1.09	3.85	2.74	8.99
Woburn	5.75	5.95	1.47	2.06	8.09	8.38	2.06	2.89	1.79	2.49

TABLE 15-10. FEATURES OF THE MODELS FOR PREDICTING DISTANCE FROM HAZARDOUS WASTE SITES

Name	Model	Marginal price	Bias correction
D1	Double-log	MP1	No
D2	Double-log	MP2	No
D3	Semi-log	MP1	No
D4	Semi-log	MP2	No
D5	Double-log	MP1	Yes
D6	Double-log	MP2	Yes
D7	Semi-log	MP1	Yes
D8	Semi-log	MP2	Yes

cases than ±50 percent of the actual distances, this is not a particularly good performance pattern.* This conclusion would not have been as apparent from simple comparisons of the overall average predictions with the average actual distances. These results are reported in Table 15-11. However, student-t tests of the equality of the means, under the assumption of independence of the two variables and equality of their variances, suggest that all but one (D5--the double-log model using the predicted price and the bias adjustment) reject the null hypothesis of equality of means.

These findings are to some extent qualified by considering the movements in the actual distances in comparison to the predictions across towns. This is accomplished using a simple regression approach originally proposed by Theil [1961] for evaluating forecast accuracy. It involves regressing the actual values of the distance on each of the predictions and testing two null hypotheses--that the intercept is zero and the slope unity. In other words, the points are assumed to cluster around a 45° line when actual distances are plotted as a function of the predicted distances. Table 15-12 reports these results for the eight approaches considered throughout our analysis. For all of the models that used the predicted housing price to estimate the marginal price of distance, both of these hypotheses are rejected. By contrast, the actual housing price used in these calculations does not allow a rejection of one of the null hypotheses. That is, the results seem to indicate that the actual and predicted values cannot be argued to diverge from a 45° line based on the slope parameter, but clearly exhibit a constant displacement of the intercept. These findings must be interpreted cautiously for several reasons. Failure to reject the null hypothesis of unity for the slope parameter is not a strong conclusion when the slope parameter is imprecisely estimated. It can also be interpreted as an indication of no association between the actual and predicted values of the distance.

The results using the models based on predicted housing price should be interpreted carefully for another reason. They include the actual distance on both sides of the equation. That is, distance influences the predicted housing

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*The ±50 percent was selected to parallel the proposal of the Cummings, Brookshire, and Schulze [1984] methodology for assessing the reference accuracy of contingent valuation estimates.

TABLE 15-11. OVERALL MEANS FOR PREDICTED AND ACTUAL DISTANCES

Distance to nearest industrial plant with hazardous wastes	Mean	t[a]	Standard deviation of the mean
D1	5.83	2.74	.097
D2	6.19	2.11	.074
D3	1.02	11.11	.094
D4	1.79	9.77	.097
D5	8.22	-1.41	.136
D6	8.72	-2.29	.104
D7	1.43	10.28	.131
D8	2.52	8.39	.136
Actual distance selected[b]	7.40	-	.566

[a]t-ratio for null hypothesis of equality of means under the assumption of equality of variances.

[b]This distance is the average of the minimum distances from hazardous waste sites based on the housing sales in the Harrison data.

TABLE 15-12. A COMPARISON OF ACTUAL AND PREDICTED DISTANCES[a]

Independent variables	Models							
	D1	D2	D3	D4	D5	D6	D7	D8
Intercept	23.03 (5.42)	6.51 (0.99)	12.40 (20.66)	6.96 (4.45)	23.03 (5.42)	6.51 (0.99)	12.40 (20.66)	6.96 (4.45)
Prediction (D_i)	-2.68 (-3.70)	0.15 (0.14)	-4.92 (-10.03)	0.25 (0.30)	-1.90 (-3.70)	0.10 (.14)	-3.50 (-10.03)	0.18 (0.30)
t_1[b]	-5.09	-0.81	-12.06	-0.93	-5.65	-1.19	-12.89	-1.42
R^2	0.209	0.00	0.66	0.00	0.21	0.00	0.66	0.00
F	13.72	0.02	100.51	0.09	13.72	0.02	100.51	0.09

[a]The numbers in parentheses below the estimated coefficients are t-ratios for the null hypothesis of no association.

[b]t_1 is the t-ratio for testing the null hypothesis that the slope parameter is unity.

price and therefore is present in a nonlinear relationship determining the predicted distance. There is no way to avoid this outcome if the predicted price is to form the basis for the estimates of the marginal price for distance. There are, however, other factors changing across towns, so it is not ensured that the models based on predicted price would not yield a tautological relationship for the actual-predicted regression models.

While the overall findings of this analysis at this stage indicate inconsistency between the results of the two models, this does not necessarily imply that either of them is incorrect. It can easily be a reflection of the differing assumptions underlying each framework.*

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*It should also be noted that the demand-for-distance models could be modified to estimate the implicit price for distance and compare implicit values. We also performed these comparisons for both models. The results were completely implausible with the double-log specification and therefore will not be reported here. With the semi-log model, the findings were more plausible, but not in close correspondence with the estimated marginal prices from the hedonic model. For example, the overall averages across the 54 towns for the marginal prices MP1 and MP2 are given below in comparison with the results of inverting the demand for distance function and predicting the constant marginal price (designated as VAL).

Estimated of Marginal Value	Mean	Standard Deviation	t
MP1	9,498.61	3,692.87	-12.21
MP2	6,660.34	1,936.39	-10.76
VAL	2,354.82	2,212.65	

Allowing VAL to play the role of the actual marginal price, regressions comparing VAL and the marginal prices derived from the hedonic models are as follows:

$$VAL = \underset{(8.835)}{5{,}868.65} \; \underset{\substack{(-5.66) \\ (-15.31)}}{-0.370} \, MP1$$

$R^2 = 0.381$
$F = 32.06$

$$VAL = \underset{(0.527)}{561.92} \; \underset{\substack{(1.75) \\ (-4.75)}}{+0.269} \, MP2$$

$R^2 = 0.056$
$F = 3.06$

The results of tests of equality of means (given in the column labeled t) indicate that the null hypothesis must be rejected at the .01 significance level. The regression analysis is also clear in indicating incompatibility between each

15.11 SUMMARY

It must be acknowledged that a large number of assumptions and judgments were required to complete this comparison. They have been enumerated throughout this chapter, but a few of the more important considerations are reiterated here. One of the most important arises with the property value model. It was acknowledged to be an early version of the hedonic function initially developed by Harrison [1983] and revised in Harrison and Stock [1984]. Nonetheless, the specification used was a plausible formulation for the model and was not obviously inferior to the revised model. Further evaluation of the two property value models is necessary before a clear choice can be made.

A second consideration concerns the compromises required in the representation of the nature of the constraints facing the individual. One of the most important of these involved treating the marginal price of distance as constant. Most hedonic property value models do not make this assumption. Indeed, it is inconsistent with both versions of the Harrison property value model. However, there was no simple way to avoid this problem. Communication of the demand for distance question in the survey required a direct and simple explanation of the price of distance. It was felt that presentation of a function or price schedule would have decreased the chances for successfully administering the question and lengthened an interview that was felt to be too long already.

Despite these qualifications and limitations, the research has highlighted a number of dimensions of comparative analyses that were implicit, maintained assumptions in past studies. Equally important, it has suggested an alternative means of judging the compatibility of two models. Rather than comparing each approach's estimate of an unknown marginal valuation, we used the models together to predict an observable response that could then be used to evaluate the methods' compatibility by gauging the relationship of these predictions with

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of the method's estimates of the marginal valuation of distance. The statistic in parentheses immediately below the estimated parameters is the t-ratio for the null hypothesis of no association. Below this statistic for the case of the slope parameters is the t-ratio for the null hypothesis that each slope parameter is unity.

actual responses. Of course, this procedure does not allow for the identification of which method is "at fault." However, it does provide an alternative standard for judging compatibility and a clearer criteria for what that compatibility might mean by allowing one to consider the performance of these types of predictions in relationship to other types of predictive performance of other economic models.

This procedure demonstrates the use of a reference group or relative standard in judging the compatibility of benefit estimation methods. Past comparisons have focused on each method's estimates of an economic valuation concept that can never be known--e.g., the true willingness to pay for reductions in air pollution or reductions in the risk of exposure to hazardous wastes. Therefore, the precision (in conventional terms) of these methods' estimates cannot be gauged with real-world data. We have suggested that since each method describes a choice and valuation process, the methods may be combined to predict some economic outcome that can be observed. These predictions can then be compared with actual choices.

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CHAPTER 16

POLICY IMPLICATIONS AND RESEARCH AGENDA

16.1 INTRODUCTION

This chapter has two objectives--first, to consider the policy implications of the valuation estimates derived from the contingent valuation survey and, second, to outline the further research that follows from the activities undertaken during Phase I of the project. Our discussion to this point has deliberately avoided consideration of both the potential policy uses for these estimates and a comparison of them with earlier efforts to value risk changes. There are several reasons for holding the discussion of these issues until the end of the report. The most important of these arises from the caveat emphasized throughout the presentation of our empirical results: They are preliminary. The data have been used for detailed econometric and comparative analyses to begin the process of developing final estimates. These efforts have identified a large number of assumptions required to use the sample responses in a particular task. In many cases it will be necessary to evaluate the implications of alternative sets of assumptions and to refine the econometric techniques used with these assumptions and the data before a final set of results can be developed. Indeed, the preliminary statistical analyses have highlighted problems that would not have been apparent from the summary statistics used to describe the survey results. In the analysis of the contingent valuation results, for example, the problems posed by missing values for key attitudinal and risk perception variables were identified as important to the development of models reflecting these influences. Equally important, heteroscedasticity in the errors associated with the respondents' valuations for the two risk reductions appeared to be an especially important consideration for further econometric modeling of these marginal valuations. Finally, treatment of the zero bids and the truncated nature of the distribution of valuation responses will require further analysis.

It should be acknowledged that these issues are important to both the econometric modeling of valuation responses and the development of summary statistics to describe the distribution of these responses. They cannot be avoided by focusing exclusively on the summary statistics for the valuation responses.

A second reason for postponing discussion of policy interpretations stems from the objectives of the research:

- To develop a set of estimates of the individuals' valuations for risk changes in a format that allowed analysis of the factors influencing these valuation decisions.
- To compare the contingent valuation and hedonic approaches for describing the behavioral responses to (and the valuations of) changes in the risks of exposure to hazardous wastes.

These objectives relate primarily to technical issues associated with the modeling and measurement of the values for risk changes. They do not extend to the tasks associated with using valuation information in decisionmaking with respect to the specific policy actions that are associated with hazardous wastes and would be expected to lead to changes in the risk of exposure to these substances. Accordingly, this chapter's discussion of policy issues addresses only one issue: "How do these valuation estimates compare with those frequently in use for policy decisions involving risk change?"

16.2 GUIDE TO THE CHAPTER

Section 16.3 of this chapter offers a comparative assessment of our valuation results. Section 16.4 considers the research issues that have emerged from our preliminary analysis. In contrast to the work undertaken under Phase I, most of these tasks are empirical. Where further conceptual analysis is required, it is motivated by the empirical research. Finally, Section 16.5 contains a brief summary of the chapter.

16.3 THE INCREMENTAL VALUES FOR RISK CHANGES USED IN POLICY ANALYSES

One of the most obvious questions that might be posed in interpreting our results is, "How do they compare with estimates of the values for 'statistical lives'?"* While we will attempt to discuss this issue in what follows, it is important to recognize a larger number of qualifications that must be raised with any such comparison.

Most of the frequently cited estimates of the values for statistical lives are the result of empirical models for labor market compensation. In these studies, wage rates (or earnings) are specified as a function of the individual worker's characteristics and his job characteristics.† One of these job characteristics is a risk measure. The hedonic wage model is assumed to describe the compensation (in higher wages) that is required in equilibrium (based on the existing distribution of individuals and their respective attitudes toward risk and jobs) to have the marginal individual accept an increment to his risk of injury or death on the job. While there have also been studies of other individual or household decisions involving risk (see Violette and Chestnut [1983] for a review), these will not be considered here.

Table 16-1 summarizes the highlights from four frequently cited studies of labor market job risk decisions. The values for statistical lives derived from these studies range from $630,000 (in 1984 dollars) in the Thaler-Rosen [1975] analysis to $6,300,000 (in the same units) in the Viscusi [1981] analysis. The use of the term "value of a statistical life" to describe these incremental values is in many respects unfortunate. It is simply an index of the rate per unit of risk at which workers are compensated. It does not imply the acceptance of any of the estimates as "the value of a life." Rather, there are two equivalent ways of interpreting the index: (1) the scaling of a marginal risk premium by the level of risk to derive the dollar value per unit of

*Most estimates of the value of a statistical life come from the aggregate willingness to pay by many people for small reductions in their own small risks of death. As a result of the aggregation, the willingness to pay to save one statistical life refers to that for some person who cannot be identified. Thus, these values may differ from those expressed for the lives of individuals who can be identified (e.g., trapped coal miners).

†Hedonic wage models have also been used in the valuation of environmental amenities such as air quality (see Bartik and Smith [forthcoming] for a discussion of these models). These analyses would imply that, for wage functions estimated with a cross-section of workers extending outside a single geographic area, site attributes ought to be an additional determinant of real wagers. See Smith [1983] for further discussion.

TABLE 16-1. LABOR MARKET ESTIMATES OF VALUE OF UNIT OF RISK REDUCTION

Study	Risk measure	Mean fatality rate	Implicit value (1984 dollars)[a]
Thaler-Rosen [1975]	Occupational death rate	0.001	$630,000
Smith [1976]	BLS industry death rate	0.0001	$3.5 million
Viscusi [1979]	BLS industry fatal and nonfatal risk	0.0001	$3.2 to $4.2 million
Viscusi [1981]	BLS industry fatal and nonfatal lost workday risk	0.0001	$6.3 million

Source: Viscusi [1983].

[a]These values were converted from the estimates reported in Viscusi, using the consumer price index.

risk or (2) treating the value as the sum of the marginal values for a specified risk reduction over a group large enough to yield a reduction in accidental deaths by one life in expected value terms. In either case, the wage premiums are based on a specific institutional mechanism for compensating workers to induce them to assume risk. Since there are constant payments irrespective of the state of nature realized, this mechanism is an option price format. (See Smith [1985] for a discussion of this point in relation to hedonic property value models.) Equally important, the risks involved are annual risks of death from an on-the-job accident. Thus, in equilibrium, the wage premium is an ex ante measure of the incremental option price.

Our contingent valuation responses are also ex ante measures designed to correspond to an option price. Nonetheless, there are some important differences between our results and those of the earlier studies. First, the perceived mechanisms for adjustment may well be different in the two cases. For the worker, there may be opportunities for compensation of families after a fatal accident affects one of its members (e.g., subsidized company insurance, benefit programs through unions, etc.). In the scenarios posed as part of the contingent valuation analysis, these mechanisms are assumed to be nonexistent in the description of the question, but this format does not in itself necessarily prevent the respondents from adjusting their reported valuations to reflect their own perceived opportunities for state dependent adjustments.

Second, the analysis from labor market studies is conditional upon a selection process that has matched individuals willing to accept greater risk with those providing it. Consequently, the marginal valuation of a risk change will be sensitive to the composition of the sample used to estimate the wage model that forms the bases for the estimates.* This opportunity was not available to the respondents to our survey. While it is possible that those individuals least willing to accept risk will have moved from locations with the highest perceived risk, this is not relevant to our contingent valuation questions. In these questions, risk levels are posed to individuals. It is, of course, con-

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*It will also be sensitive to the information on risk available to individuals and how the job risks are perceived. Some preliminary evidence on this issue is presented in Viscusi [1979]. More recent findings are in Viscusi and O'Connor [1984].

ceivable that an extreme aversion to risk might lead to rejection of the hypothetical scenario. However, our analysis of protest bids did not indicate this type of response.

Third, the job risk measure is a risk of death as if an accident on the job was always fatal. While this view is not correct, the wage models have not attempted to describe the decision process as a multi-stage lottery. Both Viscusi [1981] and Smith [1983] have incorporated nonfatal accident rates, but neither study has attempted to explicitly describe the process in the same form as the description of the risks presented in our contingent valuation analysis. The question requesting values for a risk reduction does identify the process as a multi-stage lottery in which the event exposure must first be realized before the risk of the health effect (death) must be considered. Depending upon how job risks are perceived, this is a potentially important distinction. Psychological research has suggested that individuals can have difficulty in dealing with multi-stage lotteries (e.g., Schum [1980].)

Finally and perhaps most importantly, the job risk is an annual risk for any empirical analysis. Once an individual leaves the work environment each day, the risk of an on-the-job accident is eliminated for that day. By contrast, the risk of exposure to hazardous wastes in a given location is continuous--always present so long as the individual is present at the location. Moreover, the outcome is also different. In the on-the-job accident, the outcome is a fatality at the time of the event. With the contingent valuation, the outcome is a fatality 30 years after the exposure. As a consequence, time plays a very different role in the two cases.

With these qualifications, Table 16-2 reports the calculated values per unit of risk in a format comparable to the values for statistical lives reported in Table 16-1. They are based on the mean valuation responses from the sample with protest bids excluded (see Table 11-7). Appendix H contains a table with identical information that includes protest bids. Three different calculations are reported--the annual incremental value per unit of risk and two different values of what we have designated the annuity value of the risk change. The annual value is simply the annual bid scaled by the unit change in the risk of death implied by the reduction in the risk of exposure and the conditional probabilities that were posed for each design point in the contingent