Comparing and Evaluating Different Environmental Risks

Richard D. Morgenstern

Visiting Scholar, Resources for the Future and
Associate Assistant Administrator for Policy, Planning and Evaluation (on leave)
U.S Environmental Protection Agency

1616 P St. NW Washington, D.C. 20036
Phone: 202-328-5037 Fax: 202-939-3460
Email: MORGENST@RFF>ORG

Abstract

Winston Churchill once said that democracy is the worst approach to government except for all the others that have been tried. In a sense, one can make the same point about the use of comparative risk analysis to set environmental priorities. As a method, comparative risk analysis has many limitations. Yet if such analysis is not done explicitly, it almost certainly occurs implicitly. In that case, decisionmaking is driven by public fears, special interest lobbying and bureaucratic preferences. Often, the resulting policies do not reflect the best interests of our citizenry.

The challenges posed in this workshop are monumental. In fact, responding to them has the potential to become a life's work. Certainly the old adage that "the perfect is the enemy of the very good" applies in this case. My modest contribution to your thinking about these issues is to report on two major efforts undertaken in the U.S. that attempt to make cross-cutting comparisons among environmental problems.

The first approach, known as comparative risk analysis (CRA) was developed largely in the traditions of the biological and physical sciences. *Unfinished Business,* completed in 1987, represents the first systematic attempt by the U.S. Environmental Protection Agency (USEPA) to look broadly across the spectrum of environmental problems and make judgments about which problems pose the greatest risks to human health, the environment, and the quality of life. The CRA methodology underlying *Unfinished Business* is interdisciplinary in the broadest sense of the term, combining scientific analyses from several disciplines along with the informed judgments of experts. In the decade since the original publication of *Unfinished Business* more than fifty separate studies, conducted in the U.S. and abroad, have attempted to validate and extend the basic CRA methodology.

The second approach, benefit cost analysis, is drawn from a single discipline, namely, economics. While economists have often been criticized as knowing "the price of everything and the value of nothing," considerable effort has gone into conducting economic analyses of environmental issues for at least the past two decades in the U.S. Historically, most economic analyses have focused on single environmental problems, usually in the context of establishing regulations or standards. Recently, the USEPA completed a major study that attempts to assess, retrospectively, the overall benefits and costs of all air pollution regulations, *The Benefits and Costs of the Clean Air Act 1970-1990*, (USEPA, 1997). While the focus of this study is on the aggregate benefits and costs of the air pollution control program over a twenty year period, the study does provide some insights into the relative importance, from an economic perspective, of some of the individual activities carried out under the Clean Air Act. The comparative aspect of this new study can be thought of as an economist's approach to comparative risk assessment.

The consideration of these two major EPA studies raises an immediate question about terminology. Risk assessment typically refers to efforts to analyze the nature and magnitude of hazards faced by humans or ecosystems. Comparative risk assessment attempts to distinguish the more serious from the less serious hazards faced by humans or ecosystems. In contrast, risk management typically focuses on more policy

relevant issues, e.g., what should be done about a particular problem? It is widely agreed that economic considerations are a critical part of the risk management process. In contrast, scientists typically see risk assessment as a largely scientific endeavor, devoid of economic considerations.

In recent years economists have entered the fray by attempting to express in monetary terms the consequences of different physical outcomes (risks) which the scientists have estimated. Economists emphasize that benefit-cost analysis can be used to systematically integrate information from multiple disciplines – including the biological and other physical sciences underlying risk assessment – to assess the broad implications of policy choices. *Unfinished Business* should be thought of as an exercise in risk assessment.

The economic methodology underlying *The Benefits and Costs of the Clean Air Act 1970-1990* differs in at least two important respects from the CRA approach of *Unfinished Business*. First, by addressing the costs and not just the improvement in health or ecological well being associated with risk reduction, economic analysis explicitly considers risk management issues. Second, economic analysis treats the results of risk assessment as inputs to the broader question, "what is it worth to society to reduce particular risks?" Whereas CRA seeks to quantify, or at least develop rankings of risks, generally expressed in physical terms, economic analysis attempts to ask the further question of how society values these different risks. As noted, especially outside the economics community, there is considerable skepticism about the ability of the discipline of economics to conduct this latter analysis.

This paper consists of two sections: a) a description and assessment of comparative risk analysis, as applied to *Unfinished Business*; and b) a description and assessment of the economic methodologies, as applied in *The Benefits and Costs of the Clean Air Act 1970-1990*. Future work needs to push beyond the aggregate analyses examined in this paper and focus on more detailed assessments of individual programs and policies. Such assessments can help assure we get the maximum possible environmental protection for the resources committed.

1. Introduction

The intellectual challenges posed in this workshop are truly monumental. As I understand it, your long term goals are to: a) identify all possible environmental hazards (impacts) caused by global change; b) estimate the risks of those impacts; c) quantify those risks for a comparative risk study, including trade-offs that may exist between environmental protection and economic development.

It is clear that responding to these challenges has the potential to become a life's work. Certainly the old adage that "the perfect is the enemy of the very good" applies in this case. My modest contribution to your thinking about these issues is to report on two major efforts undertaken in the U.S. that attempt to make cross-cutting comparisons among environmental problems.

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In recent years economists have entered the fray by attempting to express in monetary terms the consequences of different physical outcomes (risks) which the scientists have estimated. Economists emphasize that benefit cost analysis can be used to systematically integrate information from multiple disciplines – including the biological and other physical sciences underlying risk assessment – to assess the broad implications of policy choices. Even though some of the follow on work, including some of the CRA studies conducted at the state and local level, as well as those conducted outside the US, have attempted to address the questions of how the results of the risk assessment should be used in management decisions, it should be understood that *Unfinished Business* focused exclusively on risk assessment.

The economic methodology underlying *The Benefits and Costs of the Clean Air Act 1970-1990,* differs in at least two important respects from the CRA approach of *Unfinished Business.* First, by addressing the costs and not just the improvement in health or ecological well being associated with risk reduction, economic analysis explicitly considers risk management issues. Second, economic analysis treats the results of risk assessment as inputs to the broader question, "what is it worth to society to reduce particular risks?" Whereas CRA seeks to quantify, or at least develop rankings of risks, generally expressed in physical terms, benefit cost analysis attempts to ask the further question of how society values these different risks. As noted, especially outside the economics community, there is considerable skepticism about the ability of the discipline of economics to conduct this latter analysis.

This paper consists of two sections: a) a description and assessment of comparative risk analysis, particularly as applied to *Unfinished Business*; and b) a description and assessment of the

economic methodologies, particularly as applied in *The Benefits and Costs of the Clean Air Act 1970-1990.* Future work needs to push beyond the aggregate analyses reviewed in this paper and focus on more detailed assessments of individual programs and policies. Such assessments can help assure we get the maximum possible environmental protection for the resources committed.

2. Comparative Risk Analysis

When the Environmental Protection Agency was established in 1970, the most pressing environmental problems in the United States were obvious: soot and smoke from cars and smokestacks, and raw sewage and chemicals from municipal and industrial waste water.

Since 1970 the U.S. has done much to abate the most visible forms of pollution, but many problems remain. Moreover, new problems have been "discovered" or have risen in importance, such as indoor radon, global warming, toxic and hazardous waste. Many of these new problems are difficult to evaluate, in part because they involve slow cumulative changes with very serious possible ultimate effects and also because of the considerable scientific uncertainty surrounding their final effects. Many of these problems involve toxic chemicals that may cause cancer or birth defects at levels of exposure that are difficult to detect. And many involve persistent contaminants that can move from one environmental medium to another, causing further damage even after controls for one medium have been applied.

The complexity and gravity of these issues make it particularly important that a public agency apply its finite resources where they will have the greatest effect. Choosing which environmental programs to emphasize should be viewed as an attempt to maximize the health and ecological benefits from the public and private resources that EPA can command. In principle, the environmental agency should analyze its set of investment opportunities in terms of their relative impacts on public health and the environment.

In practice, priority setting at EPA does not much resemble this approach. A wide variety of factors combine to make such priority setting difficult. One major difficulty stems from the multiple statutory goals governing the agency. EPA administers more than a dozen major statutes, which contain a multitude of goals and prescriptions. Over the years, the goals have generally become more specific, detailing what EPA is to do by when and the consequences for EPA if it does not carry out these instructions. Occasionally the goals conflict, as when a statute governing one medium (for example, water) mandates controls that transfer pollution to another medium (for example, air).

Achieving all of the statutory mandates is impossible with the limited resources available. The laws do not recognize that some of the goals are unlikely to be achieved, and they give little guidance as to how to choose among goals when all of them cannot be met. EPA is held accountable for each missed goal.

Mirroring these problems are the diverse public and political pressures brought to bear on the agency. Each pressure is aimed at a particular program: "Clean up the abandoned hazardous waste site in my neighborhood quickly," or "My company can't afford to comply with your proposed air pollution control regulations." Petitioners are not satisfied when EPA does not comply with their requests because "other things take priority." The home owner worried about a nearby hazardous waste site is not impressed by EPA's response that other sites will be cleaned

up first because they score higher on a hazard ranking system. The industrial plant manager is not satisfied when told that a proposed regulation is in place because it abates health effects at an acceptable cost per case avoided. In sum, there is little external appreciation for EPA's need to set priorities across programs.

Internal pressures also make rational priority setting difficult. As in many bureaucracies, long-established programs build an internal constituency of employees as well as an external one. And in an area such as environmental protection with a substantial technical component, existing programs build a critical knowledge base – for example, monitoring results, engineering information on relevant control technologies, and toxicological data on relevant pollutants – that can be used to justify spending more on these programs. By contrast, a new program designed to deal with an emerging environmental problem will have difficulty making its case because of the uncertainty involved and lack of good data.

Even if the bureaucratic and institutional obstacles to rational priority setting did not exist, environmental priority setting would still be extremely difficult methodologically. A critical element in setting priorities is being able to predict accurately and then compare the likely results of alternative actions. Impediments to doing this well in the environmental field include the following:

--*A severe lack of knowledge about environmental processes.* There are thousands of potentially toxic chemicals in commerce and the scientific community has a toxicological understanding of only several hundred. Scientists know little about the chemicals' synergistic or antagonistic effects or about complex chemical transformations involving pollutants in the atmosphere or in groundwater. Similarly, they know precious little about the reactions of entire ecosystems (as opposed to single species) to environmental pollution, and their data bases on emissions, ambient levels, exposures, and uptake of pollutants are quite limited.

--*Methodological limitations in specifying environmental "results."* Scientists can measure quantities such as emissions or ambient concentrations, but these are not the ultimate terms in which environmental changes should be evaluated. We pursue environmental improvements because we care fundamentally about human health and ecological quality. Yet in the scientific community as well as among the general public it is difficult to measure progress in human health and the environment. And it goes without saying that without a clear metric, it is very difficult to compare the two. Do we care more about a low risk of birth defects in future generations, or about a higher incidence of gastroenteritis in the current populations? Do we care more about episodic fish kills from pollution in rivers, or about reproductive difficulties in birds exposed to certain pesticides? Even if we could assess the risks inherent in these events accurately, we still would not know how to value them.

--*EPA does not directly implement most environmental programs.* Projecting the results of environmental programs is inherently difficult because implementation is typically carried out by the private sector and by state and local governments. In assessing programs EPA must judge the likely slippage between its regulatory proclamations and actions of others.

Even absent these influences it is difficult to set rational priorities without clear goals and good information. Statutory mandates and public, political, and bureaucratic pressures further discourage it. Overall, rational priority setting in the environmental area becomes a truly monumental task.

In recent years there have been some improvements risk assessment techniques. Perhaps most important have been advances in techniques for the human health risks of exposure to environmental pollutants. For cancer impacts, in particular, there is now a common denominator for comparing different programs, and there are quantitative procedures for estimating this common denominator. These methods are generally used in priority setting at the margin in helping to decide which potential new regulations to adopt and which to reject. Using risk assessment and other techniques, EPA typically calculates the cost per cancer case avoided for each new proposed regulation. Applying a similar cost-effectiveness cutoff level across all regulations provides some consistency to EPA decision making at the margin in the human health area. For non-cancer impacts there have also been some advances, although the quantification efforts still lag considerably behind those of cancer. (Some observers argue, however, that EPA's increasing ability to analyze human health effects quantitatively has caused the agency to pay too little attention to nonquantifiable concerns such as ecological quality.)

Unfinished Business was an ambitious project to determine the comparative magnitude of the various environmental problems that EPA might address. The aim was to develop a broad picture of environmental problems in terms of the relative risks they pose to human health and the environment. What are the largest problems EPA might tackle? What are the smallest? In a world of limited resources, it was thought this profile of relative risks would be a good starting point for agency priority setting.

The method used to compare environmental problems can best be described as systematically generating data, analysis and informed judgements among agency experts. About 75 career managers and experts representing all EPA programs participated in four work groups over a period of about a year. Each work group was chaired by a respected senior career environmental official.

This sort of study was new for EPA. The agency had a great deal of experience in assessing risks in the context of particular regulatory issues, such as comparing the risk reductions offered by alternative regulatory approaches to controlling a single pollutant from a single type of source. EPA also had some limited experience in program wide risk assessment. But a study of the scope of *Unfinished Business*, covering multiple sorts of risks and all environmental programs, was novel.

In conducting the project, participants organized and limited their work in four important ways. First, the universe of environmental problems was divided into 31 pieces. Each piece represents an environmental problem area defined along lines corresponding generally to existing programs or statutes. Some of the 31 problem areas are "criteria" air pollutants from mobile and stationary sources, hazardous air pollutants; contaminants in drinking water; abandoned hazardous waste (e.g., Superfund) sites; pesticide residues in food; and worker exposures to toxic chemicals. Other ways of slicing the pie – by pollutant, by route of exposure, by source category, or by environmental medium – were possible. Participants thought it most important to define the units in terms corresponding roughly to program areas in order to provide findings that would be directly relevant to program priority decisions.

Second, four different types of risk were considered for each problem area: cancer risks, noncancer health risks; ecological effects, and welfare effects (such as visibility impairment or damage to materials). Each type of risk was analyzed separately. No one type was deemed

more important than another, and no attempt was made to "add" risks for the problem areas across the four risk types in order to compile aggregate scores.

Third, in view of the already massive scope of the project, participants decided to limit it by not considering risk management aspects of the problems, such as the economic or technical controllability of the risks; the benefits to society of the activities that cause the risks, or the statutory and public mandate (or lack thereof) for EPA to deal with the risks. Further, they decided to exclude the qualitative aspects of the risks that people find important, e.g., the degree to which they may be voluntary, familiar, or equitable.

These decisions about where to limit the scope of the study were carefully considered. To provide a broad guide to EPA priority setting, it was deemed critical to include within the study all the issue areas the agency might address and all types of risk that EPA generally seeks to abate. The study's scope thus includes some areas that are primarily the province of other agencies such as risks from exposure from consumer products, and some areas for which EPA has no clear statutory authority, such as indoor air pollution. The decision to limit the project's scope by not considering the controllability of the risks both made the project more manageable and, by having the results fall short of translating directly into recommended agency priorities, made the project less threatening to participants.

Finally, because the intent of the project was to identify areas of unfinished business for EPA, risks were assessed as they currently exist, given the levels of controls that are already in place. The project did not aim to assess risks that had been abated by EPA's programs or that would be abated by them when full compliance with current regulatory requirements was achieved. By looking at existing or residual risks, project participants gained an idea of what more the agency could aim to accomplish with additional efforts in various program areas, but they did not examine what would be lost if the agency reduced its efforts in these areas. To the extent that priority setting legitimately involves both new investments in some areas and reductions in others, the results of *Unfinished Business* directly inform only the investment decision portion of the process.

The project participants assembled and analyzed masses of existing data on pollutants, exposures, and effects, but ultimately had to fill substantial gaps in available data by using their collective judgment. In retrospect, the project involved more judgement and less objective analysis than was expected. The quantity and quality of available information were worse than was hoped for; in effect, the agency knows in a precise away much less about environmental problems than it should.

In addition to data deficiencies, the work groups had to contend with numerous methodological problems. Standard assessment methods existed for cancer health effects and for welfare effects, but new approaches had to be improvised for ecological risks and noncancer health effects. Difficult questions had to be resolved: e.g., should risks that occur far in the future be discounted relative to those occurring today? Overlaps and inconsistencies were discovered in the list of 31 problem areas: for example, should leachate from a hazardous waste site that contaminates groundwater used for drinking be classified as a hazardous waste problem, a drinking water problem, or both? In reviewing the project three years later, EPA's Science Advisory Board raised other criticisms as well (see EPA (1990)).

Despite these difficulties, participants in the project expressed confidence in their final relative rankings. Although the leaps of judgement and manipulation of limited data were initially very

disturbing for many scientists in the work groups, by the end of the process they felt generally satisfied both with the process they had created to rank the problem areas and with the results.

The major findings of the project are rankings of the 31 problem areas for each of the four types of risk. The rankings are based on risks current at the time of the report (1987), and assume that existing controls stayed in place. The full results are shown in table 1. More generally, one can make several observations about the findings of *Unfinished Business:*

- ◆No problems rank high (or low) in all risk types
- ◆Some problems high on 3 risk types, or at least medium on all four risk types
- ◆Some problems high on health, low on ecological/welfare
- ◆Some problems high on ecological/welfare, low on health
- ◆Some problems high risk/low EPA effort
- ◆Some problems low risk/high EPA effort

Public attitudes about environmental problems, as measured by national surveys of the general population, provide another way of thinking about the importance of different environmental problems. In December 1987 and January 1988 the Roper Organization polled nationwide samples, employing essentially the same list of environmental problems used in *Unfinished Business*. Unlike the EPA experts, however, the subjects in the Roper polls were not limited to considering only "risk" in their assessments. Rather, they were free to consider the full range of intangible effects, concerning both risk assessment and risk management issues, in ranking the seriousness of environmental problems. For a listing of the Roper results and a comparison to *Unfinished Business*, see table 2. In general, the Roper results suggest that the public views the seriousness of environmental problems quite differently than do EPA experts. For example, the public ranked the risks from hazardous waste sites as most serious, whereas the EPA experts ranked such risks as generally low. Conversely, the public ranked the risks from global warming as quite low while the EPA experts ranked them as quite high.

Why the major differences between EPA experts and Roper respondents? The subject of environmental risk, of course, is vast and it is difficult for anyone to have full knowledge of the area. Research has shown that people often overestimate the frequency and seriousness of dramatic and well-publicized causes of death. In contrast, they often underestimate the risks from more familiar, accepted causes that claim lives one by one. The difference between the rankings of experts and those of the general public is, itself, a fascinating issue. It raises many questions about governance, particularly in a democracy. Put simply, should a society focus available resources and technology where they can have the greatest tangible impact on human and ecological health, or should it focus them on those problems about which the public is most upset? While the answer to this question is complex – and certainly beyond the scope of this paper – it is useful perspective when considering questions of comparative risk assessment.

In summary, I emphasize the historical context in which *Unfinished Business* was conducted. Specifically, it was designed to avoid several shortcomings that typify priority setting at EPA.

- ■It was aimed explicitly to compare environmental problem areas with each other. Problems were not addressed in isolation.
- ■The analysis was prospective in nature and was not limited to increments or margins. The residual risks associated with entire problem areas were compared to each other.

- The analysis focused on the ultimate impacts of – so-called environmental results – of environmental problems.
- The analysis was not constrained by statutory, public or political pressures.
- The analysis attempted to make maximum use of the expertise and information within EPA.

Yet it is clear that *Unfinished Business* falls well short of what is needed for a full guide to priority setting. As noted, it dealt with risk assessment and not risk management issues. Thus, potential control actions to mitigate risks were not considered. Notwithstanding this limitation, *Unfinished Business* has served as model for more than fifty separate studies, conducted in the U.S. and abroad, some of which have attempted to validate and extend the basic CRA methodology, and some of which have attempted to include risk management considerations. Two statements by EPA's Science Advisory Board address some of the broader implications of the CRA approach. In its1990 report the SAB stated:

"The value of (Unfinished Business)...rests on the fact that EPA began to see the long-term public policy importance of understanding relative risks."

Also in the same report, the Board observed that:

"There are heavy costs involved if society fails to set environmental priorities based on risk. If finite resources are expended on lower priority problems at the expense of higher-priority risks, then society will face needlessly higher risks. If priorities are established based on the greatest opportunities to reduce risk, total risk will be reduced in a more efficient way, lessening threats to both public health and local and global ecosystems."

3. Benefit Cost Analysis

The U.S.EPA estimates that we devote about $150 billion annually to environmental protection. Certainly the magnitude of these expenditures – on the order of 2 percent of the Gross Domestic Product (GDP) – raises questions about the efficiency and effectiveness of the overall environmental management system. Are we getting good value for our money? Could we do better? Are their specific environmental programs which provide particularly good value for our money? Are there specific programs which provide less value?

The burgeoning field of environmental economics can help answer some of these questions. Specifically, economic analysis can serve as a tool for arraying information about the benefits and costs of environmental policies, and as a mechanism for revealing the cost-effectiveness of alternative approaches. It can also provide an accounting framework for tracking and exploring the implications of environmental decisions.

This section addresses the basic question of how much value we are getting for the resources committed to one particular environmental problem, namely air pollution. The focus is on the aggregate or economy-wide benefits and costs of clean air policies carried out in the U.S. over the past several decades. The methodology and results of a recently completed EPA study, *The*

Benefits and Costs of the Clean Air Act 1970-1990, are reported in some detail as a means of comparing aggregate benefits to aggregate costs, and as a means of comparing particular environmental control efforts to one another.

As noted, the methodology underlying economic analysis of environmental issues, differs in at least two important respects from the CRA approach of *Unfinished Business.* First, by explicitly addressing the costs of reducing risks, economic analysis considers risk management issues. Second, economic analysis treats the results of risk assessment as inputs to the broader question, "what is it worth to society to reduce particular risks?" Whereas CRA seeks to quantify risks in physical terms, or at least develop estimate of relative risks, economic analysis attempts to ask the further question of how society values these different risks. While there is considerable skepticism, especially outside the economics community about the ability of economists to conduct this type of analysis, it is widely practiced in the U.S. and elsewhere. (For a general critique of the strengths and weaknesses of economic analysis, see Morgenstern (1997, especially pages 25-31) and the literature cited therein.)

Economic analysis of environmental programs and policies can serve multiple purposes. It can help allocate resources more efficiently, encourage transparency in decisionmaking, and provide a framework for consistent data collection and identification of gaps in knowledge. Economic analysis also allows for the aggregation of many dissimilar effects, e.g., improvements in health, visibility, and agricultural output, into one measure of net benefits expressed in a single currency. Economic analysis can help policymakers identify interventions that generate more benefits than costs and assist them in choosing the best intervention from among those that do.

Environmental policies can improve human health, increase output of forests and other natural resources, reduce corrosion or soiling of economic assets, and enhance recreational and other environmental assets. A taxonomy, incorporating broad categories of environmental benefits, is shown in Table 3. Some environmental benefits, e.g., increased output of forests, are measured in commonly used indicators of economic activity, for example, the gross domestic product (GDP). Other benefits are the non-market, welfare-enhancing type that typically are not represented in the GDP, for example, improved human health or greater biodiversity. It is estimated that more than 90 percent of the environmental benefits of the Clean Air and Clean Water Acts are of the non-market, welfare-enhancing type not represented in the GDP (Freeman (1982)). Although researchers are trying to develop comprehensive measures of economic activity that capture a broad set of environmental benefits (and costs), for example, "green GDP," there are strong theoretical and practical reasons for excluding such welfare-enhancing benefits from a commonly used measure of economic activity like GDP. Yet no one doubts that human welfare -- rather than GDP -- is what societies are ultimately concerned with. The fact that such welfare-enhancing benefits are difficult to value and often involve specialized terminology and measurement techniques does not mean that they are any less valuable than those benefits that are measured by the GDP.

The estimation of costs can be as difficult an undertaking as the estimation of benefits -- a fact not often appreciated by even the most knowledgeable practitioners in the field. For example, the most commonly used measure of environmental costs is reported out-of-pocket expenditures for regulatory compliance. However, this is a narrow measure that may either under- or overstate true compliance costs. On the one hand, the omission of items like legal expenses and diverted

management focus suggests that reported out-of-pocket expenditures would tend to understate total compliance costs. On the other hand, failure to account for improved worker health or increased innovation tends to overstate total compliance costs. Table 4 contains a taxonomy of environmental compliance costs borne by the private sector, including firms and households, and all levels of government, including the EPA. The reader should note, however, that the cost estimates reported in this paper generally represent reported out-of-pocket expenditures for regulatory compliance. Depending on the importance of the other (often less well measured) cost items listed in table 4, reported compliance costs may under or overstate total compliance costs.

Given this brief introduction to environmental benefits and costs, we now may turn to our basic question, namely, what do we know about the overall health, welfare, ecological and other benefits of the Clean Air Act and how do these benefits compare with estimated costs? Can we apply an economic framework to determine whether we are getting value for our money? To parallel *Unfinished Business*, can we make these judgments about specific program elements of the Clean Air Act, not just the whole?

In a major study Freeman developed the first and - until quite recently - the only comprehensive benefit-cost analysis of the Clean Air Act (Freeman, 1982). His study was controversial upon publication because it involved a great many assumptions - some would say "leaps of faith" - and attempted to reduce a complex set of issues to a few numbers. One of the key issues in such studies is the question of the baseline: what would ambient air conditions have been in the absence of federal legislation? Ideally, one would compare environmental quality levels with and without the federally mandated controls, holding all other things constant, including the patterns of production, technology, and demand for goods and services which, in turn, determine the generation of pollutants. Such a measure should compare an observed outcome resulting from the policy with a hypothetical or counter-factual position reflecting the same underlying economic conditions and differing only with respect to the impact of the environmental policy. Unfortunately, data and resource limitations prevented Freeman from making such a comparison in his original study. Instead, he measured the benefits of air pollution by examining the actual improvements in air quality observed between 1970 and 1978. As Freeman notes, such measures are likely to underestimate the true benefits because they fail to account for the significant economic growth over the period.

Table 5 presents Freeman's results for air pollution benefits and costs in 1978 (converted to 1995 dollars). Total benefits of the air pollution program range from $12.3 to $123.3 billion with what Freeman calls a "most reasonable" point estimate of $49.1 billion. Overall, more than 75 percent of the benefits are health related. Costs of the air pollution program are estimated to be $35.0 billion. Freeman concludes that, taken as a whole, it is highly likely that air pollution control has been worthwhile on benefit-cost grounds.

Drawing on the sizable body of research conducted in the intervening years, a recent EPA study expands on Freeman's original work. Like Freeman's estimates, the new study synthesizes and integrates a large body of information derived from the scientific and economics literatures. The EPA study, which was mandated by Congress as part of the 1990 Air Act Amendments, assesses the benefits and costs of the Clean Air Act, 1970-1990. It was developed by EPA in conjunction with a Congressionally mandated panel of distinguished economists and scientists from outside the government.

The new EPA study updates the Freeman methodology by developing and comparing two scenarios as a basis to evaluate progress under the Clean Air Act: "control" vs. "no-control." The "no control" scenario essentially freezes federal, state, and local air pollution controls at levels of stringency and effectiveness which prevailed in 1970 and attributes the benefits and costs of air pollution controls from 1970-1990 to federal law. In all likelihood, state and local regulation would have required some air pollution controls even in the absence of the Clean Air Act. Certain states, e.g., California, might have required very tight controls. It is also likely that industry would have acted on its own to reduce at least some of its emissions. If one assumed that state and local regulations would have been equivalent to federal regulations then a benefit-cost analysis of the federal clean air act would be a meaningless exercise: the incremental benefits and costs of any federal initiatives would equal zero. On the other hand, any attempt to predict how states' and localities' regulations or voluntary efforts would have differed from the Clean Air Act is extremely speculative. Thus, the freezing of emissions at 1970 emission rates is a reasonable, albeit unrealistic, assumption. Both the "control" and "no control" scenarios are evaluated by a sequence of economic, emissions, air quality, physical effect, economic valuation, and uncertainty models to estimate the benefits and costs of the Act. The analytical sequence incorporating these various steps is shown in figure 1. The air quality modeling involves a number of key issues worthy of mention. For sulfur dioxide, nitrogen oxides, and carbon monoxide, improvements in air quality under the control scenario are roughly proportional to the estimated reduction in local area emissions. In contrast, differences in estimated ground level ozone concentrations vary significantly from one location to another, because of local differences in the relative proportion of VOCs and NOx, and weather conditions. Many pollutants contribute to ambient concentrations of particulate matter and, in fact, specific sources vary according to region, urban vs. rural, and other factors. From a human health standpoint, fine particles, which can be respired deep into the lungs, are the greatest concern. Many of these fine particles are formed in the atmosphere through chemical conversion of gaseous pollutants. They are referred to as secondary particles. The three most important secondary particles are (1) sulfates, which derive primarily from sulfur dioxide emissions, (2) nitrates, which derive primarily from nitrogen oxides emissions, and (3) organic aerosols, which can be directly emitted or can form from volatile organic compound emissions.

The total estimated improvements in air quality across the country compared to baseline were substantial: 40 percent reduction in sulfur dioxide, 30 percent reduction in nitrogen oxides, 50 percent reduction in carbon monoxide, 15 percent reduction in ozone and about 45 percent reduction in particle concentrations (including both directly emitted and secondary particles). Human health effects or benefits are derived by combining air quality improvements with estimates of dose-response functions derived from the scientific literature. Table 6 presents selected health benefits of the Clean Air Act 1970-1990, in thousands of cases reduced per year. The mid-range estimates of reduced mortality, for example, show that in 1975 the air pollution controls in place reduced premature deaths attributable to airborne particles (PM10), ozone, sulfur dioxide, and lead by an estimated 20,000 cases. By 1990 the corresponding number of premature deaths avoided stood at 79,000. Similarly, the mid-range estimate for heart attacks avoided rose from 1,000 in 1975 to 18,000 in 1990, largely due to the reduction of lead in the environment.

To develop estimates of economic benefits it is necessary to translate these physical effects into dollar terms. This is often the most contentious aspect of any benefit-cost analysis. Table 7 displays the economic values, drawn from the economics literature, used in the EPA study. Heart attacks and reduced IQ points, for example, are valued at $587,000 per case, and $5500 per point, respectively. In the case of mortality it is not possible to "value" the lives of victims in a benefit-cost sense. One can, however, determine the compensation required for individuals to accept relatively small reductions in mortality risk. Typically, they are inferred from observed behavior, for example, sales of safety devices such as smoke detectors, or wage differentials associated with high risk occupations. For expository purposes this valuation is expressed as "dollars per life saved" even though the actual valuation is really based on small changes in mortality risk. The estimate of $4.8 million per life saved represents an average value from the literature.

The total monetized economic benefit attributable to the CAA was derived by applying the valuation estimates discussed above to the complete stream of physical effects calculated for the 1970-1990 period. In developing these estimates, steps are taken to avoid the double counting of benefits and costs. EPA reports that the estimated benefits of the Clean Air Act realized during the period from 1970 to 1990 range from $5.6 to $49.4 trillion, with a central estimate of $22.2 trillion. By comparison, the value of direct compliance expenditures over the same period equals approximately $.5 trillion. Comparing central estimates, Americans received roughly $45 of value in reduced risks of death, illness, and other adverse effects for every one dollar spent to control air pollution. Thus, taken as a whole, the benefits of the Clean Air Act clearly outweigh the costs. As noted in the study, "...even considering the large number of uncertainties permeating each step of the analysis, it is extremely unlikely that the converse could be true." (EPA (1997), page ES-11).

A result of this sort stimulates many questions, e.g., what specific regulations account for the most benefits? How do the net benefits of recently promulgated regulations compare to those of older regulations? While the EPA study methodology does not allow one to answer such questions directly, a number of comparisons are possible. Table 8 displays benefits by endpoint category. Note that PM mortality alone accounts for three-fourths of the total benefits. Lead mortality benefits are also quite substantial. At first glance this might suggest that direct control of particulate matter and lead are virtually the only important actions taken under the Clean Air Act, 1970-1990. Yet, the situation is not that simple. For example, secondary particles, which have been associated with premature mortality, account for a large portion of the total benefits. As noted, these particles are formed in the atmosphere from SO2, NOx and VOC emissions which, in turn, are governed by multiple EPA regulations, including those affecting existing as well as new sources. Thus, one cannot say with confidence that the calculated PM benefits derive strictly from regulations explicitly aimed at controlling particles. Some of the calculated PM benefits are clearly associated with these broader control efforts.

Nonetheless, it is clear from this review of *The Benefits and Costs of the Clean Air Act 1970-1990* that even though the costs were not separated out by program element, the efforts to control PM, including PM precursors, and lead are probably the most cost-beneficial elements of the Clean Air Act. Critics will note that not all the program elements of the Clean Air Act were quantified for this study. This is certainly the case and the report clearly makes that point.

However, given the overwhelming magnitude of the PM and lead benefits, it would take a truly extraordinary estimate of benefits from other programs to overturn this basic conclusion.

Overall, it is clear that benefit-cost analysis of the type described here is getting more attention than ever before from the US Congress and the public. Yet, like CRA – and probably more so – benefit-cost analysis still engenders considerable controversy. Some of the controversy stems from the imprecision of the questions themselves, e.g., what do "value" and "cost" really mean in the context of environmental health or natural resources? Other controversy stems from differences in methodology of various empirical studies used to quantify the sometimes-abstract concepts involved in applying economic analysis to environmental issues. While benefit-cost analysis provides another lens, and a quite different lens from CRA, on the issue of "what's important?", it is obvious that there is no "correct" answer. Instead, there is a continuing search for a clear and consistent method for comparing and evaluating environmental issues. This search is likely to go on for some time. The two approaches addressed in this paper should be seen as part of evolving story. It is easy to say, as Winston Churchill said about democracy, that it has many flaws. But it is hard to see what a better system would look like.

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Table 1:Summary of Results from EPA *Unfinished Business* Report

No problems rank relatively high in all four types of risk or relatively low in all four. Whether an environmental problem appears large or not depends critically on the type of adverse effect with which one is concerned.

Problems that rank relatively high in three of four risk types, or at least medium in all four include:

criteria air pollutants from mobile and stationary sources (includes acid precipitation).
stratospheric ozone depletion
pesticide residues on food
- runoff and air deposition of pesticides ("other" pesticide risks)

Problems that rank relatively high in cancer and noncancer health risks but low in ecological and welfare risks include:

- hazardous/toxic air pollutants
- indoor radon
- indoor air pollution other than radon
- drinking water as it arrives at the tap
- pesticide application
- exposure to consumer products
- worker exposures to chemicals

Problems that rank relatively high in ecological and welfare risk, but low in both health risks include:

- global warming
- point and non-point sources of surface water pollution
- physical alteration of aquatic habitats (including estuaries and wetlands) and mining waste

Problems related to ground water consistently rank medium or low, principally,

- active hazardous sites (RCRA)
- inactive hazardous waste sites (Superfund)
- municipal non-hazardous waste sites
- industrial non-hazardous waste sites
- underground storage tanks

Other major categories of environmental problems, receiving generally mixed and/or medium/low rankings included:

- contaminated sludge
- mining waste
- accidental releases - toxic chemicals
- accidental releases - oil spills
- new toxic chemicals
- biotechnology (environmental releases of genetically altered materials)

Table 2.: How the Public Ranks Environmental Problems

Data drawn from polls conducted by the Roper Organization, Inc., 1984 6, and analyzed by EPA.

Public Perception of Risk and Ranking	Roper Area	Corresponding EPA Environmental Problem Area
High	1. Chemical waste disposal	Hazardous waste sites - active Hazardous waste sites - inactive
	2. Water pollution	Direct point source discharges Indirect point source discharges Nonpoint source discharges
	3. Chemical plant accidents	Accidental releases - toxics
	4. Air pollution	Criteria air pollutants Hazardous air pollutants
Moderate	5. Oil tanker spills	Accidental Releases - oil spills
	6. Exposure on the job	Worker exposure
	7. Eating pesticide-sprayed food	Pesticide residues on foods
	8. Pesticides in farming	Application of pesticides "Other" pesticide risks
	9. Drinking water	Drinking water
Lower	10. Indoor air pollution	Indoor air pollution
	11. Indoor air pollution	Consumer product exposure
	12. Genetic engineering	Biotechnology
	13. Strip mining	
Mining waste	-	
	14. Non-nuclear radiation	Radiation - other than radon
	15. The"greenhouse" effect	
CO2 and global warming		

Table 3: Taxonomy of Environmental Benefits

To Individuals
Mortality
Morbidity (acute, chronic)
To Production/Consumption
Crops/Forests/Fisheries
Water-Using Industries
Municipal Water Supply
To Economic Assets
Materials (corrosion, soiling)
Property Values
To Environmental Assets
Recreation
Other use values (visibility)
Nonuse (passive use)

Table 4: A Taxonomy of Environmental Costs

Government Administration of Environmental Statutes and Regulations
Monitoring
Enforcement
Private Sector Compliance Expenditures
Capital
Operating
Other Direct Costs
Legal and Other Transactional
Shifted Management Focus
Disrupted Production
Offsetting Benefits
Resource Inputs
Worker Health
Increased Innovation
Economy-Wide Effects
Product Substitution
Discouraged Investment
Retarded Innovation
Transition Costs
Unemployment
Obsolete Capital
Social Impacts
Loss of Well-Paying Jobs
Economic Security Impacts

Source: Adapted from Jaffee, et al.(1995), page 139.

Table 5: Air Pollution Control Benefits and Costs in 1978 (in billions of 1995 dollars)

Category	Range	Most Reasonable	Point Estimate
<u>Benefits</u>			
Health			
Mortality	5.9 – 59.5	29.3	
Morbidity	0.6 - 26.2	6.5	
Soiling and Cleaning	2.1 - 12.7	6.3	
Vegetation	0.2 - 0.8	.6	
Materials	1.6 – 5.3	1.5	
Property Values	<u>1.9 – 18.8</u>	<u>4.9</u>	
Total	12.3 – 123.3		49.1
<u>Costs</u>			35.0

Source: Freeman (1982), page 128.

Table 6: Selected Health Benefits of the CAA, 1970-1990 (in thousands of cases reduced per year, except as noted)

Health Effect		1975	1980	1985	1990
Mortality	High	38	97	124	140
(PM_{10}, O_3, SO_2, Pb)	Mid	20	54	70	79
(thousands)	Low	11	30	40	45
Heart Attacks	High	1	9	19	24
(Pb)	Mid	1	7	14	18
(thousands)	Low	1	5	10	13
Strokes	High	1	5	10	13
(Pb)	Mid	1	4	8	10
(thousands)	Low	1	3	6	7
Respiratory symptoms (SO_2) (thousands)		66	187	165	146
Respiratory illness (NO_2) (millions)		1	4	9	15
Hypertension	High	1	6	12	16
(Pb)	Mid	1	5	10	13
(millions)	Low	1	4	8	10

Source: U.S. EPA, "The Benefits and Costs of the Clean Air Act, 1970 to 1990," Draft Report, April 1997.

Table 7: Central Estimates of Economic Value per Unit of Avoided Effect (in 1995 dollars)

Endpoint	Valuation (mid-estimate)
Mortality	$4,800,000 per case
Heart Attacks	$587,000 per case
Strokes	$587,000 per case
Hospital Admissions	
Respiratory	$7,500 per case
Ischmic Heart Disease	$10,000 per case
Congestive Heart Failure	$8,000 per case
Respiratory Illness and Symptoms	
Upper Respiratory Illness	$18 per case
Lower Respiratory Illness	$10 per case
Acute Bronchitis	$45 per case
Acute Respiratory Symptoms	$17 per case
Work Loss Days	$83 per day
Restricted Activity Days	$38 per day
Asthma Attacks	$32 per case
IQ Changes	
Lost IQ Points	$5,550 per IQ point
Incidence of IQ < 70	$52,700 per case
Hypertension	$682 per year per case
Decreased Worker Productivity	Direct Economic Valuation
Visibility	Direct Economic Valuation
Household Soiling	Direct Economic Valuation
Agriculture (Net Surplus)	Estimated Change in Economic Surplus

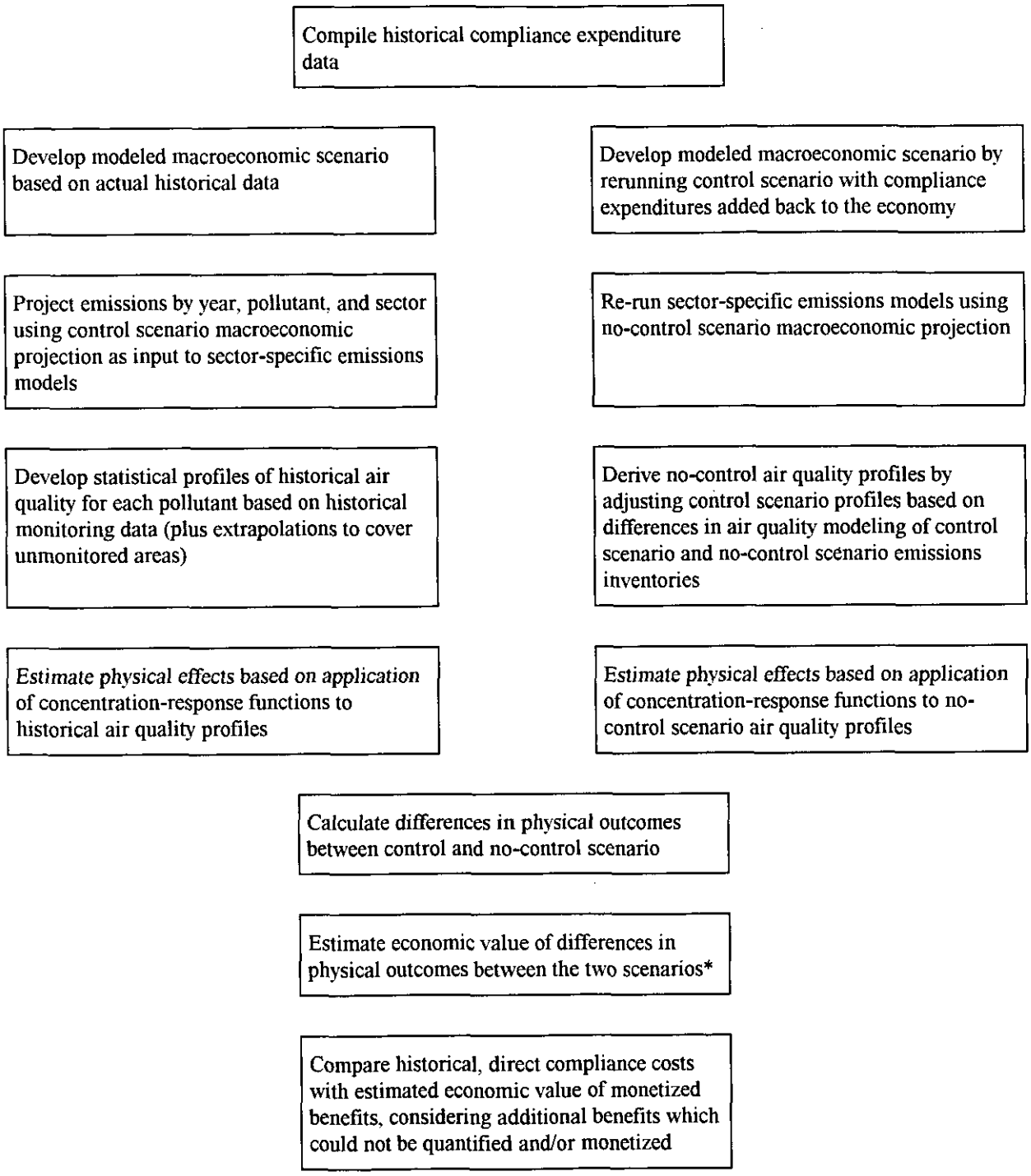
Source: U.S. EPA, "The Benefits and Costs of the Clean Air Act, 1970 to 1990," Draft Report, April, 1997.

Table 8: Total Monetized Benefits by Endpoint Category for 48 State Population for 1970 to 1990 (in billions of 1990 dollars)

Endpoint	*Pollutant(s)*	*Present Value*		
		5th%ile	*Mean*	*95th %ile*
Mortality	PM-10	$2,369	$16,632	$40,597
Mortality	Pb	$ 121	$ 1,339	$ 3,910
Chronic Bronchitis	Pb	$ 409	$ 3,313	$10,401
IQ (Lost IQ Pts + Children w/IQ<70	Pb	$ 271	$ 399	$ 551
Hypertension	Pb	$ 77	$ 98	$ 120
Hospital Admissions	PM-10, O3, Pb & CO	$ 27	$ 57	$ 120
Respiratory-Related Symptoms, Restricted Activity and Decreased Productivity	PM-10, O3, NO2 & SO2	$ 123	$ 182	$ 261
Soiling Damage	PM-10	$ 6	$ 74	$ 192
Visibility	Particulates	$ 38	$ 54	$ 71
Agriculture (Net Surplus)	O3	$ 11	$ 23	$ 35

Source: U.S. EPA, "The Benefits and Costs of the Clean Air Act, 1970 to 1990," Draft Report, April, 1997.

Figure 1. Summary of Analytical Sequence and Modeled versus Historical Data Basis



* In some cases, economic value is derived directly from physical effects modeling (e.g., agricultural yield loss).