BENEFIT-COST ANALYSIS: DO THE BENEFITS EXCEED THE COSTS?[1]

LESTER B. LAVE

DECEMBER 1991

[1]I thank Robert Axtell, Hadi Dowlatabadi, Carol Goldburg, Robert Hahn, Ben Harrison, Mark Kamlet, Daniel Nagin, Tom Romer, Kenneth Small, and Richard Zeckhauser for comments.

CITATION AND REPRODUCTION

This document is a Project Report within the Center for Science and International Affairs, Environment and Natural Resources Program Paper Series. It appears as contribution P-91-04 in the Project 88/Round II series of the Center's Environment and Natural Resources Program. Comments are welcome and may be directed to the author in care of the Center.

This paper may be cited as: Lester B. Lave, Carnegie-Mellon University, "Benefit-Cost Analysis: Do the Benefits Exceed the Costs?" ENRP Project 88/Round II Project Report 91-04, Kennedy School of Government, Harvard University.

The views expressed in this paper are those of the authors and publication does not imply their endorsement by CSIA and Harvard University. This paper may be reproduced for personal and classroom use. Any other reproduction is not permitted without written permission of the Center for Science and International Affairs, Publications, 79 JFK Street, Cambridge, MA 02138, telephone (617) 495-1351 or telefax (617) 495-1635.

PROJECT 88

Project 88/Round II focuses on the design and implementation of incentive-based environmental policies in three areas: global climate change; hazardous and solid waste problems; and resource management issues. The project includes a seminar series, a set of policy workshops, public policy reports, and student internships. Project 88/Round II is sponsored by CSIA's Environment and Natural Resources Program, Henry Lee, Executive Director. Financial support is provided by the W. Alton Jones Foundation, the Pew Charitable Trusts, the Surdna Foundation, and the U.S. Environmental Protection Agency. This series of Discussion Papers consists of revised versions of papers presented at the seminar series. For a copy of the full report of Project 88 or Project 88/Round II, contact: Professor Robert Stavins, John F. Kennedy School of Government, Harvard University, 79 John F. Kennedy Street, Cambridge, MA 02138 (617-495-1820).

Project 88 Chairmen

Senator Timothy Wirth, Colorado
Senator John Heinz, Pennsylvania

Project Director

Robert N. Stavins
Assistant Professor of Public Policy
Senior Research Associate, CSIA

Project 88/Round II is dedicated to the memory of Senator John Heinz and his vision of improving environmental policy through the application of economics.

"To carry out benefit-cost analysis, what must an individual believe about its scope? The short answer to this question is, 'Very little, if one puts it only to very little use.' In contrast, if a person thinks benefit-cost analysis can be a powerful tool of policy assessment, then he or she must have fairly powerful beliefs about what can come within its scope." (Railton, 1990, p57)

Many economists see benefit-cost analysis as a rational, analytic tool that is neutral in its values. They assert that benefit-cost analysis is essential for complicated social issues. Our eloquence about the value of this framework has enabled us to convince Congress to write benefit-cost analysis into various laws and convinced President Reagan to embrace it. The currently operational requirement for executive branch agencies is Executive Order 12291, requiring a benefit-cost analysis of any "major" regulation.

Despite the objections of "unenlightened" environmentalists, political scientists, ethicists, and others, we economists believe that social decisions should be subject to benefit-cost analysis and that the analysis identifies, at least approximately, the social optimum. Economists at the Office of Management and Budget terrorize those who cannot produce analyses with positive net benefits (see Clark et al, 1980).

"Labor unions and environmental, consumer, and other 'public interest' groups strenuously resist the notion that agencies should be forced to submit their actions to a cost-benefit test. They contend, not without reason, that while costs can be measured with a degree of accuracy, benefits are not so easily measurable. A cost-benefit requirement, they fear, would focus attention on costs without commensurate attention to relatively unquantifiable benefits" (Clark, et al, 1980, p4; see Green. 1980 for a critique).

The problems go far beyond a focus on costs. Benefit-cost advocates are, often unwittingly, relying upon a Pandora's box of utilitarian ethical beliefs as well as assumptions about the quality of current methods. If these assumptions were examined carefully, most would be rejected. We are perpetrating a fraud on ourselves and decision makers with our unqualified claims about what conclusions can be drawn from our analyses.

Benefit-cost analysis can be an extraordinarily valuable tool for policy analysis. Before it can fulfill its potential, however, economists must strip the tool of the remnants of utilitarian doctrines that we don't believe, recognize the inherent biases, and learn to interpret the outcomes of the analysis. What remains is a much less powerful tool, but a tool worthy of our confidence.

I begin this paper with the case for using benefit-cost analysis to help illuminate public policy regarding environmental issues. I then go on to a critique of formal benefit-cost analysis. The problems are divided between fundamental issues of theory and implementation, both conceptual and practical. The foundation of benefit-cost analysis is flawed; the tool cannot provide what some economists claim. The practical difficulties are even greater. Even if the framework were best when implemented by a master with unlimited time and resources for analysis, it is a problematic tool in practice when resources are extremely limited, time is short, and the analyses are being done by people with little training or experience. Finally, I examine how benefit-cost analysis is used in the political arena.

I. The Case for Benefit-Cost Analysis

Texts (Mishan, 1982; Sassone and Schaffer, 1978; Stokey and Zeckhauser, 1978) praise benefit-cost analysis because it:

1. Encourages a systematic statement of the goals to be accomplished.
2. Encourages analysts to identify and evaluate a wide range of options for accomplishing the stated goals.
3. Is a systematic, analytic approach that attempts to explore the implications of each option.
4. Requires the analyst to confront the tradeoffs among options, both at the detailed level for each individual dimension and at the aggregate level in terms of total expenditures.
5. Encourages a search for externalities and an evaluation of those that have been identified.
6. Focuses on the allocation of benefits and costs over time and translates them to a single time period.
7. Seeks to accomplish the stated goals at least cost.
8. Can be used to identify the data and analyses of importance.
9. Can be used to specify a research and development agenda to provide important data not currently available.
10. Seeks to isolate and quantify social interest, not self interest.

11. Recognizes that there are desirable and undesirable aspects of each situation and characterizes these as "benefits" and "costs."

12. Encourages objective, value free analysis.

13. Identifies the option with the greatest net benefit, which is described as the one that is best for society.

Benefit-cost analysis can be thought of as an "accounting framework" for exploring social decisions by some textbook authors. Theorists tend to see it as an optimizing tool that maximizes social welfare. I have ordered the descriptions from those needed for an accounting framework to those needed for the tool to optimize social welfare. The first six assumptions characterize an accounting framework that can be extremely helpful in examining social decisions. Attribute 7 sharpens the economic focus by introducing a goal that might not be stated in attribute 1: cost-effectiveness. Attribute 10 adds a further goal, the social interest. Having defined a social goal, "benefits" and "costs" can be defined. Attribute 12 is a myth widely believed among benefit-cost analysts; unfortunately, the analysis cannot be value free, as shown below. Attribute 13 is true, as Railton (1990) points out, only under stringent assumptions.

Executive Order 12291 assumes that all 13 attributes are correct. In requiring benefit-cost analysis for every major regulatory decision, it assumes that the first six attributes are true (and the analysis is not costly). In requiring that the option with the greatest net benefit be chosen (unless precluded by law), it assumes the validity of all 13 attributes.

Reagan's advisers praised both the accounting framework and optimizing roles of benefit cost analysis. For example, Miller (1989) asserts that the best way to get some discipline and analysis into regulatory agencies that were "out of control" is benefit-cost analysis. Just having to go through the steps of a benefit-cost analysis should prove enlightening for agencies that don't normally use this tool. Miller (1989, p 91) also defends the optimizing role: "Executive Order 12291... is no more than common sense ... Of course, the way an agency has estimated the benefits and costs can be disputed in particular cases...Without some check, like that provided by President Reagan's executive order, regulatory decision makers might be tempted to pander to such moralism [that disdains rational analysis] -- or to other special interests." Miller sees benefit-cost analysis at the bulwark against moralism and special interests.

As an accounting framework, benefit-cost analysis satisfies the government's need for a systematic approach to policy issues. While an individual might be satisfied with an emotional or ad hoc response, a governmental agency cannot rely on such an informal analysis. The Administrative Procedures Act, which defines the procedures that must be followed by all regulatory agencies, requires that agencies hold public hearings and listen and respond to public suggestions and complaints concerning their proposed regulations. Congress is inundated with emotional or ad hoc responses; benefit-cost analysis stands apart from these because of the framework and systematic analysis. If it is not done with care, why should benefit-cost analysis deserve greater confidence than other unsystematic reactions?

As shown below, except under assumptions that seem indefensible, benefit-cost analysis has no claim to being a tool that maximizes social welfare. But even economists who argue that benefit-cost analysis is merely an accounting framework misuse the tool. First, they assume that the analysis either is value free or that they have accounted for differences in values, a claim shown to be false below. Second, whatever they say, these economists don't interpret the outcome of the analysis in innocuous terms. Rather they focus on the alternatives with positive net benefits and tend to dismiss alternatives with negative net benefits. In practice, economists act as if an estimate that the net benefits are large or even positive is a conclusion to be relied upon, despite their acknowledgment of objections to the methods and estimates.

Laurence Tribe dismisses benefit-cost analysis in hostile terms, claiming that analysts have an ideological bias, even though they claim to be operating in the public interest: "...ideology has often sought to masquerade as analysis, deriving a power it could never justify claim from the garb of neutrality it has at times contrived to wear." (Tribe, 1973, p 3).

II. Fundamental Problems with Benefit-Cost Analysis

A. Must Compensation Actually Be Paid?: The claim that benefit-cost analysis maximizes social welfare is vitiated by a fundamental problem. In few social decisions is one alternative Pareto superior to others (no one is worse off and at least one

person is better off). But, if some people lose, the option with the greatest net benefit cannot be said to be socially preferred, based on the Pareto criterion. If benefit-cost analysis cannot discern whether one option is superior to another, it is much less valuable.

Some of the best economic minds have attempted to overcome the difficulty. Kaldor and Hicks proposed criteria in 1939: Proposal A is superior to B if the winners could bribe the losers and still be better off and if the losers couldn't bribe the winners and still be better off. However, if the compensation is not actually paid, the Kaldor-Hicks criteria can lead to outcomes that all reasonable people would reject. Consider a project that would have the king of Saudi Arabia gain $50 billion, but would cost every American whose income is below the subsistence level $100. This project certainly passes the Kaldor-Hicks test, since the king could afford to bribe the poor Americans and still be better off. Assuming it is impractical to compensate the losers however, few economists would think that this project increases social welfare. The Kaldor-Hicks criteria implicitly assume that a dollar of benefit is fungible and that a dollar of cost is pretty much independent of who bears it. These assumptions seems ludicrous and don't predict the operation of political systems.[2] Since it isn't practical to pay compensation, they argue that the Kaldor-Hicks criteria is preferable to "pure politics." However, they neglect other options, such as taking no government action.

---

[2]Still another difficulty isthat people confuse what they have with what they can expect to getunder some new proposal. Insofar as people act as if their prospective gains from some deal are "money in the bank" compensation may not be possible. For example, people might take the status quoto be a pristine environment, since that is to result from existing legislation, rather than the terrible environmental quality actually prevailing.

The Leonard-Zeckhauser Defense: Leonard and Zeckhauser (1986) defend the Kaldor-Hicks criteria on different, but still mistaken grounds. They concede that "It would of course be preferable to carry out the compensation..." (Leonard and Zeckhauser, 1986, p33).

They propose a Rawlesian contractarian argument concerning the class of all mechanisms that might be used to decide public policy. "What mechanisms for making decisions would individuals choose if they had to contract before they knew their identities in society or the kinds of problems they would confront? Our answer is that, on an expected-value basis, cost-benefit analysis would serve them best and hence would be chosen" (Leonard and Zeckhauser, 1986, p 33). Unfortunately, this argument rests on several assumptions: (1) Benefit-cost analysis is the (only) efficient decision framework, (2) benefit-cost analysis can be applied to essentially any social decision, and (3) the values of the analyst are not important in determining the outcome of the analysis.

Is Benefit-Cost Analysis the Most Efficient Decision Framework?: Interesting social issues are fraught with ignorance and uncertainty. Rarely can the uncertainty be handled by adding a random error (with mean zero) to the correct answer. Often, important issues are ignored (because they can't be quantified) or missed, e.g., current attempts to do a benefit-cost analysis of controlling emissions of greenhouse gases to arrest global climate change. The uncertainties here are so fundamental that the implications of global warming are largely unknown (National Research Council, 1991; Lave, 1991). Quantitative and qualitative uncertainties are so pervasive in "interesting" (non trivial) social issues that the assertion of efficiency has no foundation.

Should All Issues Be Decided By Benefit-Cost Analysis? The range of issues to which benefit-cost analysis is applied is a second difficulty. Consider whether to confiscate Zeckhauser's property (in order to pay tribute to Saddam Hussein) and transform Leonard from professor into a kamakazi pilot (for an attack on Grenada). While they might believe

that estimated costs will exceed estimated benefits, Leonard and Zeckhauser are unlikely to agree to submit these proposals to benefit-cost analysis.

Some people object to benefit-cost analysis of mandatory seat belt use while others object to using benefit-cost analysis to set health and safety standards. If one sees an issue primarily in efficiency terms, benefit-cost analysis might be the best decision framework. If instead the issue is seen in ethical or similar terms, benefit-cost analysis is anathema.

The Role of the Analyst's Values: Subjecting Zeckhauser's property and Leonard's life to benefit-cost analysis may seem absurd. However, these proposals are analogous to the way that pacifists see analyses of defense expenditures, environmentalists see analyses of new dams and canals, and urban planners see analyses of new highways. Those with views and values different from the analyst see benefit-cost analysis as an absurd, illogical, inconsistent ritual (see Wildavsky, 1966), e.g., quantifying the dollar value of preventing the extinction of the snail darter. While minorities might find benefit-cost analysis better than autocratic rule, they certainly don't welcome it. The dissident minority would prefer having a constitution that limits the scope of government activities (obviating the need for a benefit-cost analysis). They want to place many questions outside the scope of benefit-cost analysis and the majority values that would victimize them systematically.

In particular, since benefit-cost analysts need economic training, and since graduate students in economics either self-select based on a belief in the market mechanisms or find it difficult to pass the courses if they don't share this view, there is an inherent bias that

can be expected to emerge from benefit-cost analyses. Environmentalists are correct in asserting that benefit-cost analysis is biased against their views.

This point has a more subtle implication. Suppose that the values of the benefit-cost analyst were quite different from mine. If so, the recommendations are likely to make no sense to me. My benefit-cost analysis would lead to a preferred outcome (the one with the greatest net benefit) quite different from that derived by the official analyst. If benefit-cost analysts have a wide range of values, I might be better off by choosing an alternative analysis framework or by choosing to have no collective action.[3] In short, the contractarian argument suggested by Leonard and Zeckhauser is an interesting idea, but their assertion is mistaken.

The Trumbull Defense Trumbull (1990) defends benefit-cost analysis and the use of the Kaldor-Hicks criteria on the grounds that they utilize the affected individuals' own valuation of the gains and losses. All economists would agree that individuals' valuation is a legitimate, even important input to the decision. Does a benefit-cost analysis reflects individuals' preferences if compensation is not paid? People have preferences concerning the distribution of income, particularly when some individuals are paying and not benefiting. In arguing that the Kaldor-Hicks criteria is a sufficient basis for judging a policy to be superior, Trumbull, Leonard and Zeckhauser, and others are asserting implicitly that the social preferences with respect to income redistribution can be ignored. That is true for projects

[3]Still another approach to rescuing benefit-cost analysis has been the attempt to find special conditions under which superiority can be asserted without having to pay compensation (Small, 1987). This work has not produced interesting results.

where the redistribution is small and from rich to poor; it isn't likely to be true where the distribution is from poor to rich and the effects are nontrivial.

Not compensating losers poses subtle difficulties. The magnitude, and even the sign, of benefits and costs depends on the level and distribution of income. If income is concentrated in the hands of those who value boating and swimming, a willingness to pay measure will favor damming a river. If income is concentrated in the hands of those who value wildlife and undisturbed nature, a benefit-cost analysis is likely to find negative net benefits for the dam. A project that has a large effect on the income distribution could give rise to contradictory outcomes depending on whether the ex ante or ex post distribution is used.

Zerbe (1991) proposes a modified Kaldor-Hick criteria: Calculate the least expensive way to pay compensation. If benefits still exceed costs, the project has a net social benefit, even if compensation isn't paid. However, short of actually paying compensation, none of these proposals work. For example, assume the cost of compensating individuals for the lost $100 is $120. If so, the King of Saudi Arabia could compensate every individual who lost and still be better off. Nonetheless, unless the compensation is actually paid, Zerbe's criterion only tells us that benefits exceed costs by more than a small amount. That information would not change my judgment that the proposal is objectionable -- unless compensation is actually paid.

Although economists have labored long and hard to find a way around having to pay compensation and make everyone better, we have failed. Many economists have known this for some time, although the profession continues to perform benefit-cost analysis and to place

great confidence in the alternative (s) with the greatest net benefit. In doing so, they are implicitly embracing utilitarianism and myths about the neutrality of economic analysis.

B. What Is Wrong with Being a Utilitarian?

"May you be governed by utilitarians!" Think of living in a society governed by a benevolent despot who works hard to "provide the greatest good for the greatest number." If you have a Ph.D in economics from an American university, your heart probably warms to this prospect.

Achieving the "greatest good for the greatest number" defines a relative, in contrast to an absolute morality. In a relative morality, no Bible or constitution guarantees free speech or praises honesty and self-sacrifice, while condemning theft and murder (Kelman, 1981; 1982). Zerbe (1991) gives the example of a crowd wishing harm to someone because of his race. The utility of the crowd for seeing the man beaten might be greater than the disutility to the victim. Few people would want to live in a society where you might be beaten or killed because the sum of utilities "for" was greater than the sum of utilities "against."

One way of dealing with this objection is to ask whether the utility of society would be higher if this behavior were forbidden in general, rather than subject to evaluation in each case. Thus, a utilitarian society could arrive at rights, although they would still be relative, not absolute. These rights would be subject to a continuing benefit-cost analysis; whenever the estimated net benefit of one became negative, it would no longer be social policy.

Unfortunately, those in power frequently find reasons to want to suspend civil liberties, confiscate property, and jail or execute people without due process. To persuade us to give up our constitutional guarantees, a utilitarian leader might promise that these values would ordinarily hold, that she would suspend them only in "unusual" situations. Events such as the internment of Japanese-Americans during World War II, the more recent internment of Iraqis in Great Britain during the Persian Gulf war, and Watergate do not foster trust in the judgment of even democratically elected leaders in the USA and England.

Leaders are attempting to accomplish some ends. Inevitably, they will regard constraints on the means they may use as unfortunate. They are repeatedly tempted to intrude on the values "slightly" in "compelling" cases. If freedom of speech were subject to a benefit-cost analysis in each case, one would see much less freedom than when it is guaranteed constitutionally[4].

C. Other Problems with Benefit-Cost Analysis: 1. Is Everything for Sale?

Kelman (1981) cites other reasons for distrusting utilitarianism [5]. Valuing nonmarket items is difficult, arbitrary, and may be repugnant. Would you sell your

[4]The counter argument is that the utilitarian leader would have a more credible basis for asserting that the values would not be sacrificed except for stated circumstances, since the circumstances would have been thought through. Does detailing the circumstances under which the freedoms would be sacrificed add or subtract credibility? Would you vote for a candidate who detailed the exceptional circumstances under which he would lie, cheat, and steal or a candidate who said he wouldn't lie, cheat, and steal under any circumstances?

[5]Van Doren (1989) defends benefit-cost analysis against the usual political science argument that it doesn't attendto symbols. He argues that preserving symbols has a cost and that the public doesn't have uniform values that praise the same symbols;the costs of preserving symbols should be taken more seriously. Thepolitical process is filled with rent seeking, with an interest group seeking wealth and favoritism. Benefit-cost analysis alerts peopleof the implications of proposed legislation or regulation, getting them to protect their own interests. Van Doren does insist that compensation actually be paid to those who are injured.

daughter's teddy bear? Putting a dollar price on things defines them as being "in commerce" and changes the way we think about them. Saying that your wedding ring is not for sale means that it isn't analogous to laxative suppositories. In theory, there are circumstances under which I would have sold the sexual services of my adolescent daughter and son, but I don't regard thinking through these circumstances as uplifting, calming, or enlightening. Few, if any of us will ever face these circumstances; I see no value in torturing myself to sketch the offer curve[6].

2. Situation Specific Values: Another fundamental difficulty is that values and judgments often are situation specific; they change radically from one setting to another. For example, my willingness to pay to reduce the chance of immediate death by one in 100,000 is different depending on whether this is an occupational risk or involves recreation. What is the dollar value associated with not having to shoot someone? Is this value different for a burglar in your home at night than for your child? Our actions have subtle implications that make valuing an item or action dependent on the precise setting. Thus, the dollar values that Viscusi (1983) estimates for lowering the chance of premature death in an occupational setting may have little relationship to the dollar value that people would put on lowering the chance of cancer from tolerating carcinogens in their drinking water. The estimated values

---

[6]"To argue that the sacred value of human life in these situations must be respected is not to deny in any way the value of efficiency in life-saving and the importance of saving more lives rather than fewer whenever possible. This point is rather a more subtle one. It is to suggest that there may be irresolvable tensions between our rationalistic, revisionist sentiments, on the one hand, and our conservative, ritualistic sentiments on the other. A rationalistic decision procedure may unavoidably threaten some of these sentiments, which may suggest that it is better not to make that procedure too absolute, too open, or too openly identified with public agencies like EPA that were created to pursue moral as well as other goals. It may perhaps be necessary to live with some controversies rather than to resolve them technocratically, and to tolerate "pockets" or modest levels of inefficiency for this purpose" MacLean, 1990, p 103). cf. Van Doren, 1989.

didn't predict how much the price of a toilet bowl cleaner would have to be reduced to lead consumers to purchase a slightly more dangerous version (Viscusi and Magat, 1987).

Fischhoff (1991) points out how sensitive are expressions of value to the precise question, and even the context, including preceding questions. A respondent's answers often are internally inconsistent. Subjects sometimes give the same value to preventing one lake from being polluted as preventing 5, 100, or 1,000 lakes from being polluted. Clearly, the respondent's answers are not appropriate for detailed analysis.

3. Valuing Nonmarket Goods and Services: Economists have attempted to quantify and value effects such as unpleasant odors, eye irritation, a greater chance of getting cancer, improved visibility, improved recreation, and the value of preserving a natural setting, including one that will not be visited (Cummings, et al, 1986). Clever people have found ingenious ways to value these effects. But, we economists haven't asked the question: Can decision makers have confidence in these estimates? Economists have even started challenging the assumption that people have fixed utility functions (Akerlof, 1991). The fundamental question isn't whether the estimates are clever or the best available, but whether they are reliable. Do we have unbiased estimates with a relatively small error term? I would not want to bet the family jewels on the numbers estimated.[7]

4. Is Efficiency the Only Important Criterion? The fundamental basis for benefit-cost analysis is its theoretical efficiency. As shown above, this efficiency is doubtful for social

[7]Miller has no patience with these questions about whether government officials should be able to interpret estimates even if they are not very reliable: "If we have given government officials the power to impose costs on the activities of private citizens or otherwise control them, we cannot say they cannot be trusted to weigh benefits and costs in determining what they do. If regulatory statutes allow discretion, the enforcing agency would be irresponsible -- and in my view unfair -- not to weight the benefits and costs of its policies" (Miller, 1989, p92).

issues. Even if the efficiency were real, benefit-cost analysis neglects other social criteria for evaluation: equity, administrative simplicity, transparency, and improved environmental quality (Lave, 1981a). I know of no presumption that maximizing efficiency simultaneously will maximize the other evaluation criteria. Indeed, why would one expect a positive correlation between efficiency and the other evaluation criteria?

5. Benefit-Cost Analysis for Personal Decisions? Fischhoff (1977) notes that few people desire to maximize net benefits in their personal decisions. They don't attempt to translate the multiple dimensions into a scalar, and certainly don't try to translate everything into dollars. Would you use a formal benefit-cost analysis to decide what career to pursue or which person to ask to be your spouse? Even conceptually, benefit-cost analysis isn't likely to be of much help in nonmarginal decisions, such as whether to have children. Before experiencing them, it is hard to know what will be the distribution of pleasure and irritation you will get from caring for your children. But it is impossible to gain information without taking a distinctly nonmarginal step.

Other difficulties can be listed briefly: While the analysis should account for multiple dimensions and interactions among them, this rarely occurs (Lave, 1981b, 1984).[8] For many projects, all the consequences of a decision cannot be enumerated, implying that all important consequences may not have been considered.[9] If so, the analysis should be

[8]For example, when Congress (or the National Highway Transportation Safety Agency) sets standards for safety, fuel economy, and pollution emissions, they must recognize that adding additional safety features adds weight and thus decreases fuel efficiency, just as does tightening emissions standards (Lave, 1981b). A benefit-cost analysis must account for these interactions (Lave, 1984).

[9]For example, the evaluation of the safety of nuclear power reactors got too large for the computers available (Rasmussen, 1981).

viewed in terms of "bounded rationality" (Simon, 1955) rather than efficiency or optimizing. Estimating parameters is difficult because available data may represent a different circumstance.[10] People differ in the ways they handle risky situations and there is no single method that will satisfy all people. For example, Lave and Romer (1984) point out that a safety standard is a public good. Since people have different safety goals, instituting a single standard will make almost everyone unhappy in the sense that the goal won't be as safe as, or will be more expensive than, they desire.

III. Implementation Difficulties

Whatever the theoretical difficulties, they are dominated by the difficulties of implementing benefit-cost analyses. For example, the tool have been criticized as biased and as serving the incumbent politicians. However,

> "any technique employed in the political process may be distorted to suit parochial ends and particular interest groups. Cost-benefit analysis can be an advocacy weapon, and it can be used by knaves. But it does not create knaves, and to some extent it may even police their behavior. The critical question is whether it is more or less subject to manipulation than alternative decision processes. Our claim is that its ultimate grounding in analytic disciplines affords some protection" (Leonard & Zeckhauser, 1986, p31).}

1. Selecting a Valuation Concept: Often there are several bases for valuation. Choosing among them can be difficult. For example, if 100,000 salmon return each year to spawn in a river, and if construction of a dam would prevent spawning, how should the loss of these salmon be estimated? One way is to measure the price of salmon in local fish markets

[10]For example, there has been an evolution in the design of cooling pumps for nuclear reactors. Modern pumps are made of different materials with different quality control (Atomic Energy Commission, 1974, 1975; Primack, 1975).

and subtract the cost of catching, transporting, and retailing them. The result is the value of a salmon in the river for consumption. This "producer surplus" probably amounts to less than $1 per pound. This line of reasoning results in such a low value for environmental benefits that society's welfare is likely to be increased by damming the river or making it into a sewer.

The price of a salmon carcass on ice has nothing to do with the value of preserving the wilderness habitat. Suspending plastic salmon in a sewer or displaying real salmon in aquariums (where they can be seen more easily and reliably) doesn't address the environmental values. We joke that possible extinction of the snail darter was used to stop building the Tellico dam, even though the fish is no good to eat (White, 1981). Should we value California condors in terms of how good they taste? Would bald eagles be more highly valued if they performed for tourists[11]?

Some fisherman appear to value catching salmon out of all proportion to the value of the salmon on ice at your favorite fish monger. We see individuals pay more than $1000 per fish for the sport of catching them. Other individuals are willing to pay large amounts of money to see wild animals, not even catching them or shooting them, e.g., people going to see migrating whales or whooping cranes or going on picture taking safaris. Indeed, some people are willing to pay to prevent anyone from disturbing wild animals, e.g., leaving salmon uncaught and even unseen.

I would not be willing to sell the flowers in my front yard for the price of cut flowers in the florist shop. If they were equivalent, it would be less expensive for me to buy flowers

[11]Should a trained seal be the national symbol?

than to grow them. Does anyone think the sensible way to value a whooping crane or spotted owl is in terms of the market price (per pound) of a turkey? Would you feel fairly compensated if someone killed your pet dog, offering you as compensation the retail value of this amount of dog meat -- less the cost of butchering, transport, and retailing?

As a trip to your shopping mall will reveal, many salmon are valued at what the carcass will fetch; many flowers are valued at what they sell for in the florist shop. When should an uncaught salmon be valued at $1 per pound and when at $1,000 per pound? Economists have attempted to estimate existence values, option values, and to explore what would be the effect of imbuing the environment with rights, e.g., giving trees rights (Baumol and Oates, 1988). Some items have a value in commerce which is quite different from their personal value. If there is no easy way to make marginal substitutions, the value difference can persist. In addition, some people refuse to regard some items as being in commerce, even though they can be purchased, e.g., sexual intercourse or old growth forests. If society cannot agree on the valuation of the benefits and costs, social optimization is not possible, or at least is not simple. Social decisions are made, but few have even a remote claim to being optimal. Often, wisdom calls for stating the benefits and costs in multidimensional terms, not in dollars.

2. Neglecting the Primary Objective: The federal government has announced plans to set aside a forest area equal to the combined size of Massachusetts and Vermont in order to prevent the extinction of the spotted owl. This means that the agency is implicitly valuing a pair of spotted owls at more than $1 million per year. It cannot be that U.S. society values these owls at so great a dollar amount. Furthermore, the issue of how much forest to set

aside has been a contentious one for a decade, calling forth intense opposition from loggers and logging communities. This is not a case where the parties are unaware of what some faceless regulators are doing. No reasonable benefit analysis could come up with $1 million per year to preserve a nesting pair of spotted owls, or perhaps $1 billion per year to preserve all of these owls in their forest homes. Rather than rushing to the media to label this proposal as absurd, economists would do better to assume, for purposes of the discussion, that the decision is a sound one.

What social values could justify this decision? It appears that people want to preserve old growth forest and the species that live there. The spotted owl is no more than an indicator species or "label" for what is desired. Economists incur ridicule by assuming naively that the indicator species is the only issue. Whether the USA should incur a cost of more than $1 billion per year requires examining a large bundle of benefits, including romantic notions about preserving the virgin forest.

In practice, benefit-cost analysis is an unimaginative, book-keeper's activity. The tool seems to encourage a narrow analysis. All too often, economists miss the primary benefits (or costs) in doing the analysis.

3. Who Has Standing? Whose benefits and costs are to be counted? What weights are to be given to each individual? Trumbull (1990) asserts that the benefits of those who violate the law ought not to be counted (the criminal's utility from his act) and that all who are affected by a policy, including future generations be counted. Zerbe (1991) notes that "standing" is defined by political and legal rights, such as the right to sue. For example, the U.S. Supreme Court decided that the psychological costs of residents around Three

Mile Island need not be counted in establishing policy, presumably because the experts agreed that there was no basis for the fear. Thus, a benefit-cost analysis would ignore these costs, even though they were quite real to the individuals. Zerbe(1991) conjectures that the cases where standing is most controversial will be the cases where political and legal decisions, not benefit-cost analyses are needed.

Should a nation be altruistic enough to give full weight to the benefits and costs that occur to those living outside its borders, e.g., fishing with monofiliment nets or greenhouse effects? While we might hope that all nations would behave in this way, it seems unlikely that they would do so without some meta authority to arbitrate conflicts.

Attempting to account for the preferences of future generations runs into the practical difficulty of not knowing what they will want. Anyone who has bought gifts for other people and been the recipient of gifts knows how difficult it is to get even a vague idea of the preferences of others. This is all the more true of a generation socialized by different ideas and facing different opportunities and constraints. Imagine an eskimo saving a choice piece of blubber for you or your great grandfather deliberately not building a privy on the best site so that it would be available for your use.

4. The Correct Discount Rates: The difficulties of reducing the disparate benefits and costs to a scalar have their parallel in reducing the time stream of benefits and costs to a single date. A large body of literature has been devoted to determining the proper discount rate for market goods and services that accrue over time (Baumol, 1972; Sandmo, 1973; Sandmo and Dreze, 1973; Jenkins, 1973; Parfit, 1983). Of particular difficulty is the choice of a rate that will properly account for transfers across generations (Berry, 1983;

Kneese et al, 1983; Page, 1983). Despite general agreement on the proper concept (at least for a time period of less than a generation), there is little agreement on the number that ought to be used in a particular analysis. What discount rate should be used for future risks of disease, death, destruction of environmental amenities, etc.? For example, what is the value of a program that prevents the extinction of a species for an additional 50 years?

5. Valuation in the Presence of Risks: In the 1960s, there was growing recognition that benefit-cost analyses of waterway projects had been simplistic (Campen, 1986). It was already recognized that social benefits were multidimensional. For example, building a dam could provide not only flood control, but also electricity generation, a year round water supply, and a lake for recreation. Enlarging the dam was also seen to have multidimensional costs: Since land was flooded for the reservoir, some fish and plants would cease to exist here. Other effects were more difficult to classify: Land in the flood plain was now protected from frequent flooding, but still subject to large floods. How should we value land where the threat of flooding from frequent small storms has been removed but there is an increase in the amount of damage that would be done in very rare large storms (National Research Council, 1985; Epple and Lave, 1988)?

IV. Problems with Benefit-Cost Analysis in Practice

These conceptual difficulties are the grist for academic theorists. Reality is more bleak. What should EPA Administrator Reilly infer from a benefit-cost analysis of a new automobile emissions standard? Suppose he were informed the analysis was done by a GS 9

with a B.A. (or even an MBA) in six weeks with no supplementary budget? The analyses produced by government agencies contain major flaws in theory, quantification, and analysis. We economists lose our credibility and risk ridicule by requiring analyses we know will have major flaws and insisting that the option with the greatest measured net benefit is the optimal choice.

Myriad other problems occur in practice. We assume that market prices reflect a purely competitive market, even in concentrated industries. We assume that tastes don't change over time. We assume that many "small" externalities don't need to be included in the analysis because they are unimportant.

A benefit-cost analysis will reveal legions of uncertainties and gaps in knowledge. If these are displayed to the reader, they might create a bias toward finding the analysis unworthy of confidence and would certainly lead to a long, unreadable report. If they are not highlighted, the public might have more confidence in the analysis than is warranted.

In practice, what decision makers learn from benefit-cost analysis comes from the executive summary. But no one or two page summary can indicate the range of uncertainties and other qualifications that a decision maker must know to use the analysis intelligently. For example, global climate change issues are so awash in uncertainty that definitive actions are not possible (see National Research Council, 1991). Because the analysis seems to be scientific, it is often presented as if disagreeing with the results is akin to asserting that two plus two isn't equal to four.

I conclude that in neither theory nor practice does benefit-cost analysis have a legitimate claim to be the optimizing framework that many economists believe it is; our

current attempts at benefit-cost analysis probably are biased (Lave, 1971). Although we have no conceptual difficultly with how to incorporate nonmarket effects, we don't have accurate ways to incorporate them into current analyses. In short, I conclude that the estimated net benefit of current social issues may be biased and misleading; the deficiencies stem from both theory and practice. Even if we hired the best and brightest economists and gave them essentially unlimited resources, they could not carry out a benefit-cost analysis of complicated issues that would give a confident estimate of the net social benefit. For example, consider an analysis of whether to build a nuclear power plant on Long Island, New York or whether to open northern Alaska to production of petroleum.

Benefit-cost analysis requires hundreds of value judgments, most of them small and hidden. Which environmental effects are nontrivial will depend on whether the analyst believes that rocks have the same rights as people or whether she believes that nature is nasty and cruel: Does she favor draining swamps or extolling wetlands? Even if both analysts were doing their best to be objective and neutral, their analyses would look very different.

Our quest for technocratic neutrality leads to the conclusion that, if benefit-cost analyses differ, one must be wrong. In fact there is a range of uncertainty concerning the extent of physical effects and a range of uncertainty concerning valuation. Benefit-cost analyses could be quite different and yet each could be equally valid in the sense that disparities are due to value differences in structuring and monetizing, although each structure could be equally valid from a technocratic viewpoint.

This recognition leads to a shocking assertion. The same economist might do quite different benefit-cost analyses of the same issue, depending on who the client is. A

principled analyst could produce analyses with quite different preferred options (the one with the largest net benefits).

A decision maker cannot interpret a benefit-cost analysis properly without knowing the values of the analyst and sponsoring organization. Although a different analysis could be an indication of technical inadequacy or misconduct, it could also result from value differences. A reviewer has the difficult task of determining whether an analysis is technically accurate and spelling out the values used.

V. Alternative Frameworks and Criteria

Benefit-cost analysis is one of several decision frameworks that Congress has written into legislation: (1) No risk, (2) risk-risk, (3) technology based standards, (4) risk-benefit analysis, (5) Cost-effectiveness analysis (Lave, 1981a). In terms of the breadth of considerations, tradeoffs considered, and thus efficiency optimization, the frameworks are in rough order, leading to benefit-cost analysis. Similarly, they are listed in rough order in terms of the amount of data and analysis required. For example, cost-effectiveness analysis doesn't require data and theory that would make benefits and cost comparable, but it does not result in optimization unless the goal just happens to be the one with maximum net benefits.

Just as benefit-cost analysis (maximizing net benefits) assumes utilitarian ethics, each of the other decision frameworks implicitly assumes an ethical background. For example, the "no risk" framework assumes that protecting human health is the only goal; no tradeoffs are relevant concerning such other attributes as health vs. private or public consumption.

The framework is simplistic in not recognizing more complicated implications, such as the risk-risk tradeoffs of the second framework. The risk-risk framework continues to focus only on health. Technology based standards rest upon a naive assumption that the technology drives the solution and that other considerations, including health and consumption, are either not important or are handled in an obvious fashion. Risk-benefit analysis examines the health risks and general benefits of a technology. It assumes that other types of risk are not relevant. Finally, cost-effectiveness is based on the premise that efficiency is the most important attribute, that choosing the desired goal is simple or not possible analytically. Although Congress could be forthright in declaring its goals, more often it expresses its values more subtly by choosing one of these decision frameworks.

Economists value efficiency and tend to downplay the importance of value judgments -- we joke that you don't want to know the details of how sausage, legislation, or regulations are made.

VI. Does Benefit-Cost Analysis Change Political Decisions?

Like our utilitarian predecessors, economists seek to optimize social decisions. In distinction to special interest groups, we economists see ourselves as providing neutral advice that is essential to making social decisions that serve the public interest (see Miller and Yandle, 1979; Clark et al., 1980; White, 1981).

At the opposite extreme, political economists see government decisions as resulting from interest groups who are able to put together winning coalitions. Decisions are not "good" or "bad." Rather they are successful (adopted) or unsuccessful (not adopted).

In this view, benefit-cost analysis is simply an attempt by one special interest group (economists, who think of themselves as virtuous and helpful) to influence the agenda and voting.

Indeed, in practice, benefit-cost analysis is a means by which an interest group can secure the support of uncommitted voters or legislators. If one side thinks that a benefit-cost analysis will be favorable (i.e., their proposal can be shown to be efficient), they should commission an analysis. The other side might counter by focusing on the advantages of their proposal, such as helping a deserving group or improving the environment; they might also attack the benefit-cost analysis as mean-spirited or inconclusive, showing the tenuous nature of some parameter estimates or the arbitrariness of some valuations. For example, in the 1980s business groups attacked environmental proposals by commissioning benefit-cost analyses which showed the high costs of the improvement; environmental groups defended the proposals saying that no price could be put on environmental improvements; they also showed flaws in the benefit-cost analysis (Gruenspecht and Lave, 1991).

This view leads to the question: Which group will play the benefit-cost card, and under what circumstances? In the usual political interpretation, a small interest group with a great deal to gain (representing a small proportion of the voters) battles a small interest group that has a great deal to lose; most Congressmen have no direct interest in the matter. The proponents try to put together a winning coalition while the opponents try to block it. In their efforts to gain supporters, each side will claim that they are acting in the public interest and will want data and analyses to support their claim. One way of convincing people is a benefit-cost analysis. The analysis could convince those with no direct interest that the

proposal is in the public interest; more likely, it could convince others that they have a fair amount to gain or lose if the legislation is passed. For example, a benefit-cost analysis of the 1977 Clean Air Act Amendments showed western coal producers that they had much to gain if regulation were simply on the basis of emissions while the eastern coal producers had much to lose.

The benefit-cost analysis clarified who would win and lose and by how much, along with showing that there would be a large net efficiency loss (Ackerman and Hassler, 1980).

VII. The Presidency Versus Congress

Our system of government checks and balances means that no individual or institution has the power to make policy. "Dispersion of power has three important consequences for environmental policy making. First and foremost is the dispersion of responsibility. In the United States, it is easy to shift the blame for nearly everything to someone else. Second, because no one controls the entire policy making process, each participant tries to squeeze as much as possible out of the limited portion he or she controls. Third, given the complexity of the entire process, it is difficult to see the connection between the decisions of each participant and eventual outcomes" (Melnick, 1990, p26).

In an attempt to impose some discipline on the system, Gerald Ford and his successors have issued executive orders to executive branch agencies. The orders require agencies to investigate a wider range of considerations than Congress wrote into legislation, or at least a wider range of considerations than the relevant oversight committee wants to stress. The

executive orders also rule out considerations that Congress thought were paramount, namely equity.

American presidents have not been less political than Congress. In general, presidents have not been more courageous than Congress in revealing their values in major controversies concerning food additives, occupational safety and health, waterway projects, or toxic substances in the environment.

Nonetheless, the institution of the presidency is different from the institution of Congress. Compared to the president, Congress gives more weight to seniority, getting along by going along, coalition formation for public works, and is better able to hide behind rules committees and not scheduling issues for debate and votes.

Benefit-cost analysis has drawn fire because it is used to circumvent the value judgments Congress wrote into legislation. What sense is there in doing a benefit-cost analysis of the snail darter if Congress passed legislation that attempts to prevent species extinction? If Congress specified that no carcinogens should be added to food, why perform a benefit-cost analysis? Since Congress has instructed the Administrator of EPA to set ambient air quality standards for the criteria pollutants that "...protect the most sensitive group with an ample margin of safety" (1970 Clean Air Act Amendments) what is the point of finding the standard that maximizes net benefit?

The Office of Management and Budget might answer that it is valuable to know how great is the difference in net social benefit between the best option and the one mandated by Congress. If this difference is large, Congress and the public ought to rethink the Congressional mandate.

Unfortunately, this answer neglects the inadequacies of benefit-cost analysis. When the analysis doesn't deal with equity issues, and at best brushes past the criteria of transparency, administrative simplicity, and goal achievement, the results must be interpreted with care.

This point is more general: Benefit-cost analysis, in practice, is static. It doesn't account for new discoveries, advances in technologies, or many other adjustments. In principal, the adjustments could be included, even though they are highly uncertain. However, the analyses must be defended against hostile critics. An agency speculating that technology forcing will be successful would find it difficult to defend its numerical estimates. I remarked two decades ago that a carefully done benefit-cost analysis will tend to be biased toward understating benefits and overstating costs (Lave, 1971).

VIII. Inherent Problems with Environmental Regulation

Environmental regulation is in trouble for many reasons (Portney, 1990; Swartzman, 1982): (1) EPA and the other agencies don't have a clear idea of what they should accomplish. Legislation is contradictory or full of pious hopes rather than working goals, e.g.,"... no discharge in waterways by 1985" (1972 Clean Water Act). Without goals, efficiency isn't defined; benefit-cost analysis and other economic tools are irrelevant, or at least less relevant (Gruenspecht and Lave, 1991). For example, cost-effectiveness analysis can be used to attain some goal (or small number of goals) efficiently, even though no precise goal is specified; however, this framework is severely limited.

The lack of goals results in small part from the reluctance of Congressmen to take stands that will earn them enemies. More important is the rapidly changing nature of public opinion regarding environmental issues. If, as time passes, incomes rise, more people become educated, people with less enlightened views die, and environmental abatement occurs without catastrophic consequences to the economy, environmental issues will become more important to the public. If incomes fall and defense or other issues grow in importance, environmental issues likely will become less important. Thus, the secular trend is toward greater concern, with business cycles and regional wars reversing the trend temporarily. Federal judges are subject to the same pressures and trends, and the nature and aggressiveness of court intervention changes over time and across regions of the country.

(2) The environmental sciences and ecology are inherently complicated. The ability to predict the effects of a discharge on human health or ecology is primitive. Thus, there is sharp disagreement among experts, e.g., the effects of the Valdez oil spill and possibility of nuclear winter. Eventually these issues get settled, but the public rarely hears about the resolution, even though the problem initially was front page news.

(3) As environmental expenditures have become significant, they have become more important to the political process. A new regulation can affect the president's public image. The effects are too important to escape Whitehouse review and reformulation.

(4) In the debate, the sides become more polarized until the issue ceases to be examined and is transformed into a test of strength. For example, public opinions about the environmental affects of acid rain were shaped by preliminary scientific data from the late 1970s; government studies of the 1980s seemed to be regarded as irrelevant, even when they

contradicted the earlier conclusions that acid rain was acidifying many lakes and killing trees. Under some circumstances, scientific data become irrelevant, even if the vote is still years away (Oversight Review Board of the National Acid Precipitation Assessment Program, 1991).

(5) There is no agreement about how the issues ought to be framed. Is the fundamental concern environmental preservation or a healthy local economy? Is the focus now, the next century, or all of future time?

IX. Beyond Benefit-Cost Analysis

Benefit-cost analysis is inherently a time and resource consuming analysis. For formal benefit-cost analysis to convey a net social benefit, it must be applied only to issues of sufficient importance that the resource expenditures are worth while. Many issues can be handled with simpler frameworks, such as "no risk," "technology based standards" or "cost-effectiveness." Using one of the other frameworks would, at least in theory, result in lower efficiency. However, only in economic models are information gathering and analysis free. Accounting for these costs and the inherent limitations of benefit-cost analysis, a formal analysis will be socially beneficial only for a limited number of cases. More limited analyses, from one of the other decision frameworks, or a quick and dirty benefit-cost analysis should be preferred for most social issues.

A decision analysis is likely to be more enlightening if it emphasizes:

(1) Problem Definition: What issues are to be considered, what remedies are possible, and what are the goals?

(2) Statement of objectives: Unless the goals are stated, a complicated social problem degenerates into people talking past each other as they address different goals.

(3) Identification of all reasonable means to accomplish the stated objectives: Too limited a set of options will lead to suboptimization while too broad a set will waste resources and time. There are an infinite number of unreasonable alternatives.

(4) Analysis of the benefits and costs of each alternative: The benefits and costs must be quantified and, if reasonably possible, be translated into dollars. Where the translation is controversial, the analysis must be careful to summarize the effects in terms of a multidimensional array (although one of minimum size).

(5) In cases of deep controversy, the analysis should emphasize a systematic, analytic approach that uses all relevant data and helps to structure a research agenda for gathering the crucial missing data.

(6) Specify the perspective and values used in the analysis. The analysis should consider other important perspectives and values, although the possible list is endless. For example, Is the perspective current US society, US society in two decades, current advanced countries, current third world countries, or the world? Are the values of those who believe that industrialization is the only hope or that industry inherently creates more problems than it solves? Equity issues associated with who pays and who benefits are of primary importance. Eastern and western religions display quite different values.

(7) Spells out the implications of using different discount rates.

(8) Analyzes uncertainties: Each of the previous steps is filled with uncertainties, from quantification to choosing a discount rate.

(9) Interprets the results: Neither the facts nor the analysis "speak for themselves;" the analyst must interpret these for the reader.

These nine steps define a systematic analysis, a framework for pulling together diverse data and analyzing it (adapted from Office of Technology Assessment, 1982). The framework emphasizes uncertainty and values; it doesn't claim it will find a social optimum. "Once benefit-cost analysis is understood as a process meant to yield information rather than to make decisions, practitioners of benefit-cost analysis need not take sides in controversies over the nature of justice" (Railton, 1990, p62).

What Should be Analyzed: I hinted above that benefit-cost analysis is helpful for only a fraction of social issues. How can decision makers know when a benefit-cost analysis is warranted and when a less resource intensive method is superior? For example, when should an issue be resolved by negotiation among the most knowledgeable parties without any explicit attempt to determine a social optimum? One answer comes from the nine steps specified above. If these nine steps cannot be accomplished with confidence, a benefit-cost analysis is not possible.

Another answer is that benefit-cost analysis is the best way of deciding which issues should be subject to benefit-cost analysis and which components are to be the focus. In other words, benefit-cost analysis can function as a "meta" analysis to define what tools to use. I don't know of any systematic attempt to investigate this meta analysis role for benefit-cost analysis.

X. Conclusion

I join dozens of people who have scrutinized benefit-cost analysis in concluding that the tool is a useful way of structuring a complicated problem. With the exception of economists who are utilitarians or unwitting utilitarians, there is general agreement that the option identified as having the largest net benefit does not have a strong claim to being the best social choice.

The time has come to purge the utilitarian foundation from benefit-cost analysis. This means identifying the tool as a decision analysis rather than as a tool for prescribing optimal decisions. We want to praise the virtues of systematic analysis and straight thinking, not the utilitarian properties of maximizing net benefits in complicated social decisions.

We need to admit that many benefit-cost analyses are biased; some are simply worthless. We should stop defending this tool with religious fervor and give more attention to the cases where it leads to results quite different from what Congress and the public appear to desire. Efficiency is not the most important attribute of a public program.

We need to admit that benefit-cost analysis is costly to perform; it ought not to be applied to every problem or applied lightly. Few issues are worthy of a formal benefit-cost analysis. A one or two semester course in benefit-cost analysis, even at the Ph.D level, doesn't transform a neophyte into a master, or even journeyman practitioner. The economic aspects of the analysis are sufficiently difficult and subtle that an apprenticeship system is needed, with few apprentices being promoted to journeymen, and few journeyman becoming masters. Economists who are regarded as masters are sometimes alarmingly ignorant about the limitations of their methods. We need to spend more time identifying attributes, and

being more careful not to eliminate important attributes. We need to take a much more critical view about elicited values.

Insisting on translating all benefits and costs into dollars is folly. In many cases the translation cannot be done with confidence. When the analyst does so despite the problems, the result is estimates almost certain to mislead or to generate controversy. At the least, the benefits and costs should be summarized in multidimensional arrays before the square pegs are pounded into round holes.

More generally, we need to give more attention to tossing out inadequate parameter estimates, even if they are the best available. We need to admit that even the best available estimates can be so uncertain that they are unlikely to enlighten. We need to be admit in many cases that a confident benefit-cost analysis isn't possible. The basic approach can be used to structure the problem and to give values to parts of the problem, but it simply isn't possible to derive a meaningful estimate of net social benefits.

Finally, we need to be more conscious of how we, and the analysis, are used. This is policy analysis, not fundamental research. Partial information can mislead and analysts can, even inadvertently, become advocates. It is not enough to provide a caveat that this analysis may be underestimating costs and overestimating benefits. We must investigate the extent of the possible bias. Along with other proponents of benefit-cost analysis, I praise it for forcing analysts to think systematically about social issues, collect data, and do analyses to clarify the implications of decisions. Unfortunately, the median application of the tool not only doesn't point to the best policy, it tends to mislead. We economists have a

great deal of work to be before we can make benefit-cost analysis into the helpful tool that we know that it can be.

XI. References Cited

Ackerman, Bruce A. and William T. Hassler (1980), Beyond the New Deal: Coal and the Clean Air Act, New Haven: Yale University Press.

Akerlof, George A. (1991), "Procrastination and Obedience," American Economic Review, 81:1-19.

Atomic Energy Commission (1974, 1975), "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Power Plants," WASH 1400, Washington, D.C.

Baumol, William J. (1972), "On the Social Rate of Discount," American Economic Review, 58:788-802.

Baumol, William J. and Wallace E. Oates (1988), The Theory of Environmental Pollution, New York: Cambridge University Press.

Berry, Brian (1983), "Intergenerational Justice in Energy Policy," 15-30, in D. MacLean and P.G. Brown (eds), Energy and the Future, Totowa, NJ: Rowman and Littlefield.

Campen, James T. (1986), Benefit, Cost, and Beyond: The Political Economy of Benefit-Cost Analysis, Cambridge, MA: Ballinger.

Clark, Timothy B., Marvin H. Kosters, and James C. Miller, III (1980), "Introduction), 1-5, in T.B. Clark, M.H. Kosters, and J.C. Miller III, Reforming Regulation, Washington, DC: American Enterprise Institute for Policy Research.

Cummings, Robert G., David S. Brookshire, and William Schultze (1986), Valuing Public Goods: The Contingent Valuation Method, Totowa, NJ: Rowman and Allenheld.

Epple, Dennis and Lester Lave (1988), "The Role of Insurance in Managing Natural Hazard Risks: Private Versus Social Decisions," Risk Analysis, 8:421-33.

Fischhoff, Baruch (1977), "Cost Benefit Analysis and the Art of Motorcycle Maintenance," Policy Sciences, 8:177-202.

Fischhoff, Baruch (1991), "Value Elicitation: Is there Anything in There?" American Psychologist.

Green, Mark J. (1980), "Cost-Benefit Analysis as a Mirage," 113-116, in T.B. Clark, M.H. Kosters, and J.C. Miller III, Reforming Regulation, Washington, DC: American Enterprise Institute for Policy Research.

Gruenspecht, Howard and Lester Lave (1991), "Increasing the Efficiency and Effectiveness of Environmental Decisions: Benefit-Cost Analysis and Effluent Fees," Journal of the Air and Waste Management Association.

Jenkins, Glenn P. (1973), "The measurement of Rate of Return and Taxation from Private Capital in Canada," 211-48 in W.A. Niskanen et al, Benefit-Cost and Policy Analysis 1972, Chicago, IL: Aldine.

Kelman, Steven (1981), "Cost-Benefit Analysis: An Ethical Critique," Regulation, 5, 33-40.

Kelman, Steven (1982), "Cost-Benefit Analysis and Environmental, Safety, and Health Regulation: Ethical and Philosophical Considerations," 137-151, in D. Swartzman, R.A. Liroff, and F.G. Croke, Cost-Benefit Analysis and Environmental Regulations: Politics, Ethics, and Methods, Washington, DC: Conservation Foundation.

Kneese, Allen V., Shaul Ben-David, and William D. Schulze (1983), "The Ethical Foundation of Benefit-Cost Analysis," 59-76, in D. MacLean and P.G. Brown (eds), Energy and the Future, Totowa, NJ: Rowman and Littlefield.

Krupnick, Alan J. and Paul R. Portney (1991), "Controlling Urban Air Pollution: A Benefit-Cost Assessment," Science 252:522-8.

Lave, Lester B. (1971), "Air Pollution Damage," in A. Kneese and B. Bower (eds), Environmental Quality Analysis, Baltimore: Johns Hopkins University press, 213-42.

Lave, Lester B. (1981a), The Strategy of Social Regulation, Washington, DC: Brookings Institution.

Lave, Lester B. (1981b), "Conflicting Federal Regulations Concerning the Automobile,: Science.

Lave, Lester B. (1984), "Controlling Contradictions Among Regulations," American Economic Review.

Lave, Lester B. (1991), "Formulating Greenhouse Policies in a Sea of Uncertainty," The Energy Journal, 12:9-21.

Lave, Lester B. and Thomas Romer (1984), "Specifying Risk Goals: Inherent Problems with Democratic Institutions," Risk Analysis, 3:217-27.

Leonard, Herman B. and Richard J. Zeckhauser (1986), "Cost-Benefit Analysis Applied to Risks: Its Philosophy and Legitimacy," 31-48, in D. MacLean (ed), Values at Risk, Totowa, NJ: Rowman Allanheld.

MacLean, Douglas E. (1990), "Comparing Values in Environmental Policies: Moral Issues and Moral Arguments," in R.B. Hammond and R. Coppock (eds), Decision Making: Report of a Conference, Washington, DC: National Academy Press, 56-106.

Melnick, R. Shep (1990), "The Politics of Benefit-Cost Analysis," in R.B. Hammond and R. Coppock (eds), Decision Making: Report of A Conference, Washington, DC: National Academy Press.

Miller III, James C. (1989), The Economist as Reformer: Revamping the FTC, 1981-1985, Washington, DC: American Enterprise Institute for Public Policy Research.

Miller III, James C. and Bruce Yandle (1979), Benefit-Cost Analyses of Social Regulation, Washington, DC: American Enterprise Institute for Public Policy Research.

Mishan, Edward J. (1982), Cost-Benefit Analysis: An Informal Introduction, 3rd ed., London: George Allen and Unwin.

National Research Council (1985), Safety of Dams: Flood and Earthquake Criteria, Washington, DC: National Research Council.

National Research Council (1991), Policy Implications of Greenhouse Warming, Washington, DC: National Academy Press.

Office of Technology Assessment (1982), Evaluation of Medical Technologies, Washington, DC.

Oversight Review Board of the National Acid Precipitation Assessment Program (1991), "The Experience and Legacy of NAPAP." Washington, DC: National Acid Precipitation Assessment Program.

Page, Talbot (1983), "Intergenerational Justice as Opportunity," 38-58, in D. MacLean and P.G. Brown (eds), Energy and the Future, Totowa, NJ: Rowman and Littlefield.

Parfit, Derek (1983), "Energy Policy and the Further Future: The Social Discount Rate, 31-37, in D. MacLean and P.G. Brown (eds), Energy and the Future, Totowa, NJ: Rowman and Littlefield.

Primack, J. (1975), "An Introduction to the Issues," Bulletin of the Atomic Scientists, 31: 15-19.

Portney, Paul R. (ed) (1990), Public Policies for Environmental Protection, Washington, DC: Resources for the Future.

Railton, Peter (1990), "Benefit-Cost Analysis as a Source of Information About Welfare," in R.B. Hammond and R. Coppock (eds), Decision Making: Report of A Conference, Washington, DC: National Academy Press, 55-82.

Rasmussen, Norman C. (1981), "The Application of Probabilistic Risk Assessment Techniques to Energy Technologies," in J. Hollander, M. Simmons, and D. Wood (eds), 123-138, Annual Review of Energy, 10, Palo Alto, CA: Annual Reviews.

Sassone, Peter G. and William A. Schaffer (1978), Cost-Benefit Analysis: A Handbook, New York: Academic Press.

Sandmo, Agnar (1973), "Discount Rates for Public Investments Under Uncertainty," 177-192, in W. A. Niskanen et al, Benefit-Cost and Policy Analysis 1972, Chicago, IL: Aldine.

Sandmo, Agnar and Jacques H. Dreze (1973), "Discount Rates for Public Investments in Closed and Open Economies," 193-210, in W.A. Niskanen et al, Benefit_cost and Policy Analysis 1972, Chicago,IL: Aldine.

Simon, Herbert A. (1955), "A Behavioral Model of Rational Choice," Quarterly Journal of Economics, 59:99-118.

Small, Kenneth A. (1987), "A Constitutional Rationale for Welfare Measurement," working paper, Department of Economics, University of California at Irvine.

Stokey, Edith and Richard Zeckhauser, A Primer for Policy Analysis, New York: W.W. Norton, 1978.

Swartzman, Daniel (1982), "Cost-Benefit Analysis in Environmental Regulation: Sources of the Controversy," 53-85, in D. Swartzman, R.A. Liroff, and K.G. Croke (eds), Cost-Benefit Analysis and Environmental Regulations: Politics, Ethics, and Methods, Washington, DC: The Conservation Foundation.

Tribe, Laurence H. (1973), "Policy Science: Analysis or Ideology," 3-47, in W. A. Niskanen, A.C. Harberger, R.H. Haveman, R. Turvey, and R. Zeckhauser (eds), Benefit-Cost and Policy Analysis 1972, Chicago: Aldine.

Trumbull, William N. (1990), "Who Has Standing in Cost-Benefit Analysis?" Journal of Policy Analysis and Management, 9:201-218.

Van Doren, Peter (1989), "Should Congress Listen to Economists?" Journal of Politics, 51:319-326.

Viscusi, W. Kip (1983), Risk By Choice: Regulating Health and Safety in the Workplace, Cambridge, MA: Harvard University Press.

Viscusi, W. Kip and Wesley A. Magat (1987), Learning About Risk: Consumer and Worker Responses to Hazard Information, Cambridge, MA: Harvard University Press.

White, Lawrence (1981), Reforming Regulation: Process and Problems, Englewood Cliffs, NJ: Prentice-Hall.

Wildavsky, Aaron (1966), "The Political Economy of Efficiency: Cost-Benefit Analysis, Systems Analysis, and Program Budgeting," Public Administration Review, 292-310.

Zerbe, Jr., Richard O (1991), "Comment: Does Benefit-cost Analysis Stand Alone? Rights and Standing," Journal of Policy Analysis and Management, 10:96-105.

CENTER FOR SCIENCE AND INTERNATIONAL AFFAIRS
John F. Kennedy School of Government
Harvard University
79 JFK Street
Cambridge, MA 02138

The Center for Science and International Affairs (CSIA) is dedicated to advancing the understanding and resolution of complex public policy problems of international scope through research at the intersection of the natural and social sciences. The number of such problems is growing, and the Center's research agenda currently encompasses international security affairs, environment and natural resources policy, and the role of science and technology in shaping the international economy and other global concerns. Each year a multinational group of predoctoral and postdoctoral scholars drawn from the social and natural sciences is in residence at the Center. More than 50 Harvard faculty members and about 70 non-resident affiliates are also involved in Center activities.

Research Staff The Center is directed by a permanent staff whose individual experience reflects its diversity of interests. Director Ashton Carter, a theoretical physicist who has worked in the Defense Department and the Congressional Office of Technology Assessment, specializes in national security affairs and science and technology policy. Lewis Branscomb, a research physicist and former chief scientist of IBM, directs the Center's Science, Technology and Public Policy program. Environmental scientist William Clark and international security expert Kurt Campbell serve as assistant directors. Henry Lee, an energy and environment expert with state government experience, serves as executive director of the Center's Environment and Natural Resources Program. Steven Miller, a political scientist, is director of studies and editor of the journal *International Security*, which is published at the Center.

Research Projects Collaborative research efforts focus on new issues of international security after the Cold War, proliferation of high-technology weapons, regional security including the Pacific Basin, avoiding nuclear war, technology policies for economic competitiveness and national security, international science and technology policy, social learning in the management of global environmental risks, market-based policies for environmental protection, and management of natural resources. In support of its research, the Center maintains a substantial specialized library in science, technology, international security, and environmental affairs.

Seminars and Conferences The Center sponsors weekly seminars, seminars with visiting experts, conferences, and dinner seminars involving visitors from government, industry, academia, the media, as well as periodic events in the Kennedy School's ARCO Forum. CSIA also sponsors the annual Lamont Lecture, which brings to the school a senior figure in international security affairs and, with the Olin Institute for Strategic Studies at Harvard's Center for International Affairs, the Strategy and Arms Control Seminar, which brings to the Cambridge community prominent figures in international security affairs.

Publications *International Security*, the quarterly journal sponsored and edited by the Center and published by the MIT press, is a leading publication in security studies and international affairs, offering a distinctive blend of scholarly research with policy relevance. Assistant Director William Clark is editor of the journal *Environment*. In addition to books, articles, and edited volumes authored by CSIA research staff and fellows, CSIA's publications include: Discussion Papers, which are working-draft manuscripts by CSIA affiliates; Occasional Papers, which are monograph-length paperback books that have grown out of research conducted at the Center; reprints of journal articles; and a newsletter, *CSIA News*.

ENVIRONMENT AND NATURAL RESOURCES PROGRAM
Center for Science and International Affairs
John F. Kennedy School of Government
Harvard University
79 JFK Street
Cambridge, MA 02138

The Environment and Natural Resources Program (ENRP) provides a locus at Harvard for interdisciplinary research on domestic and international environmental policy issues. ENRP's research agenda covers a broad spectrum of issues including: market-oriented approaches to environmental problems, natural resource and lands policy, global climate change, sustainable development and environmental risk analysis.

The Program involves faculty and senior researchers from the Kennedy School, as well as other professional schools at the university. Workshops, executive sessions, summer internships for students and the Discussion Paper series are also a part of the ENRP program.

Inquiries should be directed to:
Henry Lee
Executive Director, ENRP
(617) 495-1350

CENTER FOR SCIENCE AND INTERNATIONAL AFFAIRS
JOHN F. KENNEDY SCHOOL OF GOVERNMENT
HARVARD UNIVERSITY

Discussion Paper Series

91-13 Edward A. Parson and William C. Clark. "Learning To Manage Global Environmental Change: A Review of Relevant Theory."

91-12 Lewis M. Branscomb. "America's Emerging Technology Policy."

91-11 Sean M. Lynn-Jones. "International Security Studies after the Cold War: An Agenda for the Future."

91-10 Rapporteur's Report of the Executive Session: "Negotiating a Global Climate Change Agreement." March 14-15, 1991.

91-9 Dale W. Jorgenson and Peter J. Wilcoxen. "Reducing US Carbon Dioxide Emissions: The Cost of Different Goals."

91-8 John D. Montgomery, et al. "Values in Conflict: Policy Interactions in the Pacific Basin."

91-7 Summary of Project 88/Round II Workshop Proceedings. "Incentive-Based Policies for Municipal Solid Waste Management." May 16, 1991.

91-6 Proceedings of Project 88/Round II Forum. "Market-Based Strategies for Environmental Protection: A Tribute to Senator John Heinz of Pennsylvania." May 16, 1991.

91-5 Charles H.W. Foster and Peter P. Rogers. "Rebuilding the Nation's Wetland Heritage: A Challenge for the 1990s."

91-4 Joshua Lerner. "The Impact of Patent Scope: An Empirical Examination of New Biotechnology Firms."

The Center for Science and International Affairs (CSIA) Discussion Papers, established in 1991, will be issued on an irregular basis with three programmatic subseries: International Security, Science Technology and Public Policy, Environment and Natural Resources. This new Discussion Paper series incorporates three earlier publication series, now discontinued: The Science, Technology and Public Policy (STPP) Discussion Papers, the Energy and Environmental Policy Center (EEPC) Discussion Papers, and the CSIA Working Papers. Inquiries and orders may be directed to: Center for Science and International Affairs, Publications, Harvard University, 79 JFK Street, Cambridge, MA., 02138.

CENTER FOR SCIENCE AND INTERNATIONAL AFFAIRS
JOHN F. KENNEDY SCHOOL OF GOVERNMENT
HARVARD UNIVERSITY

Discussion Paper Series

91-3 Darius Gaskins and Bruce Stram. "A Meta Plan: A Policy Response to Global Warming."

91-2 Gary E. Marchant. "Freezing CO_2 Emissions: An Offset Policy for Slowing Global Warming."

91-1 Adam Jaffe and Robert N. Stavins. "Evaluating the Relative Effectiveness of Economic Incentives and Direct Regulation for Environmental Protection: Impacts on the Diffusion of Technology."

CENTER FOR SCIENCE AND INTERNATIONAL AFFAIRS
JOHN F. KENNEDY SCHOOL OF GOVERNMENT
HARVARD UNIVERSITY

Working Paper Series

90-3 Yan Kong. "China and Nuclear Proliferation, 1980-1990: A Select Annotated Bibliography of English-Language Publications."

90-2 John A. Parmentola. "New Tools for SLCM Verification."

90-1 Stephen J. Stillwell, jr. "'Grey Literature' in International Security Studies: A Bibliography."

89-6 Graham T. Allison, Albert Carnesale, Joseph S. Nye, Jr. eds. "*Hawks, Doves, & Owls* Revisited."

89-5 Stephen J. Stillwell, jr. "Technology Transfer & National Security: A Bibliography of Journal Articles."

89-4 Emanuel Adler. "Cognitive Evolution: A Dynamic Approach for the Study of International Relations and their Progress."

89-3 Emanuel Adler. "Seasons of Peace: Progress in Postwar International Security."

89-2 David A. Welch, ed. "Proceedings of the Cambridge Conference on the Cuban Missile Crisis."

89-1 David A. Welch, ed. "Proceedings of the Hawk's Cay Conference on the Cuban Missile Crisis."

88-2 Lynn Page Whittaker. "Report of a Conference on 'U.S. Conventional Forces: Current Commitments, Future Needs'."

88-1 Jennifer Laurendeau. "The Politics of NATO Defense Policy: Lessons of the EDC Debate, 1950-1954."

87-3 Robert P. Beschel, Jr. "Theories of Enmity in U.S.-Soviet Relations."

The Center for Science and International Affairs (CSIA) Discussion Papers, established in 1991, will be issued on an irregular basis with three programmatic subseries: International Security, Science Technology and Public Policy, Environment and Natural Resources. This new Discussion Paper series incorporates three earlier publication series, now discontinued: The Science, Technology and Public Policy (STPP) Discussion Papers, the Energy and Environmental Policy Center (EEPC) Discussion Papers, and the CSIA Working Papers. Inquiries and orders may be directed to: Center for Science and International Affairs, Publications, Harvard University, 79 JFK Street, Cambridge, MA., 02138.

CENTER FOR SCIENCE AND INTERNATIONAL AFFAIRS
JOHN F. KENNEDY SCHOOL OF GOVERNMENT
HARVARD UNIVERSITY

Working Paper Series

87-2 Stephen J. Flanagan. "Safeguarding Arms Control."

87-1 Ivo H. Daalder. "The Artificial Consensus on NATO ATBMs."

86-2 James G. Blight. "Beyond Deterrence or Beyond Utopian Ideology?: Thought Experiments for an Antinuclear Movement in Crisis."

86-1 Joseph S. Nye, Jr. "Assessing Deep Cuts."

CENTER FOR SCIENCE AND INTERNATIONAL AFFAIRS
JOHN F. KENNEDY SCHOOL OF GOVERNMENT
HARVARD UNIVERSITY

Environment and Natural Resources Program
Discussion Paper Series

E-91-03 Rapporteur's Report of the Executive Session: "Negotiating a Global Climate Change Agreement." March 14-15, 1991.

E-91-02 Charles H.W. Foster and Peter P. Rogers. "Rebuilding the Nation's Wetland Heritage: A Challenge for the 1990s."

E-91-01 Adam Jaffe and Robert N. Stavins. "Evaluating the Relative Effectiveness of Economic Incentives and Direct Regulation for Environmental Protection: Impacts on the Diffusion of Technology."

E-90-13 Robert W. Hahn and Robert N. Stavins. "Incentives Based Environment Regulation: A New Era from an Old Idea?"

E-89-14 Dale W. Jorgenson and Peter J. Wilcoxen. "Environmental Regulation and U.S. Economic Growth."

E-89-10 Robert N. Stavins. "Alternative Renewable Resources Strategies: A Simulation of Optimal Use."

E-89-06 John D. Spengler, Nancy Sullivan, Haluk Ozkaynak, James H. Ware, Martin A. Cohen, P. Barry Ryan. "Report on Ambient Exposures to Volatile Organic Compounds in the Kanawha Valley."

E-88-08 Robert N. Stavins and Adam B. Jaffe. "Forested Wetland Depletion in the United States: An Analysis of Unintended Consequences of Federal Policy and Programs."

E-88-05 Charles H.W. Foster and Peter P. Rogers. "Federal Water Policy: Toward an Agenda for Action."

E-87-03 Joseph P. Kalt. "The Political Economy of Protectionism: Tariffs and Retaliation in the Timber Industry."

E-86-10 Frederick W. Mayer and Henry Lee. "Environmental Risk Management: Research Needs and Opportunities."

E-86-07 Lauren Zeise, Richard Wilson, Edmund A.C. Crouch. "The Dose Response Relationships for Carcinogens: A Review."

The Center for Science and International Affairs (CSIA) Discussion Papers, established in 1991, will be issued on an irregular basis with three programmatic subseries: International Security, Science Technology and Public Policy, Environment and Natural Resources. This new Discussion Paper series incorporates three earlier publication series, now discontinued: The Science, Technology and Public Policy (STPP) Discussion Papers, the Energy and Environmental Policy Center (EEPC) Discussion Papers, and the CSIA Working Papers. Inquiries and orders may be directed to: Center for Science and International Affairs, Publications, Harvard University, 79 JFK Street, Cambridge, MA., 02138.

CENTER FOR SCIENCE AND INTERNATIONAL AFFAIRS
JOHN F. KENNEDY SCHOOL OF GOVERNMENT
HARVARD UNIVERSITY

Environment and Natural Resources Program
Discussion Paper Series

Project 88/Round II

P-91-04 Lester B. Lave. "Benefit-Cost Analysis: Do the Benefits Exceed the Costs?

P-91-03 Peter S. Menell. "Optimal Multi-tier Regulation: An Application to Municipal Solid Waste."

P-91-02 Summary of Project 88/Round II Workshop Proceedings. "Incentive-Based Policies for Municipal Solid Waste Management." May 16, 1991.

P-91-01 Proceedings of Project 88/Round II Forum. "Market-Based Strategies for Environmental Protection: A Tribute to Senator John Heinz of Pennsylvania." May 16, 1991.

ENRP Special Reports

M-89-02 "Proceedings: Harvard University's John F. Kennedy School of Government/Project 88 Conference: Harnessing Market Forces to Protect the Environment."

M-89-01 John Spengler, Haluk Ozkeynak, John F. McCarthy, Henry Lee. "Summary of Symposium on Health Aspects of Exposure to Asbestos in Buildings."

CENTER FOR SCIENCE AND INTERNATIONAL AFFAIRS
JOHN F. KENNEDY SCHOOL OF GOVERNMENT
HARVARD UNIVERSITY

Global Environmental Policy Project
Discussion Paper Series

G-91-02 Dale W. Jorgenson and Peter J. Wilcoxen. "Reducing US Carbon Dioxide Emissions: The Cost of Different Goals."

G-91-01 Gary E. Marchant. "Freezing CO_2 Emissions: An Offset Policy for Slowing Global Warming."

G-90-10 James K. Sebenius. "Negotiating a Regime to Control Global Warming."

G-90-09 Thomas F. Homer-Dixon. "Taxes, Fuel Consumption and CO_2."

G-90-08 Robert W. Kates, William C. Clark, Vicki Norberg-Bohm, and B.L. Turner III. "Human Sources on Global Change: A Report on Priority Research Initiatives for 1990-1995."

G-90-07 Edward A. Parson. "Transport Sector in Global Warming."

G-90-06 David G. Victor. "Tradeable Permits and Greenhouse Gas Reductions: Some Issues for U.S. Negotiators."

G-90-05 William W. Hogan and Dale W. Jorgenson. "Productivity Trends and the Cost of Reducing CO_2 Emissions."

G-90-04 Vicki Norberg-Bohm. "Potential for Carbon Dioxide Emission Reductions in Buildings."

G-90-03 Thomas G. Schelling. "Global Environmental Forces."

G-90-02 William C. Clark. "Visions of the 21st Century: Conventional Wisdom and Other Surprises in the Global Interactions of Population, Technology, and Environment."

G-90-01 William C. Clark. "The Human Ecology of Global Change."

The Center for Science and International Affairs (CSIA) Discussion Papers, established in 1991, will be issued on an irregular basis with three programmatic subseries: International Security, Science Technology and Public Policy, Environment and Natural Resources. This new Discussion Paper series incorporates three earlier publication series, now discontinued: The Science, Technology and Public Policy (STPP) Discussion Papers, the Energy and Environmental Policy Center (EEPC) Discussion Papers, and the CSIA Working Papers. Inquiries and orders may be directed to: Center for Science and International Affairs, Publications, Harvard University, 79 JFK Street, Cambridge, MA., 02138.

CENTER FOR SCIENCE AND INTERNATIONAL AFFAIRS
JOHN F. KENNEDY SCHOOL OF GOVERNMENT
HARVARD UNIVERSITY

Science, Technology and Public Policy Program
Discussion Paper Series

90-04 Maryellen Kelley and Harvey Brooks. "The Comparative Role of Large and Small Firms in the Diffusion of NC and CNC Machine Tool Technologies."

90-03 Joshua Lerner. "The Mobility of Corporate Scientists and Engineers Between Civil and Defense Activities: Evidence from the SSE Database."

90-02 Lewis M. Branscomb. "Defense Research and Technology Strategy for a Changing International Security Environment."

90-01 Brian Kahin. "The NREN as a Quasi-Public Network: Access, Use, and Pricing."

89-11 Joshua Lerner. "The Small High-Technology Company, the Government, and the Marketplace: Evidence from the SBIR Program."

89-10 Gerald L. Epstein. "Fusion Technology for Energy."

89-09 Not available.

89-08 Lewis M. Branscomb. "Dual-Use Technology: Optimizing Economic and Security Interests through National Technology Policy."

89-07 John A. Alic. "Cooperation in R&D: When Does it Work?"

89-06 Maryellen Kelley and Harvey Brooks. "'Follow-Through' and 'Breakthrough' Approaches to Federal and State Technology Policy."

89-05 Ashton B. Carter. "Anatomy of the Dual Use Relationship."

89-04 Todd A. Watkins. "Dual Use Technologies: Diffusion Structures and International Policy Convergence."

89-03 Harvey Brooks. "The Technological Factor in US Competitiveness."

89-02 John A. Alic. "Government Policies Toward High-Temperature Superconductivity."

89-01 Lewis M. Branscomb. "Policy for Science and Engineering in 1989: A Public Agenda for Economic Renewal."

The Center for Science and International Affairs (CSIA) Discussion Papers, established in 1991, will be issued on an irregular basis with three programmatic subseries: International Security, Science Technology and Public Policy, Environment and Natural Resources. This new Discussion Paper series incorporates three earlier publication series, now discontinued: The Science, Technology and Public Policy (STPP) Discussion Papers, the Energy and Environmental Policy Center (EEPC) Discussion Papers, and the CSIA Working Papers. Inquiries and orders may be directed to: Center for Science and International Affairs, Publications, Harvard University, 79 JFK Street, Cambridge, MA., 02138.