Environmental Health Policy Decisions: The Role of Uncertainty in Economic Analysis

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NRCSE

Technical Report Series

ENVIRONMENTAL HEALTH POLICY DECISIONS
THE ROLE OF UNCERTAINTY IN ECONOMIC ANALYSIS

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Revised [June/1998]

Abstract

Regulatory reform will increasingly call for more economic analysis in decisions about environmental health policy. In a recent discussion of this issue, a group of economists articulated a set of guiding principles of interest to researchers and environmental health professionals involved in quantitative risk assessments and associated regulatory outcomes. In representing a broad spectrum of such professionals, the National Environmental Health Association will play an important role in how the costs and benefits of environmental regulation are understood in terms of health-related priorities. The purpose of this work is to underscore the role of irreversibility and uncertainty for benefit-cost analysis in environmental health policy decisions. The value it places on information and flexible policy response has implications for those health professionals, particularly in the area of quantitative risk assessment, whose work affects the design and implementation of policy.

Keywords: Environmental health regulation, benefit-cost analysis, statistics

Environmental health professionals will increasingly be asked to participate in accounting for how and on which issues the dollars are spent on human health and the environment. What are the net benefits, for example, of sanitation? Are case management strategies cost effective provisions for lead-burdened children? This role seems as inevitable as it is vital to the regulatory response to these concerns. On the other hand, environmental health professionals may find themselves increasingly in the position of securing a place for the human health aspects of environmental economics and management. For example, while the

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intended benefits of controlling evaporative refueling emissions had been articulated clearly enough in terms of the risks of human exposure to benzene, it was sometimes hard to keep this in sight during the ensuing economic debate about the relative advantages of controlling emissions by modifying the gasoline pump or the design and manufacture of the automobile. These trends will only continue as debates intensify well into the next century over economic development and social welfare broadly defined.

These observations are informed by the link between economic and quantitative risk analysis on the one hand, and the critical role to be played by the National Environmental Health Association on the other, in ensuring a position for public health concerns in economic decisions about development and environmental policy. As part of a larger discussion of critical issues for the 21st Century, the importance of this link emerged in a thoughtful series of articles by Walker (1992a, 1992b) and Davis and co-authors (1993a, 1993b) on the future of environmental health. The present article follows this train of thought while noting that regulatory reform will increasingly call for more economic analysis in decisions about environmental health policy. For deeply felt policies, the difficulties of economic analysis will no doubt be a lightning rod for much heated controversy. For this reason alone, continued discussion in the direction of informed participation and further contribution among environmental health professionals is critical to the debate.

This article addresses the role of irreversibility and uncertainty in environmental health policy decisions, for example the Environmental Protection Agency's PM2.5 rule for regulating emissions of small-sized pollutant particles. The value it places on flexible policy responses, including optimal timing of policy and incremental strategies, will depend on the contributions of all environmental health professionals. So too will the value it places on information and learning which carries further lessons for the statistical design and analysis of continuing research initiatives and quantitative analyses of human health risks. Finally, a proper benefit-cost analysis of health and environmental policy holds a place for the value of lives saved, reduced morbidity and other benefits of policy. There will nevertheless remain no substitute for the ready voices and informed advocacy of public health officials.

Economic Analysis in Environmental Health Regulation

Benefit-cost analysis can ideally provide an analytical framework for weighing in economic terms the tradeoffs involved in policies affecting the environment and human health. While not an omnibus tool, it can be used appropriately to set priorities, rank and select alternatives and evaluate performance. Amidst growing national concerns about the costs, reach, and effectiveness of environmental, health and safety regulation, a group of prominent economists met recently to discuss this issue under the auspices of the American Enterprise Institute, the Annapolis Center, and Resources for the Future. In light of reforms favoring greater reliance on economic analysis in policy decisions, there emerged from these discussions a set principles in Arrow and co-authors (1996) for guiding and improving quality in the use of benefit-cost analysis in environmental, health and safety regulation.

In summarizing their statement of principles, the authors proclaim that decision-makers should be encouraged rather than precluded in the use of economic analysis to reach decisions and set regulatory priorities. Such analyses should be required of all major regulatory decisions, subject to peer review, and conducted according to an established set of guidelines. In cases where cost and benefits can not be quantified, sound decisions can still be reached with the help of qualitative descriptions of the advantages and disadvantages of policy alternatives. In all of these recommendations and throughout this discussion there appeared one important recurring theme: the ubiquity of uncertainty and so, implicitly, the role for statistical inference.

Benefit-cost analysis in environmental health regulation involves a complex aggregate of economic estimates of costs and benefits, scientific estimates of environmental impact, and biomedical estimates of risks to human health. The quality of a benefit-cost analysis and ultimately the design of environmental health policy depends on a host of factors including flexibility, uncertainty, and economic assumptions about the value of reducing the risks of morbidity and other health-related improvements. While the analysis of these factors falls theoretically within the purview of the field of environmental and resource valuation, see for example Freeman (1993), they ultimately depend from a practical perspective on critical contributions from environmental health professionals including biostatisticians, chemists, physicians, economists, and risk and public policy analysts.

Irreversibility and Uncertainty in Economic Analysis

Recent examples of this kind of crossdisciplinary effort can be found in the pages of this journal in the work of El-Gazzar and Marth (1993), Robbins and McSwane (1994) and Ballas and co-authors (1995). How do such analyses fit into the basic theory of modern benefit-cost analysis in environmental policy? And as demand for such analyses grows and the community of environmental health professionals become increasingly involved, what are the lessons and themes from environmental economics for the design, implementation and evaluation of environmental health regulation?

Policy debates that rely on traditional benefit-cost analysis usually revolve around the expected flow of costs, benefits and the social value of time or discount rates. The grounds for decision making are then the net benefits of policy as a now-or-never proposition. Environmental problems, however, are characterized by what economists call irreversibilities, uncertainties and flexibilities: three themes of environmental economics that significantly shift the grounds for decision making and the ultimate design of policy. In the face of the irreversible effects of developing pristine lands, for example, the basic idea emerged in the mid 1960's from seminal discussions about the value of preserving national parks, gradually developing over the last quarter century into the theory of optimal decision making in environmental economics and management. The result today is that, at least in theory, environmental policy decisions must reconcile certain opportunity costs and benefits, the value of flexible timing or scope of regulation, and the prospects that the future will in some way bring missing or incomplete information to light. Table 1 summarizes the basic features of environmental health policy decisions in terms of the principal elements and their implications for policy design.

A central conception in the analysis of irreversible decisions is the idea expressed by the phrase sunk costs and sunk benefits. A sunk cost is an irrecoverable cost of adopting an environmental policy, such as the cost of installing new scrubbers on factories, scrapping old machinery for new fuel efficient models, or in the form of paying higher prices for better-grade fuels. A sunk benefit, in contrast, is a negative opportunity cost or preventive benefit of adopting an environmental policy, such as the benefit of avoiding (irreversible) environ-

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Table 1. Features of Environmental Health Policy Decisions

	Sources	Economic Analysis
Irreversibility	Sunk costs and sunk benefits	Opportunity costs of regulation, damage abatement, lives saved and reduced morbidity
Uncertainty	Economic, ecological, biomedical	Statistical models of costs, pollutant stocks and human health stocks
Flexibility	Timing, scope, and design	Optimal timing and level of policy, incremental and partially reversible policies, value of information, and learning

Economic analysis of environmental health policy decisions treats the monetary value of the social costs of regulation and the social benefits of reduced risks. Statistical models of economic changes, environmental effects and human health risks are integral to the approach. Implementation requires some monitoring of key environmental, economic and health variables particularly for applications involving learning strategies, optimal timing and sequential policies.

mental damage, preserving fragile ecosystems, saving human lives or reducing morbidity. Understanding the tradeoffs imposed by such cost and benefits is key to understanding a modern approach to benefit-cost analysis.

The basic lesson is that when making environmental health decisions under uncertainty it is in the interest of society to keep its options open by proceeding flexibly with respect to the timing, design and scope of regulation. Irreversible decisions in environmental health regulation will incur certain sunk costs which, when treated traditionally, bias now-or-never decisions toward policy adoption at full levels. On the other hand, they also incur certain sunk benefits which, when treated traditionally, bias now-or-never decisions against policy adoption. Recognizing these effects leads the analysis toward the optimal timing of policy, optimal level of response, and sometimes go-slow or gradual policy adoption. Finally, the traditional treatment foregoes the possibility that new information, whether it be scientific, economic or biomedical in nature, will come to light in ways that significantly impact the design, timing and scope of the proposed regulation. Add the prospect of learning about

Exhibit 1. An illustration

This simple illustration shows the value of flexible timing and the basic effect of uncertainty. Consider a policy to reduce the stock of some pollutant thought to have ill health effects on some human population at risk. Suppose that each affected person has a 0.004 chance of dying during the next year. Suppose further that a pollution control policy is designed to reduce that chance, but the amount is unknown because of an uncertain link between the environmental pollutant and the health risk. The uncertainty lasts exactly one period and is forever resolved by the toss of a coin. In particular, suppose there is a zero reduction with probability 0.3 or a reduction of 0.001 with probability 0.7. The chance of dying therefore either remains at 0.004 or decreases to 0.003.

Next, suppose that value of a statistical life is $1,000 per individual for a policy that would reduce each individual's chance of dying by one in a thousand. The discount rate is 10% per period of benefit and the cost of regulation is $5,000 per individual. If society acts today based on future expectations, then the value V of policy is given by

$$V = -5,000 + \sum_{t=0}^{\infty} 698(1.1)^{-t} = -5,000 + 7,677 = \$2,677.$$

The net present value of policy is positive, suggesting society act today, but so far this conclusion ignores the opportunity cost of doing so rather than waiting for a tomorrow's resolution of the uncertain health link. Suppose instead that society proceeds with policy only in the event that the link is positive. Since the chance of that is seven tenths, the value V of policy is then given by

$$V = (0.7)[(-5,000/1.1) + \sum_{t=1}^{\infty} 997(1.1)^{-t}] = 4177/1.1 = \$3,797.$$

In this way society acts on policy tomorrow only in the event that new information proves that policy is bound to reduce the risk of dying by one statistical life in a thousand. Waiting for that information increases the value of policy from $2,677 to $3,797, so it is better in this case for society to wait.

Irreversibility is the principal driver of the decision to wait, otherwise society would simply recover the sunk cost of $5,000 per individual in the event of a failed policy. Nevertheless, society will only wait provided it has the flexibility or option to act tomorrow. The value of this flexibility is $1,120 (=$3,797-$2,678), which may be thought of as the amount society would be willing to pay for a policy that is flexible about timing over one that requires a now-or-never decision. Considered from another angle, an option value of $1,120 means that society would be willing to pay a sunk cost as high as $6,760 tomorrow (in place of the $5,000 today) to replace an inflexible now-or-never decision with a flexible one.

How does the degree of uncertainty affect option value? In the calculation above, the odds are 7 to 3 that the health risk declines by one in a thousand. These odds entail some degree of certainty about the policy outcome. Increase the odds to a more certain 9 to 1 and the option value of waiting drops by two orders of magnitude to a mere $11, in contrast say to even odds which effectively doubles the value of waiting. In other words, scientific certainty about the positive health link to policy brings about an incentive to act. Or interpreting the lesson in a broader sense, there is value in information or perhaps policies that learn incrementally along the way.

the future to the effect of irreversibility and the value of flexibility takes on a significant and very practical meaning. Exhibit 1 provides an illustration of the basic themes.

The Environmental Protection Agency (EPA), for example, estimates that the new PM2.5 rule, regulating small sized pollutant particles, will save some 20,000 lives a year and reduce cases of asthma by about 250,000. This is a clear public health benefit, but one based on uncertain biology and controvertible medical science. It turns out that PM2.5 particles congest the air during calm weather when there is no wind to blow them away. The epidemiological evidence linking PM2.5 pollutants and rates of asthma, for example, rests largely on correlations which leave open the medical possibility that there are other agents involved in the incidence of asthma during calm weather conditions. The circumstances are ideal, it seems, for indoor air to become stagnant, stuffy and laden with unhealthy concentrations of ordinary household chemicals, spores of moulds, dust-mite feces and so on. These intervening factors compound the uncertainty regarding the likely public health benefit of the PM2.5 rule. At the same time, the new rule will also involve considerable and no less uncertain social costs, like the sunk costs of new emissions controls, taxes, and investments in new technologies.

The PM2.5 rule will clearly have irreversible consequences (some partial and some full) for the economy and the public health. The case illustrates why uncertainty figured so prominently in the statement of guiding principles for benefit-cost analysis in Arrow and co-authors (1996). There are economic uncertainties about the cost of pollution abatement and the benefits of improved public health. There are scientific uncertainties about the ecological fate and transport of air pollutants and the exact effect of small sized particles on human respiratory disease. These considerations argue for flexible policy response to the problem, ongoing monitoring programs and funding of new or continuing research on the effects of air quality on human health. Finally, the case illustrates why regulations emerging from environmental policy generate so much heated controversy particularly over methods of risk assessment and ways of figuring uncertainty into the decision-making process.

Back to the Future of Environmental Health

Irreversibility and uncertainty in environmental health policy decisions, like the EPA's

PM2.5 rule, places value on information and flexibility in the design and implementation of policy. The realization of that value and the full consideration of public health priorities in economic analysis depend in part on the contributions all environmental health professionals. This is especially true of those involved in some area of quantitative risk assessment.

Quantitative risk assessment is a chain of essential links—hazard identification, exposure assessment, dose-response assessment, risk characterization and risk management—leading to the policy responses behind environmental health regulation. Environmental health professionals participate in this process in multiple ways. In his perspective on the future of quantitative risk assessment, Walker (1992) focused on the regulatory impact of scientific and methodological problems with the hazard identification process. His insights are relevant throughout the chain, as are those of Johnson (1992) in his discussion of exposure assessment. As the lessons of environmental economics show, scientific uncertainties and methodological limitations in quantitative risk assessment strike at the heart of decision making and risk management strategies.

Flexible strategies will typically need to call upon environmental health professionals to help monitor key environmental, economic and health variables whose conditions evolve in an uncertain world. When uncertainties tell us to go slow or to do more research, the goal is to learn about, reduce or even resolve the uncertainty. More often than not descriptions of uncertainty depend critically on statistical inference, so the implications for decision making puts a premium on the use of the most efficient statistical designs and analyses in establishing, for example, dose-response relationships. The same efficiencies should apply to monitoring programs, whether they be designed to assist in optimal policy timing or as part of retrospective studies and policy evaluations. Increasingly, modern statistical techniques, including new likelihood methods, Monte Carlo and bootstrap techniques, are designed to give more accurate estimates of uncertainty. Where appropriate it may be best to model uncertainty directly using dispersion models, volatility models or other appropriate measure of uncertainty. Finally, sensitivity analysis can be employed as standard practice in case-control studies, for example, as a way of assessing just how robust the effects of hazard exposure are for the risk of disease.

In closing, several thought provoking challenges were forecast in the future of environ-

mental health by Walker (1992b) and Davis and co-authors (1993a, 1993b). Among these were issues of economic analysis including pressing ones of cost containment, financing and the value of prevention dollars. How will the money be spent and on which issues? Will health priorities be heard above the din of economic debate? Many observers would argue that some but not all of the environmental regulation of the past two decades would pass a traditional benefit-cost analysis. Less can be said of a modern analysis since, with the exception of global warming, little has been done to evaluate the practical implications of the basic theory for weighing the opportunity costs (and benefits) for particular environmental problems and policies. To see therefore that the lessons and themes of environmental economics are applied and communicated properly in future work lies as another challenge for the community of environmental health professionals and the National Environmental Health Association.

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