Valuing Risks to the Environment

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ABSTRACT: Increasing awareness of exposure to environmental risks has focused attention on measures that would give greater assurance that such risks are effectively managed and that the adverse consequences of risky activities are mitigated. Implementing such actions is made more difficult by the uncertainties of environmental changes, their often delayed impacts, the great importance attached to extremely small risks, and the lack of clear measures of the values of environmental losses. Findings from recent behavioral studies of people's time preferences, valuations of losses relative to gains, and risk perceptions are providing information that should lead to more effective risk management strategies.

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REPORTS of potentially catastrophic environmental losses such as those accompanying the Chernobyl nuclear accident in Russia, the *Exxon Valdez* oil spill in the United States, and the cutting of tropical forests have focused increasing attention on environmental risks. These risks range from local concerns to global changes; they result from natural processes as well as human activities; and they include risks to the environment as well as risks to human welfare.

The growing awareness of environmental risks and the cost of mitigating their impacts has brought greater attention to matters of responsibility, fairness, and how incentives encourage people to pursue activities that increase risks or motivate people to undertake precautionary measures. Yet setting limitations on risky actions and choosing levels of protection invariably pose difficult trade-offs between commercial and noncommercial interests, between geographic areas, and often between current and future generations. Valuing exposures to environmental losses is made more demanding by their uncertain impacts, by the lack of market prices, and by the rarity and delayed consequences of many potential effects. These issues also can erode trust in the managers and institutions charged with the responsibility to look after the interests of the wider community.

OBJECTIVES OF ENVIRONMENTAL RISK VALUATION

The general objective of valuing environmental risks is to improve the ways in which we make choices that allow or discourage risky activities and the means of mitigating adverse consequences of such actions when they occur. A world of zero environmental risks is clearly impossible. Some risks are more worrisome than others, however, and the public interest would be better served by regulations and policies that control the more serious risks and by expenditures that are cost-effective in reducing risks and mitigating losses that are more important to the environment and to people. Greater awareness of relative values would improve our ability to recover appropriate damages from individuals responsible for environmental harms and encourage people to choose alternative activities and precautionary efforts that are consistent with the full monetary and nonmonetary losses imposed by risky activities.

Valuations of environmental losses are often contentious, however. Individuals differ widely in their valuations and willingness to make sacrifices to deal with possible adverse impacts on the environment. Understanding of the probabilistic exposure to potential sources of loss is often lacking, and the great importance imputed to extremely small, or de minimis, risks effectively blunts many people's acceptance of any compromises or trade-offs. Rationalization of risk management efforts, reflecting the relative importance of environmental losses, would not only result in more efficient use of resources but could also lead to easier resolution of disputes and make restrictions far more acceptable to affected parties.

KEY ISSUES IN VALUING ENVIRONMENTAL RISKS

Some of the reasons why environmental risk assessments are often difficult are well known, such as the lack of actuarial experience with many such risks, the limited knowledge of ecological relationships, and the prominence often given to particular episodes or events by media attention that can heavily influence people's perceptions of their relative importance. There are, however, other less well appreciated reasons of particular concern for the valuation of environmental risks. In some cases these have become apparent only as the result of recent experience and research.

Risk and characteristics

A major issue in dealing with environmental risks is that risks have multiple characteristics and people weigh these attributes differently. The results of a 1990 U.S. study demonstrated the significance of this issue by revealing striking differences between U.S. Environmental Protection Agency scientists and members of the public when asked to rate the seriousness of a list of environmental problems. Not only were the relative weights very different, but many items high on the list of one group were not even included in the concerns of the other group. This difference between public and expert perceptions of the seriousness of various risks is a common finding.[1] The problem raised for valuations is deciding whose weighings will be taken into account when identifying and setting priorities to deal with risks that have differing characteristics and therefore are considered to be more serious by some people than others.

Such differences in perspective are common and important when valuing environmental risks. The disparities may result from different information or different interpretations of facts; from different subjective calculations, particularly concerning the reluctance of many people to disregard even extremely low probability events; and from different levels of trust that cleanup activities will be as thorough or as speedy as suggested. In some cases, individuals may be confused or base their preferences on erroneous facts or interpretations; but they may also value risks differently because particular characteristics of potential events are important to them in addition to the narrower calculations of probabilities and expected losses on which expert rankings are largely based.

The differing views of the public and technical experts from industry or government laboratories toward cleanup of government-owned hazardous waste sites in the United States illustrate the nature of the problem. After many years of study, the experts have quite clear ideas of the major contaminants, their principal pathways, and the environmental costs and benefits of alternative cleanup strategies. People in local communities and throughout the country, however, maintain that values such as uses of the areas by migratory animals, the extent of public

1. Paul Slovic, "Perceptions of Risks," *Science*, 236:280-85 (1987).

involvement in decision making, or the religious importance of some sites to local Indian nations have been ignored. They are also concerned about the perceived catastrophic effects of several extremely low probability sources of emissions considered to be irrelevant by experts. The ensuing lack of agreement on which risk characteristics should be valued, and how, has resulted in a costly paralysis of the country's cleanup efforts and an alarming loss of confidence in the capabilities of government risk managers.

The case-by-case nature of risk reduction efforts in itself can pose a problem because it has the effect of legitimizing only particular types of actions. Thus an individual may be concerned about a broad class of environmental risks, but the only opportunity for expressing these preferences may be through referenda or regulations focused on specific actions that are only distantly related to the more fundamental concern. Because the resources for risk reduction activities are scarce, highly valued risk management initiatives may be neglected due to the lack of a suitable forum for their expression.

The principle seems clear that risk management decisions should be more sensitive to what really matters to people by taking account of their informed valuations of the differing characteristics of environmental risks.[2] Sorting out confusion from legitimate values may well be a problem in specific applications, however.

2. Richard H. Pildes and Cass R. Sunstein, "Reinventing the Regulatory State," *University of Chicago Law Review*, 62:1-129 (1995).

Economic measures of loss

Environmental resources, like other goods or assets, have economic value to the extent that people are willing to make sacrifices of other things in order to acquire them or to prevent their loss. If a person is willing to pay, for example, $10 to enjoy a day of fishing, we can say that this individual is willing to sacrifice the $10—or really the things that $10 could buy—in order to acquire a day of angling and this is therefore its economic value. It does not matter whether or not the $10 is actually paid, so long as we are sure that this person would really be willing to pay it if necessary. Similarly, if a person would take no less than $20 to accept the loss of access to a park, we can say that he or she would be willing to give up what $20 would buy and so this is the person's economic valuation of the loss of the park. Thus the economic value of gains is measured by how much people are willing to pay (WTP) to acquire them, and the value of losses is measured by how much people demand to accept them (their willingness to accept [WTA]).

Until recently there was little disagreement with a conventional assumption that these two measures of economic value, WTP and WTA, would be, for all practical purposes, equivalent. That is, except for limitations of wealth on the amount that individuals could pay, and similar income effects, estimates of both measures would yield the same value. Consequently, despite wide agreement that WTA is appropriate for assessing the value of losses, the equivalence assumption has been

used to justify the nearly universal practice of using the WTP measure to assess both gains and losses.

The empirical evidence strongly shows, however, that people commonly value losses more highly than otherwise commensurate gains. Results of tests demonstrating large disparities in valuations of environmental losses were first reported two decades ago, based on responses to hypothetical questions indicating that duck hunters would demand four times as much money to give up habitat than they were willing to pay to maintain the same resource.[3] Other studies based on real exchanges of money and goods showed similar differences. Further tests, using a variety of methods and controlling for such factors as strategic behavior, repeated bids and offers, and income constraints, have provided numerous replications of this basic finding,[4] with the WTA measure typically found to be from two to five or more times larger than the WTP measure.

Given the large difference between the two measures, using the amount of money that people are willing to pay to prevent a loss to assess its value is, on present evidence, almost certain to seriously bias environmental decisions and environmental risk assessments. Too few restrictions will be placed on activities posing environmental risks, as the losses will be systematically underestimated; compensation and damage awards will be too small to provide proper levels of deterrence; and too few efforts will be made to avoid environmental harms, as the value of their prevention will be inadequately assessed.[5]

Mitigation and compensation remedies

An important risk valuation issue concerns the development of appropriate remedies for harms to environmental resources attributable to human activities and actions. Whether before or after the fact, changes and remedies typically take one of two broad forms, mitigation or compensation. Mitigation refers to measures designed to either reduce the statistical risk of injury or decrease the adverse impact of a past harm. These might include, for example, redesign by installing double liners around a waste site, changes in operations by including local participation on a facility's operating board, or restoration of a damaged coastline through habitat enhancement. Compensation generally takes the forms of monetary payments or in-kind transfers to affected individuals and groups. These may include, for example, tax reductions, property value guaran-

3. Judd Hammack and Gardner Brown, *Waterfowl and Wetlands: Toward Bioeconomic Analysis* (Baltimore, MD: Johns Hopkins University Press, 1974).

4. Daniel Kahneman, Jack L. Knetsch, and Richard H. Thaler, "Experimental Tests of the Endowment Effect and the Coase Theorem," *Journal of Political Economy*, 98:1325-48 (1990). An extensive review of many of these studies is provided in Elizabeth Hoffman and Matthew L. Spitzer, "Willingness to Pay vs. Willingness to Accept: Legal and Economic Implications," *Washington University Law Quarterly*, 71:59-114 (1993).

5. Jack L. Knetsch, "Environmental Policy Implications of Disparities Between Willingness-to-Pay and Compensation-Demanded Measures of Values," *Journal of Environmental Economics and Management*, 18:227-37 (1990).

tees, or the construction of new recreation or health facilities in an affected locality.[6]

While risk management strategies commonly involve both mitigation to reduce harmful impacts and compensation to offset the consequences of environmental losses, conventional risk analysis is subject to a bias that unduly favors compensation remedies. The source of the bias is an assumption that compensation is likely to be more efficient than mitigation remedies because compensation allows injured parties to use an award for whatever they value most, whereas mitigation restricts the remedy to reducing a specific injury, which may not be the thing of highest value. However, the assumed superiority of compensation over mitigation ignores people's greater valuations of losses relative to gains. This pervasive asymmetry suggests that compensation may be a less, rather than more, efficient remedy for environmental losses; mitigation provides a highly valued reduction of a loss whereas compensation leaves people with the loss and provides a less valued gain of money or whatever in-kind change is on offer.

Time

Risk management commonly involves decisions about whether or not to initiate precautionary efforts to reduce the possibility of environmental losses that might take place decades, or even centuries, in the future. An important valuation issue is, therefore, how costs and benefits occurring at different times should be compared.

Current practice calls for weighing the importance of future gains and losses by discounting with a particular interest, or discount, rate. The procedure is analogous to compounding a present sum into the future: $100 compounded every year at a 6 percent rate would be worth $1842 at the end of fifty years, and a benefit or cost estimated to be worth $1842 fifty years in the future would, at a discount rate of 6 percent, be worth the equivalent of having $100 today. Normal procedures and analyses suggest that it is worth taking precautions today to prevent a loss worth $1842 accruing in fifty years only if the current cost is less than $100; if greater, then it would not be worth doing because the future loss counts for less than the prevention costs incurred today.

Most of the debate in the past has concerned the choice of a specific discount rate; there has been little questioning of the standard procedure of using whatever rate is selected to discount all future gains and losses by a constant rate. The results of recent research indicates, however, that a constant and unvarying discount rate may provide a poor reflection of people's actual time preference and choices.

Both anecdotal evidence and the results of controlled tests suggest that people have widely varying rates of time preference, depending on the particular circumstances or characteristics of a potential future event or outcome. For example, many individuals simultaneously borrow and save at differing rates, particularly in

6. Robin Gregory et al., "Incentive Policies to Site Hazardous Waste Facilities," *Risk Analysis*, 11:667-75 (1991).

connection with purchases of consumer durables; they frequently choose wage time patterns that may not be in their best financial interest; and they choose sequences of pleasurable and onerous events that are inconsistent with positive discount rates. Further, people appear to have much lower discount rates for long periods in the future than for short times, to discount future gains at a higher rate than future losses, and to use lower rates in discounting more important future outcomes.[7] Thus there is little evidence that individuals use a constant and unvarying rate to discount all future outcomes.

To the extent that the results of recent studies accurately depict people's true time preferences, they hold substantial implications for environmental risk valuations. Incurring present costs to avert potentially catastrophic losses far in the future, which would not appear to be worth undertaking using the constant discount rates of standard analyses, may well be economically worthwhile when account is taken of the lower time preference rates for losses, for longer time horizons, and for more important outcomes. For similar reasons, there may be less economic justification for actions that provide short-term benefits at the expense of costs accruing over future decades. Thus valuations of the benefits and costs of proposed climate-change actions, risk management proposals for dealing with hazardous wastes, and strategies for maintaining the productivity of natural systems might well differ substantially depending on whether the standard invariant discount rate is used or whether the choice of rates reflects the empirical evidence of people's actual time preferences.

7. Richard H. Thaler, "Some Empirical Evidence on Dynamic Inconsistency," *Economic Letters*, 8:201-7 (1981); George Loewenstein and Drazen Prelec, "Anomalies in Intertemporal Choice: Evidence and an Interpretation," *Quarterly Journal of Economics*, 107:573-97 (1992).

VALUATION TECHNIQUES AND STRATEGIES

There are no active and competitive markets for many environmental resources or amenities. People clearly value cleaner air and reductions in risks from groundwater contamination, but they do not purchase these in market exchanges as they do other valued goods such as food or most consumer products.[8] This is also the case with values that are not derived from direct use of the environment but instead are based on nonuse, or passive, values such as knowing that a species exists, having the option of being able to see it in the future, or being free of the guilt or feeling of responsibility of being even an indirect party to diminishing or degrading the quality of the environment.

This nonmarket, or nonpecuniary, nature of many environmental values in no way makes them less economically important. Nonpriced values still represent economic worth; people are willing to sacrifice other goods and services in order to preserve or obtain access to them.

The absence of prices, however, does make the assessment of envi-

8. Thomas C. Brown, "The Concept of Value in Resource Allocation," *Land Economics*, 60:231-46 (1984).

ronmental values much more difficult. Instead of direct observations of prices, which measure the added costs of supplying more of a product and the added benefits of consuming it, assessments of environmental values frequently must depend in large part on indirect measures of value. Consequently, while a narrow range of such impacts can be estimated with useful precision, there is as yet no generally applicable method that is agreed upon as yielding appropriate assessments of environmental values, and particularly none for measuring the costs of increased exposure to environmental losses.

In some instances, an action may lead to an environmental disruption that can be remedied by replacement or restoration, and implementation costs then may serve as a useful indication of the value of the loss.[9] However, the costs serve as a measure of loss only when the harm lends itself to full replacement or restoration, in the sense that the restored asset is taken as a complete substitute for the original endowment. The number of cases of such convergence are likely to be limited in practice.

Another instance in which market prices can be indirectly used is the so-called hedonic price method of valuation. There is usually no market for scenic views, for example, but the value of such an amenity may be captured in the price of land or houses. The value of the view is then measured by the difference in prices of houses with and without a view. While this method provides a means for estimating environmental values, the number of cases relevant to risk management in which it could be used is limited.

A somewhat related, and widely discussed, method of valuing environmental assets such as parks or other areas that prompt direct use is the travel cost method. Using the relationship between the number of people who visit a site and the travel costs they incur, this technique derives an estimate of how much visitors would pay over and above their cost of travel to gain access to the site. This provides a valid estimate of the value of the site. The value, however, is in terms of how much current users are willing to pay to use the site and not how much they would need to be compensated to forgo this use due to loss or degradation of the resource. Further, the method is limited to valuations of particular sites that are visited by people and has little applicability to more general environmental values that may be at risk.

By far the most widely used means of estimating environmental values is the contingent valuation method, in which respondents are asked to state the maximum amount of money they would be willing to pay to obtain more of a desired good or to reduce their exposure to an environmental disruption or loss. Several question formats are used and, with varying success, they produce estimates for a nearly limitless range of applications. Contingent valuation techniques, however, are ill suited to establishing loss valuations in terms of people's willingness to accept compensation to agree to give up an envi-

9. Raymond J. Kopp and V. Kerry Smith, eds., *Valuing Natural Assets: The Economics of Natural Resource Damage Assessments* (Washington, DC: Resources for the Future, 1993).

ronmental asset. Further, recent research has shown that the method is very susceptible to hypothetical effects, as actual payment levels tend to be much smaller than those indicated by respondents; to anchoring effects, whereby people are influenced by initial sums or suggested payment levels; and to factors such as embedding, in which the value of an asset can vary widely depending on how it might be combined with other goods.[10] There is also evidence that survey respondents will pay close attention to contextual cues and construct their expressed environmental values during the elicitation process rather than simply reveal them.[11] As a result, responses to contingent valuation questions may tell little about people's economic measures of value.

Recognition of these serious limitations of current valuation methods has motivated a wider search for alternative approaches that can provide useful guidance for policy design and management choices. At least three general strategies offer promise of yielding information that may well be superior, at least for some purposes, to the valuation numbers provided by more traditional methods.

The first approach focuses on the concerns of a small group of individuals who are selected to be representative of the key interests potentially affected by a proposed action. Elicitation procedures drawn from decision analysis are used to define and clarify their objectives, to determine how alternative actions would contribute to these objectives, and to structure and integrate value tradeoffs as a means for rating the worth of policy alternatives. These value integration procedures are often lengthy, but they have been used with success in several complex environmental risk cases.[12]

A second alternative approach relies on a small group of people who together form a values jury.[13] Members of an environmental values jury would act as direct representatives of the larger society, including future citizens who might be affected by an action or decision, in much the same way that jurors frequently are asked to address other tough social problems, such as guilt, responsibility, and compensation awards.

Both the values integration and jury approaches could be used to assess specific environmental risks or to select a preferred course of action from a set of alternatives that imply different environmental risks. This latter use of the approaches, which relies on a comparative judgment, can be helpful because it permits concerned parties to participate directly in the creation of alternatives and because it avoids the often difficult estimation of explicit values.

10. Daniel Kahneman and Jack L. Knetsch, "Valuing Public Goods: The Purchase of Moral Satisfaction," *Journal of Environmental Economics and Management*, 22:57-70 (1992).

11. Robin Gregory, Sarah Lichtenstein, and Paul Slovic, "Valuing Environmental Resources: A Constructive Approach," *Journal of Risk and Uncertainty*, 7:177-97 (1993).

12. Robin Gregory and Ralph Keeney, "Creating Policy Alternatives Using Stakeholder Values," *Management Science*, 40:1035-1048 (1994).

13. Thomas C. Brown, George L. Peterson, and Bruce E. Tonn, "The Values Jury to Aid Natural Resource Decisions," *Land Economics*, 71:250-60 (1995).

A third strategy centers on the derivation of a "damage schedule" that would provide scaled rankings of the relative importance of various environmental harms. The rankings reflect relative values, of which people are more certain, rather than absolute values, of which people are far more uncertain.[14] These rankings would form the basis for the design of various forms of regulatory or other controls and for the setting of damage awards, much in the way that schedules now are used to settle worker's compensation claims and establish workplace safety regulations.

CONCLUSION

The desire for improved risk assessments has led to new demands for environmental valuations to resolve disputes, to set damage awards, and to determine preferred allocations of environmentally sensitive resources. Such valuations would allow comparisons of the consequences of environmentally risky activities across a range of alternative actions.

Substantial progress has been made in recent years, leading to greater understanding of key valuation issues and of the strengths and limitations of current methods. Research studies continue to uncover new behavioral considerations, revealing the multidimensionality of people's perceptions of risks, the disparities in their valuations of losses relative to gains, and how their time preferences vary depending on characteristics of the future outcomes at issue. Such findings have a great potential to improve environmental risk valuations and risk management.

The current strong demands for valuation numbers may divert such efforts, however, and could compromise the continued rapid progress being made in understanding risk valuation issues. The recent rapid advances in this area have come far less from massive evaluation exercises geared to some specific episode—and real or threatened litigation—than from careful research. There is little reason to expect this pattern to differ greatly in the future.

14. Murray B. Rutherford, Jack L. Knetsch, and Thomas C. Brown, "Assessing Non-Pecuniary Environmental Losses: Rankings and Interim Damage Schedules" (Working paper, Simon Fraser University, 1995).