STEPHEN POLASKY
SETH BINDER

Valuing the Environment for Decisionmaking

In dealing with complex environmental issues, determining the value of multiple environmental attributes is problematic, but not doing so is even more so.

Making thoughtful decisions about environmental challenges that involve wide-ranging and potentially irreversible consequences is of profound importance for current and future human well-being. How much and how fast should greenhouse gas emissions be reduced to minimize global climate change? What standards should be set for air and water quality? What should be done to protect biodiversity and to maintain ecological processes? Addressing such questions involves weighing benefits and costs in multiple dimensions. In spite of the high stakes, however, the nation—its government and society—often fails to take systematic account of the environmental consequences in its actual decisionmaking and instead follows standard operating procedures or existing legislative mandates, or simply muddles through.

Virtually all important environmental management and policy decisions have a wide range of effects. For example, zoning or development decisions about land use can have a variety of environmental impacts (for example, on local water and air quality, the potential for flooding downstream, carbon sequestration, and habitat for wildlife) as well as economic and social effects (on economic development, jobs, and income). Similarly, decisions on limits on emissions of air pollutants or greenhouse gases can affect a range of environmental, economic, and social concerns. These results affect multiple groups who often have very different views about desired outcomes (for example, developers versus environmentalists). Effects differ across geography (upstream versus downstream) and time (current versus future impacts). Choosing among management or policy options that differ in terms of environmental, economic, and social outcomes with spatial and temporal components may at first glance seem overwhelmingly complex, with dimensions that seem incomparable. Good environmental management and policy decisionmaking, however, necessitates systematic evaluation and consideration of the effects of management and policy on the affected public. Even though the quantitative valuation of these effects will never be perfect, the outcome of attempts to assess value provides important information to help guide decisionmaking.

Decisions, decisions

Management and policy decisions typically involve difficult tradeoffs that bring improvements in some dimensions and declines in others. Ultimately, deciding whether to choose management or policy alternative A or B requires an evaluation of whether A or B is "better," where better is determined by the objectives of the decisionmaker. It is easy to conclude that one alternative is better than another if it is better in all dimensions. But making comparisons in which one alternative is better in some dimensions but worse in others requires making difficult value judgments. For example, clearing land for housing development may result in higher incomes and more jobs but reduce habitat for species and worsen local water quality. Whether land clearing is the right decision will depend on whether an increase in incomes and jobs is valued more highly than maintaining habitat and water quality. But how can one really compare income versus habitat for species or jobs versus water quality? Comparing across these different dimensions seems like comparing the proverbial apples and oranges. Reaching an environmental management or policy decision, though, requires the decisionmaker to compare apples and oranges, either explicitly or implicitly.

For an individual, deciding which college to attend, where to live, or what job to take is often a hard choice to make, in large part because it involves changes in multiple dimensions simultaneously. Moving to a new job in a new city may be a better professional opportunity and offer a new set of cultural amenities, but is it worth disrupting family life, moving away from friends, and making adjustments to a new community? Though it is difficult to compare such alternatives, people do make these decisions all the time. In choosing an option, taking account of all the factors, people make a determination that one option is better than the other available options.

As difficult as such choices can be for an individual, making environmental management and policy decisions adds yet another level of complexity. Such decisions affect many people simultaneously and thus require finding a way to aggregate values across different people to reach a decision. Management and policy decisions can make some groups better off while making others worse off, requiring a different sort of apples-and-oranges comparison.

Two methods used in such multidimensional, multiperson decisionmaking contexts are economic benefit/cost calculations and multicriteria decision analysis (MCDA). Each of these methods transforms a complex multidimensional problem involving multiple people into a single dimension that can be used to rank alternatives. These methods act like a blender that mixes apples and oranges to produce a fruit smoothie. Decisionmakers can then decide which fruit smoothie they like the best.

Economics reduces multidimensional problems to a single dimension by measuring the value of changes in each dimension with a common metric, which is typically, but not necessarily, a monetary metric. Economists tend to prefer a monetary metric because it is a pervasive, intuitive, and easily observable measure of the values that people attribute to an array of everyday goods and services. In well-functioning markets, the price of a good or service reflects its marginal value to the buyer measured in terms of the common monetary metric: what the buyer is willing to pay to have the good or service. This fact makes the marginal values of many very different goods and services commensurable. The concept extends even to environmental attributes that do not have a market value, such as clean air, as long as people are willing to make tradeoffs in their consumption of some market goods in order to obtain other nonmarket attributes.

The ability to measure values with a common monetary metric rests on two key premises. First, individual willingness to pay for an item is assumed to accurately represent the value of that item to the individual: that is, how much better off the individual is with the item than without the item, measured in monetary terms. Second, the aggregation of values to the societal level requires that the correspondence between willingness to pay and well-being be comparable across individuals, so that a measure of societal value is equal to the (appropriately weighted) sum of values across all individuals in society. This comparability is necessary in order to do benefit/cost analysis resulting in a single number that summarizes social net benefits.

With the ability to produce an aggregate social net benefit calculation for any policy option, the economic benefit/cost decision rule is simple: Choose the option that maximizes social net benefits. This simple rule can be extended to account for uncertainty by maximizing expected social net benefits, where net benefits for individuals can include risk aversion (that is, a willingness to pay to avoid being subjected to uncertain outcomes). The decision rule can also incorporate constraints that restrict outcomes, so that they do not violate minimum environmental standards

ISABELLA KIRKLAND, *NOVA: Understory*, Archival ink jet print, 61.75 x 50.75 inches, 2011.
Courtesy of Feature Inc., New York.

or basic human rights. As noted, however, the social net benefit calculation requires that individuals evaluate multiple dimensions with a single monetary metric of value and that these values be comparable across individuals. Without such interpersonal comparability, management or policy changes resulting in both winners and losers cannot be evaluated. In this case, only alternatives in which everyone is better off are clearly superior, and such alternatives are extremely unlikely to emerge.

Benefit/cost calculations have been applied to a wide variety of environmental policies. All recent presidents, both Democratic and Republican, have required agencies to evaluate the benefits and costs of regulations, including environmental regulations. Executive Order 12866 signed by President Clinton in 1993 states that agencies "shall assess both the costs and the benefits of the intended regulation" and "in choosing among alternative regulatory approaches, agencies should select those approaches that maximize net benefits" The Environmental Protection Agency (EPA) has done extensive benefit/cost calculations of regulations, particularly regulations under the Clean Air Act. The EPA estimated that the 1990 Clean Air Act would provide benefits of $2 trillion between 1990 and 2020 while imposing costs of $65 billion, a benefit-to-cost ratio of approximately 30-to-1. A prior study of the benefits and costs of the Clean Air Act from 1970 to 1990 found a similarly large benefit-to-cost ratio.

The economic benefit/cost approach to maximizing social net benefits may be thought of as belonging to the broader class of MCDA methods, all of which require explicit or implicit weighting of various attributes of expected outcomes of management or policy decisions. Although some MCDA methods accommodate only quantitative attributes, others also permit qualitative attributes. Given attributes and weights, different MCDA methods take different approaches to evaluating alternatives. Some methods seek to identify the best alternative, similar to the economic approach of maximizing social net benefits, while others, such as goal programming, seek to identify alternatives that meet certain thresholds of performance. In goal programming, aspirational or minimally acceptable thresholds are set for each criterion, and alternatives are evaluated according to the priority-weighted distances by which criteria fall short of these thresholds. In general, MCDA methods seek to maximize a social welfare function of a particular, often implicit, form.

Setting relative values

To be operational, benefit/cost and MCDA methods require information on relative values (weights) for different dimensions of value affected by environmental management or policy. Economics and decision sciences tend to take different approaches to assembling information about values. In economics, the values of different management or policy options are derived from aggregating the net benefits to individuals in society for that option. In decision sciences, a variety of methods are used to assemble information on weights to assign to different dimensions.

Antonio Briceño, *Firewood*, from the *Millions of Pieces: Only One Puzzle Project*, Digital c-print on Fuji Crystal Archival paper, 21 x 60 inches, 2010.

The task of the economist in understanding relative values for an individual is far easier for marketed goods and services than for nonmarketed environmental attributes. For marketed goods and services, economists use observations on how much is purchased at a given price over a range of different prices to construct a demand function. The demand function summarizes information on the willingness to pay of the individual for the good or service. In competitive markets, the supply function reflects the marginal cost of producing the good or service. Demand and supply can be used to define economic surplus, which is the difference between the (marginal) willingness to pay given by demand and the marginal cost of production given by supply. Summing up this difference over the entire quantity traded is equal to economic surplus; that is, the value generated from the production and consumption of the good or service.

Some environmental changes directly affect marketed goods and services, and the value of these effects can be evaluated by assessing the net change in economic surplus in the affected markets. Take, for example, the potential effects of excess nutrients in a body of water that cause dead zones (areas of low oxygen), resulting in lowered fish and shellfish populations and reduced commercial harvests. With basic information about consumer demand and the costs of supply, economists can estimate the expected loss in economic surplus from the reduction in harvests. Adjustments to economic surplus calculations are necessary when market imperfections, such as monopoly pricing, taxes, or subsidies, result in price distortions so that prices are not a true reflection of the value of marketed goods and services.

The concept of economic surplus (value) also applies to environmental attributes, such as clean air or access to natural areas, for which there is no market. Valuing nonmarket goods and services is more difficult, because there is no readily observable signal of value that is comparable to a market price. Economists have devised a suite of nonmarket valuation tools that can be applied to value nonmarketed environmental attributes. Some nonmarket valuation methods use observable expenditure on a different marketed good or service to draw an inference about the value of the nonmarketed environmental attribute of interest. For example, housing prices may reflect the increased willingness to pay for housing in locations with better environmental amenities, such as access to lakes and parks or better air quality. The choice of where to recreate can reveal information about the relative value of environmental amenities that vary across recreation sites. Other methods of estimating value record changes in expenditures, such as changes in the cost to treat drinking water with changes in water quality.

Economists cannot use observed expenditures to value all important changes to the environment. For example, if all of the lakes in a region are polluted and no one uses them for recreation, it will be difficult to assess the value of reducing pollution on recreational value, unless one is willing to make inferences from other regions. More fundamentally, there are limited or no directly observable expenditures or other behavioral clues for some environment attributes, particularly non-use benefits such as knowing that species exist. In

ANTONIO BRICEÑO, *Overfishing*, from the *Millions of Pieces: Only One Puzzle Project*, Digital c-print on Fuji Crystal Archival paper, 21 x 60 inches, 2010.

the absence of observable behavior, economists use survey questions to ask people about values for changes in environmental attributes. Such "stated preference" methods include contingent valuation and conjoint analysis. The contingent valuation method presents survey respondents with a hypothetical change in the environment, such as a 10% increase in the size of humpback whale populations, and asks whether they would be willing to pay a specified amount for the change. Varying the specified amount and observing the proportion of people saying yes generates information analogous to a demand curve for marketed goods and services. In conjoint analysis, people are asked to rank a series of outcomes that differ in the quantities of various attributes. Conjoint analysis allows direct evaluation of how people trade off one attribute versus another, such as an improvement in air quality versus greater access to open space. If one of the attributes is income or expenditure, then the analyst can also estimate willingness to pay.

Some actions, such as emissions of greenhouse gases, cause changes in multiple dimensions that occur over extended periods. For example, a change in carbon storage in ecosystems that reduces atmospheric concentrations causes changes in climate forcing and ocean acidification, which in turn affect myriad other environmental attributes, including precipitation patterns, with effects on agricultural production, the probability and severity of flooding, and the health of marine resources, among others. Summarizing the value of all these changes into a single estimate of the social cost of carbon (SCC) requires complex integrated assessment models that predict both environmental and economic outcomes and attach estimates of the value of those outcomes. Further complicating matters, SCC estimates depend on levels of emissions that can be affected by the very policy choice that SCC is meant to inform. For this reason and others, such as the choice of social discount rate, the estimates of the SCC range from near zero to hundreds of dollars per ton of carbon.

Instead of the often-complex process of economic valuation, MCDA typically relies on a set of alternative methods for establishing relative values or weights on different criteria, to be chosen by the decisionmakers. The identification of weights may be done by introspection, deliberation, or negotiation—or some combination of the three—among stakeholders. Setting relative weights may also be done as part of an iterative process in which alternatives are evaluated, weights reassessed in light of the evaluation, and new criteria weights applied.

One example of how relative weights for different criteria are set in MCDA is through application of the analytical hierarchy process. In this process, decisionmakers are asked to determine a set of top-level criteria, and within each of these to determine the subcomponent criteria. They are then asked to rank the relative importance of criteria at each level of the hierarchy. For example, suppose a decisionmaker is evaluating policies aimed at controlling non–point-source pollution from agriculture with two overarching criteria of water quality and economic effects. If these criteria are assigned equal importance, then each receives a weight of 0.5. At the next level of hierarchy, suppose that the water quality criteria include water clarity, dissolved oxygen content, and temperature, and that the economic criteria include farm income and jobs. If the decisionmaker believes that water clarity is twice as important as dissolved oxygen, and dissolved oxygen is twice as important as temperature, their weights at this level of hierarchy are 4/7, 2/7, and 1/7, respectively. Suppose that jobs are ranked as twice as important as farm income, then the weights would be 2/3 and 1/3. The overall weights in the analysis would then be 0.5 times these values: 2/7 for water clarity, 1/7 for dissolved oxygen content, 1/14 for water temperature, 1/3 for jobs, and 1/6 for farm income.

A potentially important difference between economic and MCDA approaches to valuation is in whose values are incorporated. In principle, valuation in benefit/cost assessments includes the value of everyone affected by management or policy choices, though in practice there may be questions about whether economic valuation methods accurately reflect societal values. In MCDA, it is typically a smaller subset of people that is involved in setting relative weights. For local-scale problems, MCDA methods could include all affected parties in a deliberative process, but as the scale of the problem grows, this will not be possible. For larger-scale environmental problems, ranging up to global concerns such as climate change, there is the question of representation and whether those present adequately reflect the views of the wider public. In addition, relative weights in MCDA should not be treated as constant but should reflect changes in circumstances, something that is typically captured in economic valuation methods.

Weighty issues

Any environmental management or policy decision is likely to entail winners and losers. How should the distribution of benefits and costs across groups be treated in environmental management and policy decisions? Critics of benefit/cost analysis contend that reliance on economic valuation systematically disadvantages those with less money. Greater wealth means greater ability (and thus willingness) to pay, so benefit/cost analysis effectively gives more weight to those with more money ("voting with dollars"). One way to answer this criticism is to give a higher weight to the values of those with less wealth. Economists have found considerable evidence of diminishing marginal utility of income, meaning that the value of an additional dollar to a poor person is greater than to a rich person. This fact can be used to justify "equity weights" based on differences in wealth. For example, an equity weight argument would mean that otherwise equal damages from future climate change should be given greater weight in low-income countries than in high-income countries. In addition, if society is committed to protecting the interests of particular groups, it can constrain consideration of options to those that achieve specified distributional goals.

Since the effects of alternative environmental management and policy options will differ across generations, a fundamental challenge in valuing environmental management and policy decisions is how to aggregate benefits and costs that accrue to current and future generations (inter-generational distribution). For example, more aggressive climate change mitigation strategies impose costs on the current generation but generate benefits for future generations.Economists typically use discounting to aggregate benefits and costs over time. The standard economic rationale for discounting is that investments yield a positive expected real rate of return, so that having a dollar today is worth more than having a dollar in the future. Costs and benefits realized at different points in time are thus commensurable in present value terms after discounting.

The standard discounting approach works well for near-term private investment decisions, but what about for long-term social decisions affecting the welfare of future generations? If one accepts the principle of equal moral standing of all generations, there would seem to be little ethical justification for discounting future welfare. Frank Ramsay, the father of economic approaches to discounting and growth theory, maintained that it was "ethically indefensible" to treat the welfare of current and future generations differently. However, to the extent that future generations are expected to be better off than the current generation, discounting can be justified as an intergenerational application of equity weights. By the same principle, if environmental conditions worsen significantly and future generations are expected to be less well off than the present generation, this would imply a negative discount rate; that is, discounting of present benefits relative to future benefits. As recent debates on climate change policy aptly illustrate, there is little agreement among economists, or between economists and

KATJA LOHER, *Bee-Doublebubble (Why Did the Bees Leave?)*, Video sculpture; 9:00 minutes, 14 x 14 x 10 inches, 2012.

VINCENT CALLEBAUT, *Aerial View of Coral Reef, A Matrix and Plug-In For 1000 Passive Houses, Port-Au-Prince, Haiti*, Archival ink jet print of architectural rendering, 19 x 23.5 inches, 2011.
Courtesy of Vincent Callebaut Architectures, Paris.

others, on discounting.

Uncertainty is a central issue in environmental management and policy. Uncertainty enters at various steps in the link between management and policy choices and eventual effects on the value of outcomes. There can be uncertainty about how changes in management or policy affect choices made by individuals and businesses (behavioral uncertainty), how changes in human actions affect the environment (scientific uncertainty), and how consequent changes in the environment will affect human well-being (value uncertainty). Recent work on the value of ecosystems services illustrates each of these uncertainties. For example, the Conservation Reserve Program, which pays landowners for taking land out of production and restores perennial vegetation, can shift patterns of land use and, in turn, result in changes in carbon sequestration, water quality, and habitat provision. Program participation and the provision of services depend on the choices of individual landowners, which are uncertain. There are key gaps in the science linking land use to service provision, such as how changes in land use will affect changes in carbon storage in soil or populations of particular species, making provision uncertain even when behavioral uncertainty is ignored. There are also key gaps in information pertaining to the link between services and benefits, making value uncertain even if provision is known. The value of water quality improvement, for example, depends as much on who uses the water and for what purpose as on the water quality itself.

Economic approaches typically use an expected utility framework to deal with uncertainty, where the value of each potential outcome is weighted by its probability of occurrence. This approach summarizes expected social net benefits across dimensions, as discussed above, but also across all possible outcomes that could occur given a management or policy choice. Using the expected utility framework, however, requires information about probabilities as well as values under all potential outcomes. For environmental issues involving complex system dynamics, such as climate change or the provision of ecosystem services, the list of possible outcomes in the future may be unknown, much less how to specify probabilities or likely values for each of these outcomes. Beyond the challenge of scientific uncertainty, there may also be uncertainty about the preferences of future generation and how they will value various outcomes. Inability to objectively quantify probabilities or values requires modifying expected utility, such as by using subjective judgments to establish probabilities or values, or setting bounds on decisions thought to pose unacceptable risks (for example, safe minimum standards). A particular challenge to making decisions under uncertainty arises from consideration of catastrophic outcomes. It is difficult to set probabilities on such events because they are rare, but small changes in assumptions about these probabilities can lead to large changes in policy advice.

People make mistakes, often in systematic and predictable ways. They tend to be overly optimistic, biased toward the present, and averse to losses. They have trouble thinking through complex problems, especially those with uncertainty. Given these facts, some analysts question the validity of using valuation studies that rely on observed choices, survey responses, or even deliberative processes among affected parties as an important input for setting environmental policy. The alternative, however, would be to delegate judgments about the relative value of outcomes to political leaders or scientific experts. Elected leaders, at least in theory, should reflect public values. Environmental scientists, however, have no special claim to understanding public values. In either case, there is no guarantee that top-down decisions will reflect the underlying values of the public at large any better than an imperfect reflection of values gathered through valuation exercises.

In principle, economic valuation methods can estimate value for all environmental attributes, either through inferences from observable behavior or responses in stated preference surveys. In practice, however, it is generally not possible to get a complete economic assessment of all environmental values. Some values connected with the environment are notoriously difficult to assess in monetary terms. For example, what is the monetary value of conserving species with important spiritual or cultural value? Some critics contend that individuals are cognitively incapable of evaluating tradeoffs between utilitarian goods (such as commodities and ecosystem services) and moral goods (such as the existence of a species). There are sharp disagreements between psychologists and economists—and among economists themselves—on this point. Even when it is possible in principle to estimate monetary values, there may be insufficient data to do so. Nevertheless, economic methods can provide evidence about the value of many important environmental attributes.

The value of valuation

Though difficult, collecting information about the relative values of alternative potential outcomes, in all of their multiple dimensions, is vital to good environmental management and policy decisionmaking. Setting environmental policy is not simply a matter of applying the best science, as important as that is. Environmental management and policy typically involve making decisions about tradeoffs among multiple objectives about which society cares. Making decisions about such tradeoffs involves making value judgments. If these judgments are to improve human well-being, they should reflect the underlying values of individuals affected by the policy.

Economic valuation methods applied in the context of environmental management and policy seek to inform decisionmaking by collecting information about the value of alternatives to affected individuals and then aggregating these values to determine an estimate of social net benefits. In simple benefit/cost analysis, the management or policy option with the highest social net benefits should then be the preferred option. The great advantage of the simple benefit/cost approach is that it incorporates economic valuation methods to represent values of the affected public, summarizes this information into a single ranking, and uses this ranking to help guide policy. Valuation information can also be combined with other decisions rules, such as those that minimize the risk of bad outcomes occurring.

Rather than trying to summarize everything in a single number, as in simple benefit/cost analysis, it may be better to disaggregate results and report a wider set of results instead. Reporting a single number can hide important implicit value judgments. Though less tidy, reporting a set of results has the advantage of letting decisionmakers see important distributional consequences by reporting benefits and costs to different groups (such as income classes, geographic regions, and generations), as well as a range of possible outcomes under important sources of uncertainty. Additionally, results can be shown for different assumptions about important parameter values over which there may be disagreement (for example, the discount rate). Doing so makes clear the effect of different modeling and value judgments on the ranking of alternatives and lets decisionmakers better understand whether rankings are robust to changes in assumptions. For example, in reviewing efforts by economists to measure "inclusive wealth" intended to value all natural, human, manufactured, and social capital in order to provide a summary measure of sustainability, Joseph Stiglitz and Amartya Sen, two Nobel laureate economists, and colleagues concluded that such attempts overreach. Instead, they recommended that a number of measures be used, including biophysical measures in which the data or understanding are insufficient to provide trustworthy estimates of monetary value.

Regardless of whether a single number or set of results is reported for each management or policy option, analysts working in support of environmental decisionmaking have a duty to make the analysis transparent and the result clear. Why decisions are made can be explained and defended. "Black box" models that only experts understand are rarely trusted by nonexperts and often fail to build support for decisions or trust in the process of decisionmaking.

Because there is no such thing as a perfect assessment of environmental effects or associated values, decisionmakers and others should view the results of benefit/cost analysis or MCDA as input into the decisionmaking process, rather than uncritically accepting the results and implementing the highest-ranked alternative. But done well, assessments that incorporate valuation information can inform and improve environmental decisionmaking.

Recommended reading

Kenneth J. Arrow, Maureen L. Cropper, George C. Eads, Robert W. Hahn, Lester B. Lave, Roger G. Noll, Paul R. Portney, Milton Russell, Richard Schmalensee, V. Kerry Smith, and Robert N. Stavins, "Is There a Role for Benefit-Cost Analysis in Environmental, Health and Safety Regulation?" *Science* 272, no. 5259 (1996): 221–222.

A. Myrick Freeman III, *The Measurement of Environmental and Resource Values: Theory and Methods* (Washington, DC: Resources for the Future, 2003).

Peter Kareiva, Heather Tallis, Taylor H. Ricketts, Gretchen C. Daily, and Stephen Polasky, *Natural Capital: Theory and Practice of Mapping Ecosystem Services* (Oxford: Oxford University Press, 2011).

Guillermo A. Mendoza and H. Martins, "Multi-Criteria Decision Analysis in Natural Resource Management: A Critical Review of Methods and New Modeling Paradigms," *Forest Ecology and Management* 230 (2006): 1–22.

Nicholas Z. Muller and Robert Mendelsohn, "Measuring the Damages of Air Pollution in the United States," *Journal of Environmental Economics and Management* 54 (2007): 1–14.

National Research Council, *Valuing Ecosystem Services: Toward Better Environmental Decision-Making* (Washington, DC: National Academies Press, 2004).

Nicholas Stern, "The Economics of Climate Change," *American Economic Review: Papers & Proceedings* 98, no. 2 (2008): 1–37.

Joseph E. Stiglitz, Amartya Sen, and Jean-Paul Fitoussi, *Mis-Measuring Our Lives: Why GDP Doesn't Add Up* (New York: The New Press, 2010).

Richard S. J. Tol, "The Economic Effects of Climate Change," *Journal of Economic Perspectives* 23, no. 2 (2009): 29–51.

U.S. Environmental Protection Agency, Office of Air and Radiation, *The Benefits and Costs of the Clean Air Act 1990-2020* (Washington, DC: U.S. Environmental Protection Agency, 2011).

Stephen Polasky (polasky@umn.edu) is Fesler-Lampert Professor of Ecological/Environmental Economics and Seth Binder is a research fellow in the Department of Applied Economics at the University of Minnesota.