

Thinking Broadly About Costs and Benefits in Ecological Management

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ABSTRACT

Decisions regarding both human and natural systems often involve either explicit or implicit consideration of relative costs and benefits. These costs and benefits, however, go well beyond those captured in conventional economic cost–benefit analysis. It is not so much the mere consideration of costs and benefits that hampers cost–benefit analysis but, rather, the narrowness and incompleteness of the subset of costs and benefits that are usually considered. To use cost–benefit analysis for social decision making, one needs to think very broadly about which categories of costs and benefits need to be addressed (including effects on built, human, social, and natural capital as well as sustainable well-being) and deal with the inherent uncertainty and imprecision attached to many of the more important categories. One needs to consider the full range of possible values and valuation methods, to shift the burden of proof to the parties that stand to gain from the decision, to deal with the distributional consequences of decisions, and to be clear about the social goals being served by the decision. Failure to think broadly enough about costs and benefits leads to decisions that serve only narrow special interests, not the sustainable well-being of society as a whole.

Keywords: Cost–benefit analysis Social decision making Resource valuation Ecological management Sustainability

INTRODUCTION

Formal cost–benefit analysis (CBA) is a methodology that is usually associated with neoclassical economics, but the consideration of costs and benefits in decision making is much broader. Decisions regarding both human and natural systems often involve either explicit or implicit consideration of relative costs and benefits. These costs and benefits, however, go well beyond those captured in conventional CBA. It is not so much the mere consideration of costs and benefits that hampers conventional CBA but, rather, the narrowness and incompleteness of the subset of costs and benefits that are usually considered. To move beyond these limitations, we must significantly broaden the range of costs and benefits that are considered. We must include effects on the 4 main types of capital that contribute to human well-being: Built, human, social, and natural capital. We also must consider the sustainability of effects on well-being, the multiple goals being served, and the inherent uncertainty and imprecision attached to many of the more important categories. In the present paper, this broader, more comprehensive version of CBA will be referred to as broad CBA (BCBA).

An essential feature of any form (even this much broader form) of CBA is the ability to compare, rank, or weigh the costs and benefits. To do this, one ultimately needs to employ some form of valuation. Contrary to conventional wisdom, even multicriteria decision analysis (MCDA) and other

approaches not based on monetary valuation require valuation to reach a decision. In MCDA, the valuation is embedded in the ranking or weighting of alternatives, and this ranking typically is done by the decision makers for whom the MCDA is performed (Kiker et al. 2005). One can only avoid this valuation component in MCDA by stopping the analysis before reaching a decision and allowing the decision maker to draw their own conclusions, which means applying their own rankings and doing the valuation themselves internally. As long as someone, somewhere, has to make choices and trade offs between competing alternatives, this both implies and requires valuation, because any choice between competing alternatives implies that the one chosen was more highly valued. That the alternatives are competing is important, because if we can find a “win–win” solution, then no real choice is required, and we can avoid valuation. Many, if not most, decisions, however, involve the problem of having to weigh and aggregate the myriad different kinds of benefits of a proposed action against its costs. From the perspective of the earlier discussion, BCBA can be seen as a form of MCDA, in which the biophysical implications of alternatives are carried forward as far as possible in the analysis.

A further implication is that in BCBA, one cannot avoid valuation, but one needs to consider the full range of possible values and valuation methods. Beyond this, one needs to deal with other outstanding problem of conventional BCA. One needs to deal with uncertainty by shifting the burden of proof to the parties that stand to gain from the decision. One also needs to recognize and deal with the distributional con-

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sequences of decisions and to be clear about the social goals being served by the decision.

In most cases, benefits and costs are both poorly understood and poorly quantified. In addition to a broader set of categories of costs and benefits, the future vision and social goals that define the degree to which something is a benefit or a cost also needs to be broadened. When doing valuation in BCBA, we thus need to consider a broader set of goals that include ecological sustainability and social fairness, along with the traditional economic goal of efficiency.

VISIONS OF THE ECONOMY AND ITS RELATIONSHIP TO THE ECOLOGICAL LIFE-SUPPORT SYSTEM

Schumpeter (1954) emphasized the importance of a preanalytic vision of the world and its major problems. Schumpeter (1954) noted that vision of this kind not only must precede historically the emergence of analytic effort in any field but also may reenter the history of every established science each time somebody teaches us to see things in a way that goes beyond the previous understanding of the facts, methods, and results of the preexisting state of the science.

Our preanalytic vision is changing in many important respects. The evolution of the human economy has passed from an era in which human-made capital was the limiting

factor in economic development to the current era, in which the remaining natural capital has become the limiting factor (Costanza and Daly 1992; Costanza, Cumberland, et al. 1997). Basic economic logic tells us that we should maximize the productivity of the scarcest (i.e., limiting) factor as well as try to increase its supply. This means that economic policy should be designed to increase the productivity of natural capital and its total amount rather than to increase the productivity of human-made capital and its accumulation, as was appropriate in the past, human-made capital was the limiting factor. This implies a very different vision of the economy and its place in the overall system.

Of course, the relative productivity of natural capital depends on its marginal contribution to sustainable welfare relative to that of other forms of capital and on the substitutability between forms of capital. As discussed later, the choice of preanalytic vision determines the meaning and interpretation of these terms.

Figure 1a shows the conventional economic preanalytic vision. The primary factors of production (land, labor, and capital) combine in the economic process to produce goods and services (usually measured as Gross National Product [GNP]). The GNP is divided into consumption, which is the sole contributor to individual utility and welfare, and invest-

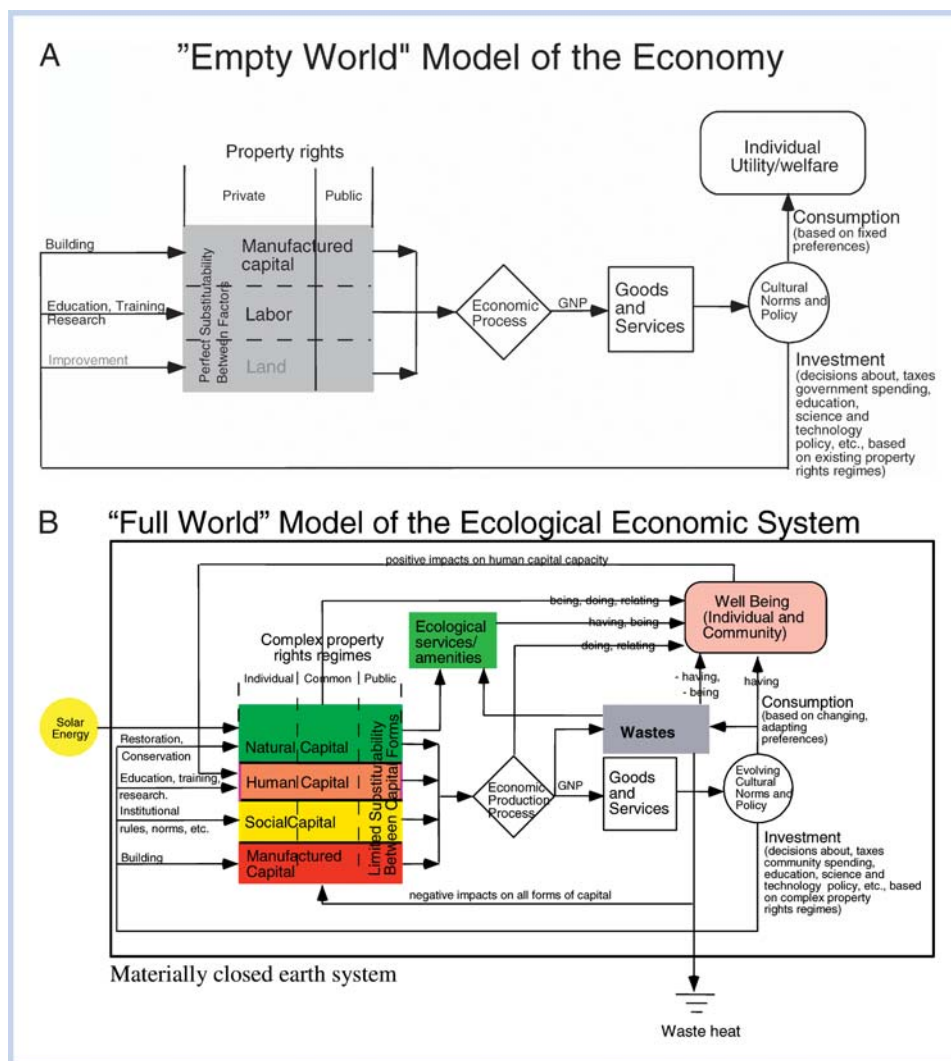


Figure 1. Empty world economics model (a) and expanded "full-world" model (b).

ment, which goes into maintaining and increasing the capital stocks. The circle labeled “economic policy” indicates that a primary economic decision has to do with how much of the GNP is consumed during this period versus how much is reinvested in building capital stocks so that we can produce and consume more in the future. Nothing in this vision of the economy would in any way limit or prevent the growth of capital, production, and consumption exponentially into the indefinite future. Preferences in this vision are fixed. Therefore, the goal is to satisfy those preferences as efficiently as possible, and the assumption is that more consumption is always better. In this model, the primary factors are perfect substitutes for each other (hence the dashed lines between them), and “land” (including ecosystem services) can be ignored almost completely. As Nordhaus and Tobin (1972) observed, the prevailing standard model of growth assumes no limits on the feasibility of expanding the supplies of nonhuman agents of production; it is basically a 2-factor model in which production depends only on labor and reproducible capital. Land and resources, the 3rd member of the classical triad, generally have been dropped, with the tacit justification that reproducible capital is a near-perfect substitute for land and other exhaustible resources. Property rights in the conventional vision usually are simplified to either private or public, and their distribution usually is taken as fixed and given. So, whereas lip service often is given to the importance of distribution issues, these issues usually are assumed to be outside the purview of economics.

Figure 1b shows an alternative ecological economics view of the process (Ekins 1992; Costanza, Cumberland, et al. 1997). Notice that the key elements of the conventional view are still present. More elements have been added, however, and some priorities have been changed. Limited substitutability exists between the basic forms of capital in this model, and their number is expanded to 4. Their names also have changed to better reflect their roles:

1. Natural capital (formerly land), which includes ecological systems, mineral deposits, and other aspects of the natural world.
2. Human capital (formerly labor), which includes the health and education of the human population, both the physical labor of humans and the know-how stored in their brains.
3. Manufactured capital, which includes all the machines and other infrastructure of the human economy.
4. Social (or cultural) capital, which is a recent concept that includes the web of interpersonal connections, institutional arrangements, rules, and norms that allow individual human interactions to occur (Berkes and Folke 1994).

Property-rights regimes in this model are complex and flexible, spanning the range from individual to common to public property. Natural capital captures solar energy and behaves as an autonomous, complex system, and the model conforms to the basic laws of thermodynamics. Natural capital contributes to the production of marketed economic goods and services, which affect human welfare. It also produces ecological services and amenities that contribute directly to human welfare without ever passing through markets. Waste also is produced by the economic process, which contributes negatively to human welfare and has a negative impact on capital and ecological services. Preferences are adapting and

changing, but basic human needs are constant. Human welfare is a function of much more than the consumption of economic goods and services. Direct interactions of various kinds (e.g., being, doing, and relating) with all forms of capital affect well-being in this model, as discussed later.

These visions of the world are significantly different. As Ekins (1992) points out, the complexities and feedback of model 2 are not simply glosses on model 1's simpler portrayal of reality. Instead, they fundamentally alter the perceived nature of that reality, and in ignoring them, conventional analysis produces serious errors. Before going further, we need to better define some difficult and often contentious terms surrounding value, values, and valuation.

DEFINITIONS OF VALUE

The terms value, valuing, and valuation have a range of meanings in different academic disciplines and in general usage. For example, value can refer to concepts as different as the numerical magnitude of a measurement (as in “the value of the variable at time t was x ”) to the worth or importance of a thing (as in the typical dictionary definition: To estimate the value, or worth, of; to rate at a certain price; to appraise; to reckon with respect to number, power, importance, etc.). What follows is an attempt to provide a set of consistent and useful definitions for the discussion ahead.

Ends versus means

An important distinction to make at the outset is that between “ends,” or goals or visions, and “means,” or methods to achieve those goals. Value is sometimes used to refer to the ends or goals themselves (as in “we value democracy” or “we value the protection of species”) and sometimes to refer to the means to the ends (as in “the value of this recreational experience is \$ x ”). This is further complicated by the fact that many ends can be “intermediate ends” and, thus, are in effect means to other ends. So, we can think of an “ends-means” spectrum or hierarchy, with some ends being more primary than others and some being considered “ultimate” ends.

Whether we think of something as an end or a means determines whether it makes sense to try to quantify its value. For example, the term “intrinsic value” is often used to refer to the value something has in itself or for its own sake (i.e., as an end or goal). Claiming that something is an end or a goal implies that it cannot be quantified further. One can talk about quantifying the contribution of something else toward achieving that goal (e.g., the value or relative contribution of a specific nature preserve in protecting species), but one cannot quantify the intrinsic value of protecting species. If, however, a goal or an end is considered to be intermediate and, therefore, a means to achieving a larger end or goal, then it can be quantified in terms of its relative contribution to achieving that larger goal.

Thus, means can be quantified, whereas ends cannot—unless they are seen to be intermediate ends toward achieving larger ends (and, therefore, are means to the larger end). The value of something as a means to an end is sometimes referred to as its “instrumental value.”

A further difficulty with the term intrinsic value is the implication that the value is, somehow, a property embedded in the object or the state of affairs itself. As described earlier, however, saying that something has intrinsic value implies that some human actors have decided that the object or state of affairs is an important end or goal. It is the human actors who

have assigned the intrinsic value, which is not a characteristic of the object or state of affairs itself. So, the term intrinsic value should be used sparingly, with the clear implication that it refers to a goal or an end assigned by human actors and is not further quantifiable. It is preferable to refer to goals or ends directly without invoking the term intrinsic value. One then can reserve the use of the term value to refer to the contribution of an object or action to achieving specific goals, objectives, or conditions (Costanza and Folke 1997).

We use the term “value systems” to refer to the constellations of norms and precepts that exist within human minds and guide human judgment and action. The term also refers to the normative and moral frameworks people use to assign importance and necessity to their beliefs and actions. Because value systems frame how people assign importance to things and activities, they also imply internal objectives. So, value systems are internal to individuals but are the result of complex patterns learned from an individual’s culture and may be externally manipulated through, for example, advertising. Preferences are a part of an individual’s value system, and these preferences may be in various states of completeness and stability, depending on the object or action being considered and the individual’s prior knowledge of it. The value of an object or action to an individual is coupled with that individual’s value system, because the latter determines the relative importance to the individual of an action or object relative to other actions or objects within the perceived world. Valuation, or valuing, is then the process of assessing the contribution of a particular object or action in meeting a particular goal.

Which ends?

While acknowledging that a range of goals exist (discussed later), for the purposes of this exercise we will consider the goal of sustainable human well-being as the ultimate goal being pursued. The preservation of ecological systems may be considered by some to be an ultimate goal or end in itself, but this assertion does not lead to any further quantification or assessment (and, thus, no valuation or valuing). Ecological systems also contribute to the goal of sustainable human well-being, and it is this contribution that we will assess in more detail later.

DETERMINANTS OF SUSTAINABLE HUMAN WELL-BEING

Given this goal, what methods are available to assess the relative contribution of objects or states of affairs in meeting the goal? Before getting there, however, we first briefly review the state of knowledge on the determinants of human well-being. What things influence well-being, and how?

Efforts to explain well-being have a long history, but there has been an explosion of interest and activity in recent years. Easterlin (2003) identified 2 main strands of prevailing theory in psychology and economics. The dominant theory in psychology has been the “set-point theory” (for a good recent review, see Lucas et al. 2003). This theory hypothesizes that each individual has a happiness set point determined by genetics and personality to which one returns after relatively brief deviations caused by life events or circumstances. This theory implies that the level of subjective well-being should not be affected at all by factors such as income, health, education, environmental amenities, and so on; it should be purely a function of the genetic makeup of the population.

Under this theory, we can do nothing about our “permanent” level of happiness.

The dominant theory in economics has been that more is better (Samuelson, 1947; Varian, 1987). Easterlin (2003) argued that “neither the prevailing psychological nor economic theories are consistent with accumulating survey evidence on happiness.” He argued that because of hedonic adaptation (i.e., people’s aspirations adapt to their changing circumstances) and social comparison (i.e., people judge their happiness relative to social peers rather than on an absolute scale), both the “set point” and “more is better” theories fail. Easterlin (2003) showed that subjective well-being tends to correlate well with health, level of education, and marital status, but not very well with income. He concluded that “people make decisions assuming that more income, comfort, and positional goods will make them happier, failing to recognize that hedonic adaptation and social comparison will come into play, raise their aspirations to about the same extent as their actual gains, and leave them feeling no happier than before. As a result, most individuals spend a disproportionate amount of their lives working to make money, and sacrifice family life and health, domains in which aspirations remain fairly constant as actual circumstances change, and where the attainment of one’s goals has a more lasting impact on happiness. Hence, a reallocation of time in favor of family life and health would, on average, increase individual happiness.”

Other studies have shown the importance of natural systems in contributing to subjective well-being. Recent research at the international scale (Vermuri and Costanza 2005) has shown that the United Nations Human Development Index, which includes proxies for both built and human capital, and an index of the value of ecosystem services per square-kilometer (as a proxy for natural capital) are significant factors in explaining reported life satisfaction (as measured using the World Values Survey during the 1990s) at the country level and, together, can explain 72% of the variation in reported life satisfaction.

Significant additional research is still needed, but 1 conclusion that can be drawn so far is that elements of built capital (income, wealth), human capital (health, education), social capital (family life, social networks), and natural capital (ecological systems and their services) all contribute to sustainable human well-being in complex ways. Learning to better assess the relative contributions of these elements and their interactions to sustainable human well-being (and, in particular, the relative contribution of ecological systems and services) is the challenge.

LIMITS OF SUBJECTIVE ASSESSMENTS

Before proceeding further, it is important to point out the limits of subjective assessments of both the state of well-being and the contributors to that state. People’s perceptions are limited. They do not have perfect information, and they have limited capacity to process the information they do have (Simon 1969; Augier 2001). Individuals may be unclear or uncertain of their goals, and an object or activity may contribute to meeting an individual’s goals without the individual being fully (or even vaguely) aware of the connection. This limitation probably is more important as it relates to the assessment of the contributors to well-being compared with assessment of the state of well-being itself. In other words, we can assume that people generally know if

they are feeling well or poorly, but they are less likely to know why. In addition, we have extrapolated from individual goals to the larger, shared goal of sustainable human well-being. So, the focus is on methods to achieve this ultimate, shared goal, and whereas individuals may be aware of the contributors to their individual well-being, they may be quite unaware of the contributors to the more aggregate well-being of the entire society. It also is clear that the aggregate well-being of human society is not the simple sum of the individual well-beings of its citizens.

Given these limits of subjective assessments, we can divide methods to value (i.e., to assess the degree of contribution to sustainable human well-being) of ecological systems and services into 2 broad groups: 1) Those that depend on subjective assessments of value, and 2) those that do not depend on subjective assessments but use other, more “objective” information. In fact, almost all practical applications involve both types of information to some degree.

VALUATION, CHOICE, AND UNCERTAINTY

The conventional vision or paradigm also assumes that tastes and preferences are fixed and given, and that the economic problem consists of optimally satisfying those preferences. Tastes and preferences usually do not change rapidly, and in the short run (i.e., 1–4 y), this assumption makes sense. However, preferences do change over longer time frames. In fact, an entire industry (advertising) is devoted to changing them, as is a large literature regarding how preferences change and how they are “constructed” (Gregory et al. 1993; Ready et al. 1995, 2001; Gregory and Slovic 1997; Norton et al. 1998; Payne et al, 1999). Sustainability is an inherently long-run problem, and in the long run, it does not make sense to assume that tastes and preferences are fixed. This is a very disturbing prospect for some economists, because it takes away the easy definition of what is optimal. If tastes and preferences are fixed and given, then we can adopt a stance of “consumer sovereignty” and just give the people what they want. We do not have to know or care why they want what they do; we simply have to satisfy their preferences as efficiently as possible. If, however, preferences are expected to change over time and under the influence of education, advertising, changing cultural assumptions, and so on, then we need a different criterion for what is “optimal,” and we have to figure out how preferences change, how they relate to this new criterion, and how they can or should be changed to satisfy the new criterion.

One alternative for this new criterion is sustainable human well-being itself, as discussed earlier. This criterion implies a 2-tiered decision process (Page 1977; Daly and Cobb 1989; Norton et al. 1998) of, first, coming to a social consensus on a sustainable scale and fair distribution and, second, using both the market and other institutions, such as education and advertising, to implement these social decisions. This might be called “community sovereignty” as opposed to “consumer sovereignty.” Straying from consumer sovereignty makes most conventional economists very uncomfortable, because it eliminates the tidy view of economics as simply the optimal satisfaction of a fixed set of preferences and opens a Pandora’s box of possibilities for manipulating preferences. If tastes and preferences can change, then who is going to decide how to change them? For example, a totalitarian government might not care at all about the preferences of its people and might

manipulate preferences to conform to the desires of a select elite rather than those of the society as a whole.

Two points need to be kept in mind in this regard: 1) Preferences are already being manipulated every day, and 2) we can just as easily apply open, democratic principles to the problem as we can hidden or totalitarian principles in deciding how to manipulate preferences. So, the question becomes whether we want preferences to be manipulated unconsciously, either by a dictatorial government or by big business acting through advertising, or whether we want to formulate preferences consciously, based on social dialogue and consensus, with a higher goal in mind. Ethics is the forging and revising of our existing preferences in the light of a higher goal. Taking preferences as given would mean that the ethical problem has been solved once and for all. Either way, this issue can no longer be avoided, and it can be handled best using open, democratic principles and innovative thinking.

VALUATION OF ECOSYSTEM SERVICES AND PREFERENCES

The issue of valuation is inseparable from the choices and decisions we have to make about ecological systems. Some argue that valuation of ecosystems is either impossible or unwise. For example, some argue that we cannot place a value on such “intangibles” as human life, environmental aesthetics, or long-term ecological benefits, but in fact, we do so every day. When we set construction standards for highways, bridges, and the like, we value human life—acknowledged or not—because spending more money on construction would save lives. Another often-made argument is that we should protect ecosystems for purely moral or esthetic reasons, and we do not need valuations of ecosystems for this purpose. Equally compelling moral arguments exist that may be in direct conflict with the moral argument to protect ecosystems, such as the moral argument that no one should go hungry. All we have done is to translate the valuation and decision problem into a new set of dimensions and a new language of discourse, one that in some sense makes the valuation and choice problem more difficult and less explicit.

So, whereas ecosystem valuation is certainly difficult, 1 choice we do not have is whether to do it. Rather, the decisions we make, as a society, about ecosystems imply valuations. We can choose whether to make these valuations explicit, whether to undertake them using the best available ecological science and understanding, and whether to explicitly acknowledge the huge uncertainties involved. As long as we are forced to make choices, however, we are doing valuation. The valuations are simply the relative weights that we give to the various aspects of the decision problem.

Society can make better choices about ecosystems if the valuation issue is made as explicit as possible. This means taking advantage of the best information we can muster and making explicit the uncertainties about valuations. It also means developing new and better ways to make good decisions in the face of these uncertainties. Ultimately, it means being explicit about our goals as a society, both in the short term and in the long term, and understanding the complex relationships between current activities and policies and their ability to achieve these goals.

This leads back to the role of individual preferences in determining value. If individual preferences change (in response to education, advertising, peer pressure, etc.), then value cannot originate completely with preferences. Value ultimately originates in the set of individual and social goals to which a society aspires.

VALUATION AND SOCIAL GOALS

As defined earlier, valuation refers to the contribution of an item to meeting a specific goal or objective. A baseball player is valuable to the extent that he contributes to the goal of the team's winning. In ecology, a gene is valuable to the extent that it contributes to the survival of the individuals possessing it and of their progeny. In conventional economics and conventional CBA, a commodity is valuable to the extent that it contributes to the goal of individual welfare, as assessed by individual willingness to pay and/or willingness to accept compensation. The point is that one cannot state a value without also stating the goal being served. Conventional economic value is based on the goal of maximization of individual utility. However, other goals (and, thus, other values) are possible. For example, if the goal is sustainability, one should assess value based on the contribution to achieving that goal, in addition to value based on the goals of individual utility maximization, social equity, or others that may be deemed important. This broadening is particularly important if the goals are potentially in conflict.

At least 3 broad subgoals have been identified as being important to managing economic systems within the context of the planet's ecological life-support system (Daly 1992) toward the ultimate goal of sustainable human well-being:

1. Assessing and insuring that the scale or magnitude of human activities within the biosphere are ecologically sustainable;
2. Distributing resources and property rights fairly, both within the current generation of humans and between this and future generations as well as between humans and other species; and
3. Efficiently allocating resources as constrained and defined by goals 1 and 2 and including both marketed and nonmarketed resources, especially ecosystem services.

Several authors have discussed valuation of ecosystem services with respect to goal 3—allocative efficiency based on individual utility maximization (see, e.g., Farber and Costanza 1987; Costanza et al. 1989; Mitchell and Carson 1989; Dixon and Hufschmidt 1990; Pearce 1993; Goulder and Kennedy 1997). We need to explore more fully the implications of extending these concepts to include valuation with respect to the other 2 goals of ecological sustainability and distributional fairness (Costanza and Folke 1997). Basing valuation on current individual preferences and utility maximization alone, as occurs in conventional analysis, does not necessarily lead to ecological sustainability or social fairness (Bishop 1993).

A 2-tiered approach that combines public discussion and consensus building on goals of sustainability and equity at the community level, with methods for modifying both prices and preferences at the individual level to better reflect these community goals, may be necessary (Rawls 1971; Norton 1995; Norton et al. 1998). Estimation of ecosystem values based on goals of sustainability and fairness requires treating preferences as endogenous and coevolving with other ecological, economic, and social variables.

VALUATION WITH SUSTAINABILITY, FAIRNESS, AND EFFICIENCY AS GOALS

Thus, we can distinguish at least 3 types of value that are relevant to the problem of valuing ecosystem services. These are laid out in Table 1 according to their corresponding goal or value basis. Efficiency-based value (E value) is based on a model of human behavior sometimes referred to as *homo economus*—that is, that humans act independently, rationally, and in their own self-interest. Value in this context (E value) is based on current individual preferences, which are assumed to be fixed or given (Gregory et al. 1993; Norton et al. 1998). No additional discussion or scientific input is required to form these preferences (because they are assumed to already exist), and value is simply people's revealed willingness to pay for the good or service in question. The best estimate of what people are willing to pay is thought to be what they would actually pay in a well-functioning market. Concerning resources or services for which there is no market (e.g., many ecosystem services), a pseudomarket can sometimes be simulated with questionnaires that elicit an individual's contingent valuation.

Fairness-based value (F value) would require that individuals vote their preferences as a member of the community, not as individuals. This different species (*homo communis*) would engage in much discussion with other members of the community and come to a consensus regarding the values that would be fair to all members of the current and future community (including nonhuman species), incorporating scientific information about possible future consequences as necessary. So, level of scientific input is set at "medium" for F-value in Table 1. One method to implement this might be Rawls' (1971) "veil of ignorance," where everyone votes as if they were operating with no knowledge of their own individual status in current or future society.

Sustainability-based value (S value) would require an assessment of the contribution to ecological sustainability of the item in question. The S value of ecosystem services is connected to their physical, chemical, and biological role in the long-term functioning of the global system. As used here, sustainability is defined as the persistence or longevity of the system and/or selected components of the system (Costanza and Patten 1995). Scientific information about the functioning of the global system thus is critical in assessing S value, and some discussion and consensus building also are necessary. If it is accepted that all species, no matter how seemingly uninteresting or lacking in immediate utility, have a role to play in natural ecosystems (Naeem et al. 1994; Tilman and Downing 1994; Holling et al. 1995), then estimates of ecosystem services may be derived from scientific studies concerning the role of ecosystems and their biota in the overall system, without direct reference to current human preferences. Humans operate as *homo naturalis* in this context—that is, expressing preferences as if they were representatives of the whole system. Instead of being merely an expression of current individual preferences, S-value becomes a system characteristic that is related to the item's evolutionary contribution to the survival of the linked ecological economic system. Using this perspective, we may be able to better estimate the values contributed by, say, maintenance of water and atmospheric quality to long-term human well-being, including the protection of opportunities of choice for future generations (Golley 1994; Perrings 1994). One way to get at these values would be to employ systems

Table 1. Valuation of ecosystem services based on the three primary goals of efficiency, fairness, and sustainability^a

Goal or value basis	Who votes	Preference basis	Level of discussion required	Level of scientific input required	Specific methods
Efficiency	<i>Homo economicus</i>	Current individual preferences	Low	Low	Willingness to pay
Fairness	<i>Homo communicus</i>	Community preferences	High	Medium	Veil of ignorance
Sustainability	<i>Homo naturalis</i>	Whole system preferences	Medium	High	Modeling with precautions

^a Reprinted from Costanza and Folke 1997.

simulation models that incorporate the major linkages in the system at the appropriate scales of time and space (Costanza et al. 1993; Bockstael et al. 1995; Voinov et al. 1999). To account for the large uncertainties involved, these models would have to be used in a precautionary way, looking for the range of possible values and erring on the side of caution (Costanza and Perrings 1990).

DEALING WITH UNCERTAINTY

All the described forms of valuation, and all forms of CBA, BCBA, and MCDA, are subject to considerable uncertainty. Moving from CBA to BCBA involves not only broadening of the types of values included but also improving the methods to describe, communicate, and deal with the uncertainty that is inherent in the analysis. On this last point, to deal with uncertainty in a way that is both fair and sustainable involves changing the burden of proof so that the parties who stand to gain from environmentally damaging activities, rather than the public, bear this burden. For example, 1 method that has been proposed to deal with this uncertainty is a flexible environmental assurance bonding system designed to incorporate environmental criteria and uncertainty into the market system and to induce positive environmental technological innovation (Costanza and Perrings 1990; Costanza and Cornwell 1992). In addition to direct charges for known environmental damages, an assurance bond equal to the current best estimate of the largest potential future environmental damages would be levied and kept in an interest-bearing escrow account. The bond (plus a portion of the interest) would be returned if, and only if, the firm could prove that the suspected damages either had not occurred or would not occur. If damages did occur, the bond would be used to rehabilitate or repair the environment and to compensate injured parties. By requiring the users of environmental resources to post a bond adequate to cover potential future environmental damages (with the possibility for refunds), the burden of proof is shifted from the public to the resource user, and a strong economic incentive is provided to research the true costs of environmentally innovative activities and to develop innovative, cost-effective pollution control technologies.

REAL DEMOCRACY

To integrate fully the 3 goals of ecological sustainability, social fairness, and economic efficiency, we also need a further step, which Sen (1995) described as “value formation through public discussion.” This can be seen as the essence of real democracy. As Buchanan (1954) put it, “The definition of

democracy as ‘government by discussion’ implies that individual values can and do change in the process of decision-making.” Limiting our valuations and social decision making to the goal of economic efficiency based on fixed preferences prevents the needed democratic discussion of values and options and leaves us with only the “illusion of choice” (Schmookler 1993). So, rather than trying to avoid the difficult questions raised by the valuation of ecological systems and services and CBA, we need to acknowledge the full range of intermediate goals being served as well as the technical difficulties involved. We must get on with the process of value formation and analysis in as participatory and democratic a way as possible, but in a way that also takes advantage of the full range and depth of scientific information we have accumulated regarding ecosystem functioning. This is not simply the application of the conventional preanalytic vision and analyses to a new problem; it requires a new, more comprehensive, more integrated preanalytic vision and new, yet-to-be-developed analyses that flow from it. This will be an enormously important challenge for the next generation of ecosystem scientists.

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