Visions, Values, Valuation, and the Need for an Ecological Economics

ROBERT COSTANZA

Practical problem solving in complex, human-dominated ecosystems requires the integration of three elements: (1) active and ongoing envisioning of both how the world works and how we would like the world to be, (2) systematic analysis appropriate to and consistent with the vision, and (3) implementation appropriate to the vision. Scientists generally focus on only the second of these steps, but integrating all three is essential to both good science and effective management. Subjective values enter in the vision element, both in terms of the formation of broad social goals and in the creation of a preanalytic vision, which necessarily precedes any form of scientific analysis.

Because of this need for vision, completely objective scientific analysis is impossible. Joseph Schumpeter (1954) put it this way:

> In practice we all start our own research from the work of our predecessors, that is, we hardly ever start from scratch. But suppose we did start from scratch, what are the steps we should have to take? Obviously, in order to be able to posit to ourselves any problems at all, we should first have to visualize a distinct set of coherent phenomena as a worthwhile object of our analytic effort. In other words, analytic effort is of necessity preceded by a preanalytic cognitive act that supplies the raw material for the analytic effort. In this book, this preanalytic cognitive act will be called Vision. It is interesting to note 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 light of which the source is not to be found in the facts, methods, and results of the preexisting state of the science. (p. 41)

Nevertheless, it is possible to separate the process into the more subjective, or normative, envisioning component and the more systematic, less subjective analysis component (which is based on the vision). "Good" science is that which makes clear its underlying preanalytic vision, and whose analysis is consistent with that vision.

> ALL SCIENTIFIC ANALYSIS IS BASED ON A "PREANALYTIC VISION," AND THE MAJOR SOURCE OF UNCERTAINTY ABOUT CURRENT ENVIRONMENTAL POLICIES RESULTS FROM DIFFERENCES IN VISIONS AND WORLD VIEWS

A changing vision of science

The task would be simpler if the vision of science were static and unchanging. But as the quote from Schumpeter makes clear, this vision is itself evolving as we learn more. This does not invalidate science, as some deconstructionists would have it. Quite the contrary: By being explicit about their underlying preanalytic vision, scientists can enhance their honesty and thereby their credibility. Scientific credibility proceeds from honest discussion of this underlying vision and its inherently subjective elements, as well as from constant, pragmatic testing of conclusions against real-world problems, rather than by appealing to a nonexistent objectivity.

The preanalytic vision of science is changing from the "logical positivist" view, which holds that science can discover ultimate truth by falsification of hypotheses, to the more pragmatic view that we do not have access to any ultimate, universal truths, but only to useful, abstract representations (models) of small parts of the world. Science, in both the logical positivist and this new "pragmatic modeling" vision, works by building models and testing them. But the new

Robert Costanza (e-mail: costza@cbl.umces.edu) is a professor at the Center for Environmental Science and the Department of Biology, and director of the Institute for Ecological Economics, at the University of Maryland, Solomons, MD 20688-0038.

vision recognizes that the tests are rarely, if ever, conclusive (especially in the life sciences and the social sciences); the models can only apply to a limited part of the real world; and the ultimate goal is therefore not truth, but quality and utility. In the words of William Deming, "All models are wrong, but some models are useful" (McCoy 1994).

The primary goal of science, then, is the creation of useful models whose utility and quality can be tested against real-world applications. The criteria by which one judges the utility and quality of models are themselves social constructs that evolve over time. There is, however, fairly broad and consistent consensus in the scientific community about what these criteria are. They include (1) testability, (2) repeatability, (3) predictability, and (4) elegance (i.e., Occam's razor: The model should be as simple as possible, but no simpler!). But because of the nature of real-world problems, there are many applications for which some of these criteria are difficult or impossible to apply. These applications may nevertheless still be judged as "good" science. For example, some purely theoretical models are not directly testable, but they may provide fertile ground for thought and debate and lead to more explicit models that are testable. Likewise, field studies of watersheds are not repeatable, strictly speaking, because no two watersheds are identical. But there is much we can learn from field studies that can be applied to other watersheds and tested against the other criteria of predictability and elegance. How simple a model can be depends on the questions being asked. If we ask a more complex or more detailed question, the model will probably have to be more complex and detailed. As science progresses and the range of applications expands, the criteria by which utility and quality are judged must also adapt to the changing applications. This inherently subjective process goes on constantly within the scientific community.

Vision and change

Research concerning the way change proceeds in various organizations and communities suggests that the most effective ingredient to move change in a particular direction is a clear, shared vision of the desired goal (Senge 1990, Wiesbord 1992, Wiesbord and Janoff 1995). Or, as Yogi Berra once said, "If you don't know where you're going, you end up somewhere else."

Yankelovich (1991) has described the crisis in governance facing modern societies as one of moving from public *opinion* to public *judgment*. Public opinion is notoriously fickle and inconsistent on those issues for which the public has not confronted the system-level implications of its opinions. Coming to judgment requires three steps: (1) consciousness raising, (2) working through, and (3) resolution. A prerequisite for all three of these steps is breaking down the gap between expert knowledge and the public, that is, a breaking down of what Yankelovich (1991, citing Habermas 1991) calls the "culture of technical control." Information in the modern world is compartmentalized and controlled by various technical elites who do not communicate with each other. This allows experts from various fields to hold contradictory opinions, and it allows the public to hold inconsistent and volatile opinions. Coming to judgment is the process of confronting and resolving these inconsistencies by breaking down the barriers between the mutually exclusive compartments into which knowledge and information have been put. For example, opinion polls show many people are highly in favor of more effort to protect the environment, but at the same time they are opposed to any diversion of tax revenues for that purpose. Coming to judgment is the process of resolving these conflicts. This can be done most effectively by formulating the choices as complete visions of the alternative states of the world, and incorporating all the divergent elements.

Visions of the economy and its relationship to the ecological life support system

Both our preanalytic vision of how the human economy relates to the rest of nature and the economy itself are also changing. The human economy has passed from an "empty-world" era, in which human-made capital was the limiting factor in economic development, to the current "full-world" era, in which remaining natural capital has become the limiting factor (Costanza et al. 1997). Basic economic logic tells us that we should maximize the productivity of the scarcest (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 when it was limiting. This implies a very different vision of the economy and its place in the overall system.

Figure 1a shows the conventional economic preanalytic vision (Costanza et al. 1997). 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). GNP is divided into consumption, which is the sole contributor to individual utility and welfare, and investment, which goes into maintaining and increasing the capital stocks. Preferences are fixed. In this model, the primary factors are perfect substitutes for each other, so "land" (including ecosystem services) can be almost ignored, and the lines between all the forms of capital are fuzzy. Property rights are usually simplified to either private or public, and their distribution is usually taken as fixed and given.

Figure 1b shows an alternative "ecological economics" view of the process (Ekins 1992, Costanza et al. 1997). Notice that the key elements of the conventional view are still present, but more has been added and some priorities have changed. There is limited substitutability between the basic forms of capital in this model, and their number has expanded to four. Their names have also changed to better reflect their roles: (1) natural capital (formerly land) includes ecological systems, mineral deposits, and other aspects of the natural world; (2) human capital (formerly labor) includes

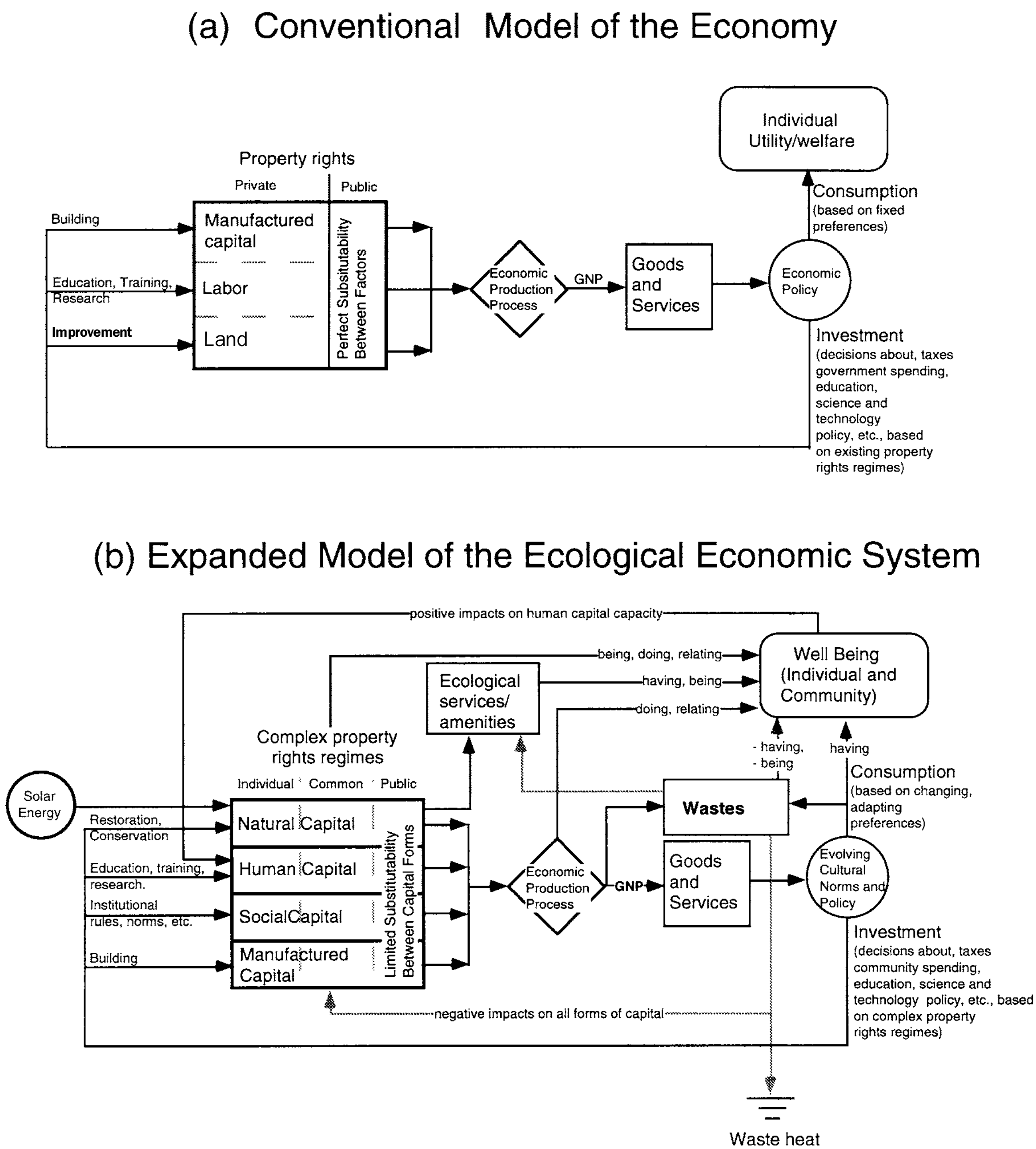

Figure 1. Different visions of the economy based on disparate world views. Conventional economics model (a) and expanded ecological economics model (b).

both the physical labor of humans and the know-how stored in their brains; (3) manufactured capital still includes all the machines and other infrastructure of the human economy; and (4) social (or cultural) capital. Social capital is a recent concept that includes the web of interpersonal connections, institutional arrangements, rules, and norms that allows 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 directly contribute to human welfare without ever passing through markets. The model also accounts for waste production by the economic process, which contributes negatively to human welfare and has a negative impact on capital and ecological services. Personal 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.

These visions of the world are significantly different. As Ekins (1992) points out, "It must be stressed that the complexities and feedbacks of model 2 are not simply glosses on model 1's simpler portrayal of reality. They fundamentally alter the perceived nature of that reality and in ignoring them conventional analysis produces serious errors" (p. 151).

Valuation and social goals

Valuation ultimately refers to the contribution of an item to meeting a specific goal or objective. A baseball player is valuable to the extent he contributes to the goal of the team's winning. In ecology, a gene is valuable to the extent it contributes to the survival of the individuals possessing it and their progeny. In conventional economics, a commodity is valuable to the extent it contributes to the goal of individual welfare, as assessed by individuals' willingness to pay. The point is that one cannot state a value without stating the goal being served. Conventional economic value is based on the goal of individual utility maximization. But 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 other goals that may be deemed important. This broadening is particularly important if the goals are potentially in conflict.

There are at least three broad goals that have been identified as important to managing economic systems within the context of the planet's ecological life support system (Daly 1992):

1. assessing and ensuring that the scale or magnitude of human activities within the biosphere is ecologically sustainable

2. distributing resources and property rights fairly, both within the current generation of humans and between this and future generations, and also between humans and other species

3. efficiently allocating resources, as constrained and defined by the two goals above, including both marketed and nonmarketed resources, especially ecosystem services

Several authors have discussed valuation of ecosystem services with respect to the third goal, allocative efficiency, based on individual utility maximization (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 two goals: ecological sustainability and distributional fairness (Costanza and Folke 1997). Basing valuation on current individual preferences and utility maximization alone, as is done in conventional analysis, does not necessarily lead to ecological sustainability or social fairness (Bishop 1993).

A Kantian or intrinsic rights approach to valuation (see Goulder and Kennedy 1997)—which holds that things have value without any reference to their uses—is one approach to distributional fairness, but it is important to recognize that the three goals are not either–or alternatives. Although they are in some senses independent criteria (Arrow and Raynaud 1986), they must all be satisfied in an integrated fashion to allow human life to continue in a desirable way. Similarly, the valuations that flow from these goals are not either–or alternatives. Rather than resort to a utilitarian or intrinsic rights dichotomy, we must integrate the three goals listed above and their consequent valuations.

A two-tiered approach that combines (1) public discussion and consensus building on sustainability and fairness goals at the community level with (2) 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). Another consequence of valuing ecosystems based on sustainability and fairness goals is that personal preferences must be treated as endogenous and coevolving with other ecological, economic, and social variables.

Valuation with sustainability, fairness, and efficiency as goals

With these goals in mind, we can distinguish at least three types of value that, when taken into account, should advance our valuation of ecosystem services. These are laid out in Table 1 according to their corresponding goal or value basis. The first, efficiency-based value (E-value), is based on a model of human behavior sometimes referred to as "*Homo economius*," in which 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 (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 revealed simply by people's 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. For resources or services for which there is no market, like many ecosystem services, a pseudo-market can sometimes be simulated with questionnaires that elicit individuals' contingent valuation.

Fairness-based value (F-value) requires that individuals vote their preferences as members of the community, not as individuals. This different species, "*Homo communicus*," engages in much discussion with other members of the community so the community can come to consensus on the values that would be fair to all members, including those in the future community as well as nonhuman species. Discussions incorporate scientific information about possible future consequences as necessary. One method to implement this might be Rawls's (1971) "veil of ignorance," according to

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

Goal or value basis	Who votes	Preference basis	Level of discussion required	Level of scientific input required	Specific methods
Efficiency (E-value)	*Homo economius*	Current individual preferences	Low	Low	Willingness to pay
Fairness (F-value)	*Homo communicus*	Community preferences	High	Medium	Veil of ignorance
Sustainability (S-value)	*Homo naturalis*	Whole system preferences	Medium	High	Modeling with precaution

Source: Costanza and Folke 1997.

which individuals vote as if they were operating with no knowledge of their own individual status in current or future society.

Sustainability-based value (S-value) requires 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. Scientific information about the functioning of the global system is thus critical in assessing S-value, and some discussion and consensus building is also necessary. If it is accepted that all species, no matter how seemingly unimportant, 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 can be derived from scientific studies of 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, 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 related to the item's evolutionary contribution to the survival of the whole ecological economic system. By adopting 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 and ultimately protect the opportunities of choice for future generations (Golley 1994, Perrings 1994). One way to get at these values would be to simulate systems using models that incorporate the major linkages in the system at the appropriate time and space scales (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).

To fully integrate the three goals of ecological sustainability, social fairness, and economic efficiency, we also need a further step: value formation through public discussion (Sen 1995). This is 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" (p. 120). By limiting our valuations and social decisionmaking to the goal of economic efficiency based on fixed preferences, we prevent the needed democratic discussion of values and options and are left with only the "illusion of choice" (Schmookler 1993). Rather than trying to avoid the difficult questions raised by the valuation of ecological systems and services, we need to acknowledge the broad range of goals being served by such a discussion, 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 on ecosystem functioning. This is not simply the application of the conventional preanalytic vision and analysis to a new problem but something that requires a new, more comprehensive and integrated preanalytic vision and new, yet-to-be-developed analyses that will flow from it. This enormously important challenge awaits the next generation of ecosystem scientists.

Four alternative visions of the future

Not only do our visions of the way the world works change but our vision of the way we would like the world to be is also evolving. Elsewhere, I have laid out four broad visions of the future (Costanza 1999, Costanza 2000). Although the number of possible visions of the future is infinite, I believe these four visions embody the basic patterns within which much of this variation occurs. Each of the visions is based on some critical assumptions about the way the world works, which may or may not turn out to be true. This format allows one to clearly identify these assumptions, assess how critical they are to the relevant vision, and recognize the consequences of their being wrong.

The four visions derive from two basic world views, whose characteristics are laid out in Table 2. These world views have been described in many ways (Bossel 1996), but one fundamental distinction has to do with one's degree of faith in technological progress (Costanza 1989). The "technological optimist" worldview assumes that technical progress can solve *all* future problems. It is a vision of continued expansion of humans and their dominion over nature. This is the default vision in current Western society, and one that represents continuation of current trends into the indefinite future. It is the "taker" culture as described so eloquently by Daniel Quinn in *Ishmael* (1992).

There are two versions of this vision, however. One corresponds to the underlying assumptions on which it is based actually being true in the real world (the positive version), and the other corresponds to those assumptions being false (the negative version), as shown in Figure 2. The positive version of the technological optimist vision I'll call *Star Trek*, after the popular TV series that is its most articulate and vividly fleshed-out manifestation. The negative version of the technological optimist vision I'll call *Mad Max*, after the popular movie of several years ago that embodies many aspects of this vision gone bad.

The "technological skeptic" vision is one that depends much less on technological change and more on social and community development. It is not in any sense antitechnology, but it does not put blind faith in technology either. The technological skeptic views technology as the servant of larger goals and seeks to encourage technologies that have the best chance of promoting development without irreversibly damaging our natural capital base. The version of this vision that corresponds to the skeptics being right about the nature of the world I'll call "Ecotopia," after the semipopular book of the late 1970s (Callenbach 1975). If the optimists turn out to be right about the real state of the world, what I'll call the "Big Government" vision comes to pass—Ronald Reagan's worst nightmare of overly protective government policies getting in the way of the free market and slowing down economic growth.

Each of these future visions is best described as a narrative from the perspective of, say, the year 2100. This allows one to make them more real and vivid. The narratives are, of course, only caricatures, but they capture the essence of the visions they represent. I have described these four futures as narratives in detail elsewhere (Costanza 1999, 2000) and here give only a summary of their main features in Figure 2.

Dealing with uncertainty at the level of future visions

How should society decide among these four visions? Does it even need to decide? Why not just let what happens happen, letting people have their own independent vision of the future as it suits them? Isn't this the essence of freedom and democracy—Individuals can pursue their own visions as they please? If we lived in our own completely isolated worlds where our actions and decisions had no effect on anyone else, this might be appropriate. A basic tenet of democracy is that individual rights are not to be limited unless they impact the rights of others. But we live in an interconnected world, which is becoming more interconnected every day as the human population grows. All of our futures are intertwined, and the actions and decisions of each of us affect everyone else, both those alive today and those yet to be born. The essence of democracy in this full-world context is government by discussion and mutual value formation. The key, as Yankelovich (1991) suggests, is coming to public judgment about the major value issues facing society, its goals and visions, and this process can be accelerated by first laying out the options in the form of relatively well-articulated visions, as I have attempted above.

We can go further in elaborating the consequences of the four visions outlined above in an effort to come more quickly to public judgment. Three of the four visions are "sustainable," in the sense that they represent continuation of the current society (only Mad Max is not), but we need a closer look at their underlying world views, their critical assumptions, and the potential costs of those assumptions being wrong.

The world view (and attendant policies) of the Star Trek vision is unbridled faith in technology and free competition, and its essential underlying assumption is that resources are unlimited, particularly cheap energy. The cost of pursuing this world view and its policies if the assumption of unlimited resources is wrong is the Mad Max vision. Likewise, the worldview (and attendant policies) of the Ecotopia vision is technological skepticism and communitarianism (the community comes first), and its essential underlying assumptions are that resources are limited and cooperation pays. The cost of pursuing this worldview and its policies if the assumption of limited resources is wrong is the Big Government vision, in which a community-first policy slows down growth relative to the free-market Star Trek vision. Figure 2 can be viewed as a payoff matrix, with each of the four cells in the matrix indicating the "payoff" of

Table 2. Some characteristics of two basic worldviews.

Technological optimist	Technological skeptic
Technical progress can deal with any future challenge	Technical progress is limited, and ecological carrying capacity must be preserved
Competition is guiding principle	Cooperation is guiding principle
Systems are linear, without discontinuties or irreversibilities	Systems are complex, nonlinear, with discontinuties and irreversibilities
Humans dominate nature	Humans are in partnership with nature
People are out for themselves	Community comes first
Market is guiding principle	Market serves larger goals

pursuing the policies of the worldview (on the left) in combination with each real state of the world (on the top).

To rank the elements of the payoff matrix, one would need to discuss the four visions outlined above with a broad range of participants and then have them evaluate each vision in terms of its overall desirability. So far, I've conducted a preliminary (nonscientific) survey with 418 participants. The American participants consisted of 17 students in an ecological economics class at the University of Maryland, 260 attendees at a convocation speech at Wartburg College in Waverly (Iowa), and 39 via the Internet. The Swedish participants consisted of 71 attendees at a Keynotes in Natural Resources Lecture at the Swedish University of Agricultural Science, Uppsala, and 31 attendees at a presentation at Stockholm University. The respondents were read the narrative version of each of the four visions in turn and were then asked the following: "For each vision, I'd like you to first state, on a scale of –10 to +10 using the scale provided, how comfortable you would be living in the world described. How desirable do you find such a world? I'm not asking you to vote for one vision over the others. Consider each vision independently, and just state how desirable (or undesirable) you would find it if you happened to find yourself there." They were also asked to give their age, gender, and household income range on the survey form. The results (mean ± standard deviation) are shown in Table 3, grouped by country and pooled.

Frequency distributions of the results are plotted in Figure 3. The majority of those surveyed found the Star Trek vision positive (mean of +2.48 ± 5.13). Given that it represents the logical extension of the currently dominant worldview and culture, it is interesting that this vision was rated so low. I had expected this vision to be rated much higher, and this result may indicate either the deep ambivalence many people have about the direction society seems to be headed or the self-selection of respondents, or both. The frequency plot and the high standard deviation also show this ambivalence toward Star Trek. The responses span the range from +10 to –10, with only a weak preponderance toward the positive side of the scale. This result applied for both the American and Swedish subgroups.

Those surveyed found the Mad Max vision very negative at –8.12 (± 3.23); only about 3% of participants rated this vision positive. This was as expected. The Americans seemed a bit less averse to Mad Max (–7.78 ± 3.41) than the Swedes (–9.12 ± 2.30) and showed a larger standard deviation.

The Big Government vision was rated on average just positive at 0.97 (± 4.29). Many found it appealing, but some found it abhorrent, probably because of the limits on individual freedom. Here there were significant differences between the Americans and Swedes, with the Swedes (+2.32 ± 3.48) being much more favorably disposed to Big Government and having a smaller standard deviation than the Americans (+0.54 ± 4.44). This also was as expected, given the cultural differences in attitudes toward government in America and Sweden. Swedes rated Big Government almost as highly as Star Trek.

Finally, most of those surveyed found the Ecotopia vision very positive at 5.81 (± 3.97). Some respondents were very positive, some only mildly so, but very few, only about 7% of those surveyed, expressed a negative reaction to such a world.

Real State of the World

Worldview and Policies	**Optimists are Right** (Resources are unlimited)	**Skeptics are Right** (Resources are limited)
Technological Optimism: Resources are unlimited Technical progress can deal with any challenge Competition promotes progress; markets are the guiding principle	**Star Trek:** Fusion energy becomes practical, solving most economic and environmental problems. Leisure time increases because robots do most work. Humans colonize the solar system, where population continues to expand.	**Mad Max:** Oil production declines and no affordable alternative emerges. Financial markets collapse and governments weaken, too broke to maintain armies and control desperate, impoverished populations. The world is run by transnational corporations, whose employees live in guarded enclaves.
Technological Skepticism: Resources are limited Real progress depends less on technology and more on social and community development Cooperation promotes progress; markets are the servants of larger goals	**Big Government:** Governments sanction companies that fail to pursue public interests. Fusion energy is slow to develop because of strict safety standards. Family planning programs stabilize population and progressive taxes equalize incomes.	**Ecotopia:** Ecological tax reform favors ecologically beneficent technologies and industries and punishes polluters and resource depletion. Habitation patterns and increased social capital reduce need for transportation and energy. A shift away from consumerism reduces waste.

Figure 2. Four visions of the future based on two basic worldviews and two alternative states of the real world.

Table 3. Results of a survey of desirability of each of the four visions. Desirability was ranked on a scale of –10 (least desirable) to +10 (most desirable) by self-selected groups of Americans and Swedes. Standard deviations are given in parentheses after the means.

	Americans (*n* = 316)	Swedes (*n* = 102)	Pooled (*n* = 418)
Star Trek	+2.38 (± 5.03)	+2.48 (± 5.45)	+2.48 (± 5.13)
Mad Max	–7.78 (± 3.41)	–9.12 (± 2.30)	–8.12 (± 3.23)
Big Government	+0.54 (± 4.44)	+2.32 (± 3.48)	+0.97 (± 4.29)
Ecotopia	+5.32 (± 4.10)	+7.33 (± 3.11)	+5.81 (± 3.97)

Notes: The Americans consisted of 17 participants in an ecological economics class at the University of Maryland, 260 attendees at a convocation speech at Wartburg College in Waverly, Iowa, 27 January 1998, and 39 via the Internet. The Swedes consisted of 71 attendees at a Keynotes in Natural Resources Lecture at the Swedish University of Agricultural Science, Uppsala, 20 April 1999 and 31 attendees at a presentation at Stockholm University, 22 April 1999.

The pooled rankings are used in the discussion, but the conclusions would be the same if using just the American rankings or just the Swedish rankings. In fact, the conclusions are fairly insensitive to the exact values of the rankings, as long as Big Government is rated higher than Mad Max, and Star Trek and Ecotopia are rated higher than Big Government.

Swedes rated Ecotopia significantly higher than Americans did, also as might be expected given cultural differences.

Some other interesting patterns emerge from the survey. All of the visions had large standard deviations, but the frequency distributions, in particular, show the Mad Max vision was consistently very negative and the Ecotopia vision was consistently very positive. Age and gender seem to play a minor, but interesting role in how individuals rated the visions. Males rated Star Trek higher than females (means of 3.66 and 1.90, respectively; $p = 0.0039$). Males also rated Mad Max higher than females (means of –7.11 and –8.20, respectively; $p = 0.0112$). The means were not significantly different by gender for either of the other two visions. Age was not significantly correlated with ranking for any of the visions, but the variance in ranking seemed to decrease somewhat with age, with younger participants showing a higher range of ratings than older participants.

Work is in progress to expand this survey and conduct a random sample of the population, but the general conclusions are fairly insensitive to the exact results.

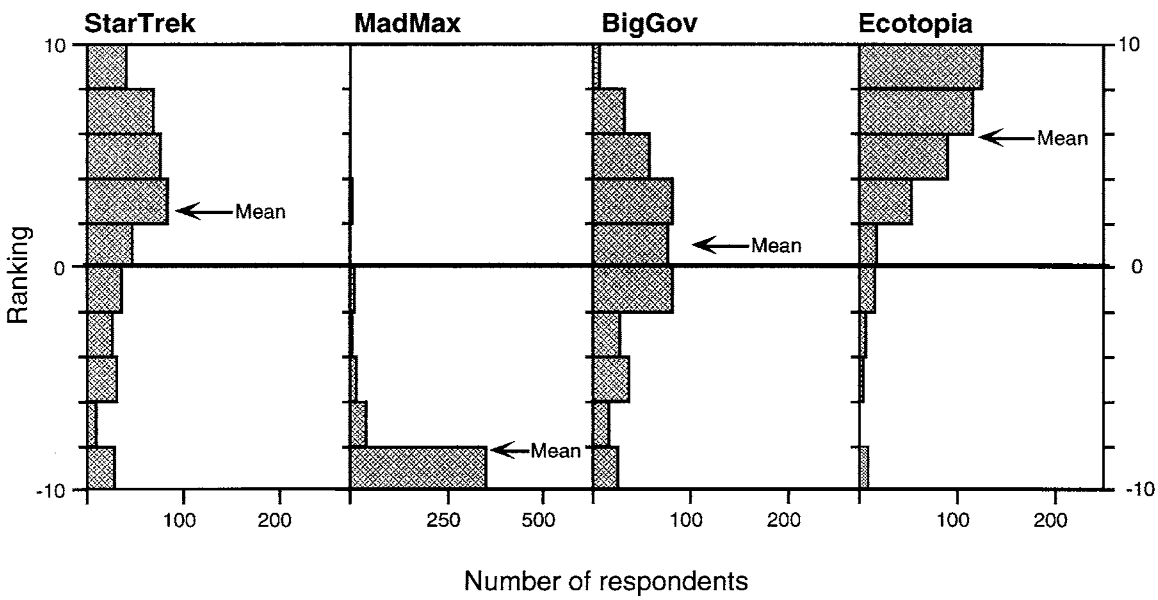

Figure 3. Results of vision desirability survey. Responses about the degree of desirability of each of the four future visions are plotted as frequency distributions. Total number of respondents in each case was 418.

Worst-case analysis

So, we find ourselves as a species facing the payoff matrix outlined in Figure 2. What do we do? We can choose between the two worldviews and their attendant policies. Yet we face pure and irreducible uncertainty concerning the real state of the world. Who knows whether fusion-based energy or something equivalent will be invented? Should we choose the Star Trek vision (and the optimist policies) merely because it is the most popular or because it is the direction things seem to be heading already?

From the perspective of game theory, this problem has a fairly definitive answer. This is a game against nature that can be played only once, and the relative probabilities of each outcome are completely unknown. In addition, we can assume that society as a whole should be risk averse in this situation. The numerical rankings on each outcome (from our preliminary survey) make it a bit easier to talk about: Star Trek is +2.5, Mad Max is –8.1, Big Government is +1.0, and Ecotopia is +5.8. One would look at each row in the matrix (corresponding to a policy set) and see what the worst outcome is for that policy set. For the optimist policy set, Mad Max (–8.1) is the worst case. For the skeptical policy set, Big Government (+1.0) is the worst case. We would then compare the worst cases and choose the policy set with the largest (most positive) ranking: +1.0 is much larger than –8.1, so we would choose the skeptic's policy. This is a standard "minimax regrets" decision rule (Milnor 1964, Rawls 1971, Bishop 1978). Although there has been some controversy in the literature about using this decision rule for situations characterized by extreme uncertainty (Ready and Bishop 1991), a recent review (Palmini 1999) shows that this rule is unambiguously preferred because it "emphasizes risk-aversion while explicitly incorporating the opportunity cost of making a 'wrong' choice" (p. 463).

If we choose the skeptic's policy set, the worst thing that can happen is Big Government, which is much better than the worst thing that can happen under the optimist's policy set, which is Mad Max. The conclusion that we should choose the skeptic's policy set is fairly insensitive to the specific values of the rankings. The rankings would have to change so that either Big Government or Ecotopia was rated *worse* than Mad Max to reverse this outcome. In fact, the way the payoff matrix is set up, Mad Max is the one really negative outcome and the only unsustainable outcome. If one of our major goals as a society is sustainability, then we should develop policies that assure us of not ending up in Mad Max, no matter what happens.

There are also some other considerations in favor of choosing the skeptic's policies. The skeptical policies are less likely to close out any options. One could still switch to the optimist's policies if the real state of the world were shown to conform to the optimist's view. For example, if fusion-based energy or its equivalent were ever mastered, one could switch to the Star Trek vision from the Big Government vision. The reverse switch from Mad Max to Ecotopia could not be made as easily, because the infrastructure would not be present. The skeptic's policies are much better at preserving options.

One can also argue that the probabilities of each state of the world being correct are not completely unknown. If one argued that the prospects for cheap, unlimited, nonpolluting energy were, in fact, very good, then the decision matrix would have to be weighted with those probabilities. But the complete dependence of the Star Trek vision on discovering a cheap, unlimited energy source weighs heavily against the probability of its occurrence. It's like leaping off the top of the World Trade Center building and hoping that you can invent a parachute before you hit the ground. It's better to wait until you have the parachute (and have tested it extensively) before you jump. By adopting the skeptic's policies, the possibility of this invention is preserved, but without utter dependence on it.

Scientific objectivity, values, and policy

I hope the foregoing discussion has put the theme of this special issue in a new and broader context. To summarize:

- There is no such thing as scientific objectivity, because all science must be (1) based on a preanalytic vision that is inherently subjective and (2) judged for utility and quality against criteria that are inherently subjective. We can, however, be very clear about the distinction between the vision and values component of the process and the analysis component built on that vision.

- The quality of scientific work can thus be judged based on its adherence to the preanalytic vision and its pragmatic utility in modeling the real world, as tested against the general criteria developed by the scientific community. We can judge between "good" science and "bad" science according to these subjectively determined criteria of quality, but it is not really honest or useful to use objectivity as a yardstick.

- Subjective values also enter the discussion when we talk about how we would like the world to be. This aspect of future visions strongly determines which set of current policies are most appropriate, given our huge level of uncertainty about the real state of the world.

- The major source of uncertainty about our current environmental policies is at this level of visions and worldviews, not in the details of analysis or implementation within a particular vision. By laying out four alternative future histories of the Earth, the critical assumptions and uncertainties underlying each vision can be more easily seen and a rational policy can be set to assure sustainability.

- A cooperative, precautionary policy set that assumes limited resources is the most rational and resilient course in the face of fundamental uncertainty about the limits of technology.

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