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Managing Our Environmental Portfolio

BY ROBERT COSTANZA, HERMAN DALY, CARL FOLKE, PAUL HAWKEN, C. S. HOLLING, ANTHONY J. MCMICHAEL, DAVID PIMENTEL, AND DAVID RAPPORT

No set of issues has tended to separate economists and ecologists, especially in the mind of the public, more than those surrounding the linkages between economic growth, human carrying capacity, and the environment. The general lack of interest among the majority of economists in problems of the environment and a parallel lack of interest among the majority of ecologists in economic issues, combined with a lack of dialogue between the two groups, has allowed extreme positions to take hold in the public debate and to influence policy to an inordinate degree.

Just one example from a book that consists of a debate between Julian Simon and Norman Myers (Myers and Simon 1994) should suffice to demonstrate just how extreme some of these positions are. Consider the following quote by Simon:

> *We now have in our hands—in our libraries, really—the technology to feed, clothe, and supply energy to an ever-growing population for the next 7 billion years. Most amazing is that most of this specific body of knowledge developed within the past hundred years or so, though it rests on knowledge that had accumulated for millennia, of course.*
>
> *Indeed, the last necessary additions to this body of knowledge—nuclear fission and space travel—occurred decades ago. Even if no new knowledge were ever invented after those advances, we would be able to go on increasing forever, improving our standard of living and our control over our environment. The discovery of genetic manipulation certainly enhances our powers greatly, but even without it we could have continued our progress forever. (Myers and Simon 1994, p. 65)*

This degree of faith in the ability of technology to solve all of humanity's problems and allow economic and population growth to continue unabated forever is certainly not shared by many economists (Arrow et al. 1995, Ravaioli and Ekins 1995). And yet, positions like these have been taken as the general view of economists on growth and the environment. For example, a recent lead article about the environment in *The Economist* (Anonymous 1997) stated that "Forecasters of scarcity and doom are not only invariably wrong, they think that being wrong proves them right." The article went on to select data out of context and "spin" the facts to make its case that environmentalists who forecast "doom and gloom" about environmental trends were invariably wrong and that economic optimists who forecast a rosy environmental future were invariably right.

A parallel situation holds for ecologists. Environmentalists (who are not necessarily ecologists) have often been equally guilty of stretching and spinning the facts to try to win the debate on the environment. They make extreme statements that are intended to dramatize the situation, but end up polarizing it instead. For example, environmentalists sometimes argue that any human presence on the planet is detrimental and that the earth would be better off without any humans at all.

The problem is that these issues are often presented, in both the scientific literature and the popular press, in a format that assumes that there is a right and a wrong answer and that attempts to lay out the opposing positions so that the audience members can choose for themselves who is right. This format may appeal to journalists trying to achieve "balanced" coverage, but the complex and important issues that are often the subjects of these debates (e.g., climate change, population growth, biodiversity loss, sustainability) ironically become muddied rather than sharpened when subjected to this format. They are not simple black and white issues, and accentuating the debate format makes it difficult to paint a richer, multicolored picture and achieve consensus on appropriate courses of action (Tannen 1998). In addition, the jour-

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nalistic search for "balance" often pits a broad scientific consensus against a few extremists willing to take the opposite position—hardly an accurate picture of the true balance of opinion in the community. This is not to say that a thorough and ongoing discussion is not necessary; rather, the format should be one of truly balanced and interactive dialogue rather than confrontational debate in the journalistic style.

In this article, we attempt to move beyond the "environment as a debate" by focusing on common ground—the environment as a productive asset shared by all of humanity. The common challenge is to manage this asset so as to maximize the probability that it will continue to support human well-being into the indefinite future. This management must be achieved in the face of huge and unresolvable uncertainties about some key assumptions having to do with the limits of technological change and the capacity of ecological life-support systems. Consequently, it is essential to combine data, ideas, and insights from ecology, environmental science, economics, business, psychology, law, engineering, and many other areas. All of these perspectives can provide at best partial truths—they are, therefore, all needed for effective management of our complex environmental portfolio in the face of uncertainty.

Debating with different visions

One reason that the environmental debate has been so rancorous, confrontational, and unproductive is that the participants are arguing within the context of very different worldviews, or visions, both of how the world is and of how they would like it to be. These worldviews can be described in many ways (Bossel 1998), but a fundamental distinction has to do with their views of technological progress (Costanza 1989, 1999).

The technological optimist worldview is one of continued expansion of humans and their dominion over nature. Through technological change, humans become independent of nature. The optimist worldview assumes, moreover, that technical progress can deal with any future challenge, that the future will be a smooth extrapolation of the past, and that the market is a good guiding principle. This is the "default" vision in current Western society, one that represents continuation of current trends into the indefinite future. The quote by Simon at the beginning of this article represents the extreme form of this vision.

The technological skeptic vision recognizes the importance of technological change but depends much less on it and more on social and community development. This worldview assumes that technical progress is ultimately constrained by the dynamic ecological carrying capacity of Earth; that the future (like the past) will be full of unpredictable, discontinuous surprises; that humans have to work in partnership with nature; and that the market is a good servant but a poor master.

Ask two people holding these different visions to debate a complex issue, such as global climate change, and the result will most likely be them angrily talking past each other, with both wondering why the other cannot see their point. The reason is that it is not possible to know whether the assumptions underlying either of these visions are correct until after the fact. In this article, we contend that the way to resolve the fundamental disagreement between the technological optimist and the technological skeptic is therefore to devise policies that maximize the chances of success regardless of which worldview turns out to be right. We show that given this fundamental uncertainty, it is better to pursue (at least provisionally) those policies associated with the skeptical worldview rather than those associated with the optimist worldview, because the benefits of being right are comparable in both cases, but the costs of being wrong when pursuing the optimist's policies are far greater and less reversible than the costs of being wrong when pursuing the skeptic's policies.

From an "empty" to a "full" world: A changing burden of proof

Why is managing humanity's environmental portfolio so important? What has changed in the world? From the optimist's point of view, nothing fundamental has changed—humans should go on dealing with the environment as they always have. From the skeptic's point of view, however, a fundamental change has occurred. The world has changed from one that was relatively empty of humans and their artifacts to one that is relatively full (Daly 1992). For more than 99% of humanity's history, our ancestors could affect only the local environment. Hunters and gatherers affected their local ecosystems, much as has any other large omnivore, but often more dramatically. For example, hunting cultures are suspected of driving several large herbivores to extinction and significantly altering the fire regimes of some ecosystems (Flannery 1994, Diamond 1997), sometimes causing a major local climatic change (Fagan 1999). Agriculturists altered local to regional vegetation patterns, hydrology, and soils even more dramatically. It has even been suggested (Tainter 1988, Yoffee and Cowgill 1988, Ponting 1991, Diamond 1997) that most historical agricultural civilizations (e.g., Egyptian, Mesopotamian, Roman, Olmec, Chacoan, Mayan) had collapsed due to inattention to the degradation of their local environmental resource bases. Industrial cultures can now affect local, regional, and global biophysical systems and environmental processes, including climate and ocean currents (Pimentel et al. 1997b, Vitousek et al. 1997). From the skeptic's point of view, the question is, can our current global civilization break from the historical trend and achieve sustainability?

During the expansion of industrial civilization in the last 200 years, humans have faced what appeared to be a limitless frontier. The optimists believe that technical progress guarantees that the frontier is still there and will remain limitless. The skeptics believe that this rapid human expansion has transformed the planet and is beginning to challenge its capacity to support humanity. Evidence for the skeptics' view includes a plateauing in per capita cereal grain production since the mid-1980s, a plateauing in ocean fisheries yield, a 10–20-fold increase in refugees (political, economic, and environmental) in the past two decades, depletion of freshwater supplies in some regions, and rapid and continuing changes in the profile of infectious diseases (i.e., 2 million deaths per year from AIDS; resurgence of cholera, TB, and malaria; antimicrobial resistance; and the emergence of various new infectious agents associated with changing land-use patterns and intensification of food production; Wilson 1995, De Cock and Greenwood 1998, McMichael et al. 1999). The optimists acknowledge these problems but contend that they are temporary and will (like all problems before them) yield to technological advance.

This uncertainty about limits has important implications for how humans manage their environmental portfolio. If it is assumed that the environment is limitless and that nothing that humans can do will seriously harm it (or at least that any problems can be fixed), then the burden of proof should be (as it has been, until now) on those who wish to show that environmental impacts have occurred. If, on the other hand, it is assumed that the environment is not limitless and, in fact, that the world is now full, then the burden of proof should be shifted to those who potentially harm the environment to show that their activities will not have any adverse effects. This harm includes not only pollution but also overharvesting, climate change, other restructuring of the environment, habitat destruction, and the introduction of exotic species. In a full world, the assumption should be that some negative impact will probably occur as a result of these stresses, singly or in combination, unless and until it can be shown otherwise (Rapport et al. 1985, McMichael 1993, McIntyre and Mosedale 1997, Paine et al. 1998).

The environment as a productive asset

The optimist believes that the environment is expendable because technology can ultimately substitute for any lost environmental services or amenities. The skeptic believes that the environment is of critical importance because it represents humanity's life-support system, a system that technology could never adequately reproduce. For people of both worldviews, however, it is clear that, at present, the services of ecological systems and the natural capital stocks that produce them are necessary to the functioning of the earth's life-support system (Daily 1997). Ecosystem services contribute significantly to economic production and human welfare (Repetto et al. 1989, Kahn 1998, Kahn and Farmer 1999) and represent a significant portion of the total economic value of the planet (Costanza et al. 1997, Pimentel et al. 1997a). Because the value of these services is not fully captured in markets or adequately quantified in terms comparable with economic services and manufactured capital, they are often given too little weight in policy decisions.

In an empty world, humans could get away with ignoring the value of environmental assets and their impacts on them because these assets would be relatively abundant. In a full world, however, neglect of the value of ecosystem services might ultimately (if the technological skeptics are correct) compromise the sustainability of human well-being and survival in the biosphere. In the current situation—where there is at least some possibility that the world is now full—the environmental portfolio must be managed in a different way. It must be managed as a critical portfolio, similar to the way in which any good business manages its valuable productive assets under uncertainty.

Managing the environmental portfolio under uncertainty

Most asset portfolios are subject to fairly high degrees of uncertainty, and business managers have developed strategies to maximize the benefits derived from these assets in the face of this uncertainty. Humanity's shared ecological assets are an extreme case, in which uncertainty is large and concerns fundamental assumptions (e.g., about the ability of technology to substitute for environmental services), and the stakes are high. The debate on the environment has polarized and trivialized attempts to deal with this uncertainty. When people assume that there are right and wrong answers in the debate—that either the optimists are right or the skeptics are right—they essentially ignore this fundamental uncertainty.

However, in the face of this fundamental uncertainty, it is not rational to blindly bank on technology's ability to solve all future environmental problems. Neither is it rational to assume that technology is impotent. The more rational position in this case of extreme uncertainty and ultrahigh stakes is one of skeptical precaution, which assumes that there will be problems but leaves open the possibility that these problems can be worked out and that they might not be as big as was first thought. This position can be taken without knowing whether the optimist's or skeptic's assumptions are correct, so it is, in effect, a worldview-independent strategy. It does not mean stifling new technology and taking no risks. On the contrary, it means managing risks appropriately, in line with their potential costs, benefits, and uncertainties and without compromising the potential health of the earth's human populations and ecosystems (Rapport et al. 1998). This strategy also means encouraging the kind of technology that has the best chance of promoting development without irreversibly damaging the natural capital base.

But, the technological optimist might counter, doesn't this strategy of skeptical precaution essentially assume that the skeptics are right? The answer is, no, not in an absolute sense—only in a provisional sense. That is, it assumes provisionally that the skeptics are right but continues to encourage technical development. This strategy makes sense because of the asymmetry of the costs and

Figure 1. Payoff matrix for technological optimism versus technological skepticism. See text for details.

Current policies	Real state of the world	
	Optimists right	Skeptics right
Technological optimist policies	High	Disaster
Technological skeptic policies	Good	Very good

benefits (Costanza 1999).

To clarify the problem, this optimist versus skeptic choice can be cast in game theoretic format using the payoff matrix shown in Figure 1, in which the alternative policies that can be pursued today (technological optimist or skeptic) are listed on the left and the real states of the world are listed on the top. The intersections are labeled with the results of the combinations of policies and states of the world. These payoffs are actually complex future states of the world that can best be described using fairly detailed narrative scenarios (Costanza 1999). For the purposes of this discussion, however, we describe them with a simple overall rating. That is, if the optimist policy is pursued and the world really does turn out to conform to the optimist's assumptions, then the payoff might be rated "Excellent." This potential for a high payoff is tempting, especially given that it has paid off in the past. Therefore, it is not surprising that so many people would like to believe that the world really does conform to the optimist's assumptions. However, if the optimist's policy is pursued and the world turns out to conform more closely to the skeptic's assumptions, then the result would be rated "Disaster" because irreversible damage to ecosystems would have occurred and technological fixes would no longer be possible. If the skeptic policy is pursued and the optimists are right, then the results would be only "Good." Economic growth would have been slowed somewhat by overly cautious policies. If the skeptical policy is pursued and the skeptical worldview turns out to be right, then the results are "Very good." In this last case, humans would have learned to live well within the ecological constraints of the planet and build a sustainable partnership with nature.

This simplified game has a fairly simple "optimal" strategy. If there is true uncertainty about the state of the world (i.e., if the relative probabilities that the skeptic and the optimist are right are unknown) and the game can be played only once, then humans should choose the policy that is the maximum of the minimum outcomes (i.e., the MaxiMin strategy). In other words, each policy is analyzed in turn, looking for the worst thing (minimum) that could happen if that policy is pursued, and the policy that is picked is the one with the largest (maximum) minimum. In the payoff matrix in Figure 1, the skeptic's policy should be pursued because the worst possible result under that policy (Good) is a better outcome than the worst outcome under the optimist policy (Disaster). In fact, in this game there is only one nonsustainable outcome (Disaster), and the object of the game is to avoid that outcome, regardless of the real state of the world, because that state will not be known until it is too late.

As an analogy, it is as if a smoker has just been told by a doctor that there is a possibility that if she continues smoking, she will contract lung cancer. For any particular individual, one can never know whether this possibility will actually happen until it does. An optimistic person might assume that "it will never happen to me" and go on smoking, heedless of the risks. She might turn out to be right, but she might not. A more skeptical person would weigh the risks and determine if the increased risk of contracting lung cancer is worth the benefits of the short-term pleasure derived from smoking. He might try to cut down on his smoking, just to be safe. However, it is not rational in this situation to attack the doctor or the medical establishment for pointing out the risks and advising that smoking might cause lung cancer. Likewise, the fact that global environmental catastrophes have not yet occurred is no reason to attack the environmental science community for pointing out the possibility that they might occur. Yet this is exactly the approach taken by *The Economist* (Anonymous 1997) and in much recent rhetoric based on the extreme technological optimist worldview.

To move beyond the confrontational debate on the environment, people have to recognize both the uncertainties and what they do know, and to use that information effectively. There is obviously some chance that humanity is approaching environmental limits. However, how big that chance is, is not known—and never will be known, until it is too late. What is certain is that the environment is currently critical to supporting life on this planet. Therefore, humanity must now manage its activities vis-a-vis the environment to ensure that this life-support capacity will not be compromised.

How can this goal be accomplished? To effectively manage the environmental portfolio, some strategies might be used that have proven effective in managing business portfolios of assets under uncertainty. The managers of large mutual funds and other business assets do not rely on the invisible hand of the market to maximize the value of their portfolios. They actively manage them in a proactive and anticipatory way. The strategies they have developed have become codified in rules of thumb that have worked for a broad range of complex assets. How would they apply to the environmental portfolio?

Protect your capital. The first rule of asset management is to protect the stock of assets and live off the interest. In the context of the environment, the natural capital stock must be protected so that humans can continue to enjoy the flow of services that derive from that stock.

Actions that deplete or degrade the stock should be taken only in dire cases, when there are no alternatives. This protective strategy should be pursued until it can be conclusively shown that there are viable substitutes.

Hedge your investments. The classic rule of portfolio management is "don't put all of your eggs in one basket." Because of uncertainty, humanity cannot afford to put all of our eggs in the optimist's "technology will solve all environmental problems" basket. Several eggs must be left in the skeptic's "preserve natural capital" basket, just to be safe. That is, ecosystem preservation must be viewed as an investment and a hedge against the possibility that other investments (i.e., technological change) may not yield the expected returns. This strategy recognizes the dependence of these other investments on the natural capital "infrastructure," at least in the short to medium term.

Don't risk more than you can afford to lose. At least for the foreseeable future, humans cannot afford to lose or damage the natural capital base and the ecosystem services that flow from it. Therefore, it should not be put at risk. As we have already noted, several regional past civilizations collapsed because they fell into this trap.

Buy insurance. In the presence of uncertainty regarding a valuable asset, one should buy insurance to protect oneself against the worst-case scenario. Buying "environmental insurance" means not harvesting everywhere (i.e., leaving refugia and reserves) and not harvesting even close to the sustainable limit. Unfortunately, recent experience in fisheries management (Ludwig et al. 1993) indicates that, with respect to the environment, humans tend collectively to buy too little insurance and take too many risks.

Why hasn't portfolio management been implemented?

If these policies are so straightforward and obvious, then why aren't they being implemented? If the global environment were owned and managed like a private firm or like a portfolio of private financial assets, they would no doubt have been implemented long ago. The problem is that the global environment is a common-property (and in many respects an open-access) resource (Hardin 1968, Hanna et al. 1996), and the scale of the management problem has far surpassed the scale of the institutions that have been developed for local environmental management (Costanza et al. 1998, Ostrom et al. 1999). There is a conflict between the costs, benefits, and other incentives perceived by private owners of small pieces of the environment, on the one hand, and the social costs, benefits, and other incentives for society as a whole, the entire environment, and future generations, on the other hand. Humans are caught in a huge social trap (Cross and Guyer 1980, Costanza 1987) because of this incentive incompatibility, which, if left uncorrected, might lead to the collapse of global industrial society. It is as if a large company, instead of being run as a single unit by its president and board of directors on behalf of all the shareholders, was instead divided into smaller, independent subunits, none of which had to account to any other for the resources it used. Such a company would not last long. But it is just this kind of system that is currently in place for managing many of the planet's environmental assets.

Given the current value of environmental assets to humanity (and the uncertainties about the core assumptions concerning their use), humans need to manage these assets at least as wisely as individual investors manage their stock portfolios. Whether the portfolio is a set of financial assets or the set of systems and processes that make up the biosphere, what really needs to be managed or controlled is the behavior of the asset manager, in the light of objective conditions (i.e., the laws of finance or ecology) and the ultimate goals. But who is the asset manager in the case of the environmental portfolio? The fundamental problem with environmental management is that no effective institutions exist at the appropriate scale for managing humanity's collective behavior and its common global environmental portfolio.

A first step toward developing such institutions is to recognize both the value of these environmental assets to society's continued survival and the unresolvable uncertainty about technology's ability to substitute for them. Only then will it be possible to move beyond the "argument culture," which inappropriately casts the complex problem of managing our environmental portfolio as a simplistic debate, to work together to design new worldview-independent policies and institutions for effective and sustainable management at the appropriate scales.

Institutions for managing the environmental portfolio

What will these new institutions look like? First of all, they will need to be integrated in a framework of sustainable governance. Costanza et al. (1998) have identified six core principles for sustainable governance: *responsibility* (access to environmental resources carries attendant responsibilities), *scale-matching* (institutions should match the scale of the environmental problem), *precaution* (in the face of uncertainty about potentially irreversible environmental impacts, humans should err on the side of caution), *adaptive management* (decision-makers should acknowledge uncertainty and continuously gather and integrate information, with the goal of adaptive improvement), *full cost allocation* (all of the internal and external costs and benefits of the use of environmental resources should be identified and appropriately allocated), and *participation* (all affected stakeholders should be engaged in the formulation and implementation of decisions concerning environmental resources).

The design of institutions that employ these principles for the sustainable governance and adaptive management of the environmental portfolio has already begun in prototype at smaller scales (Holling 1978, Walters 1986, Caldwell 1990, Lee 1993, Gunderson et al. 1995, Berkes and Folke 1998). In adaptive institutions, the implementation of policy prescriptions acknowledges the uncertainty embedded in different worldviews and models and encourages participation by all the affected stakeholder groups. Adaptive management views policy and management as experiments, in which interventions at several scales are made to achieve understanding and to identify and test the effects of policy options. Policies are taken, not as the ultimate answers, but rather as guides to the experimentation process. More emphasis is placed on monitoring and feedback to check and improve the process, and, as with all good experiments, caution is used to make sure the system under study remains intact. Some examples of evolving institutional designs that meet the criteria for sustainable governance and adaptive management of environmental assets include share-based and co-managed fisheries (Wilson 1997, Young 1998), integrated watershed management (Naiman 1994, Pelley 1997, Heathcote 1998), and marine protected areas (Bohnsack 1993, Jones 1994, Lauck et al. 1998).

Conclusions

The environmental debate is counterproductive because it is based on untestable core assumptions embedded in deeply held worldviews. To move forward, it is essential to acknowledge these different worldviews and to search for policies and institutions that are worldview independent. Regardless of worldview, there is general agreement that environmental assets are important and that their use by humans needs to be managed. Given the uncertainty and the size of the stakes, it is most rational to pursue, at least provisionally, a strategy that presumes a technologically skeptical worldview as outlined here but does not discourage ecologically and socially positive technical change. Appropriate technology is an essential ingredient in achieving sustainability. Much can be learned from the experience and strategies of the managers of financial portfolios, which are also subject to high uncertainty. Ultimately, these strategies need to be embedded in new participatory institutions that can provide sustainable governance and adaptive management of our shared environmental portfolio at the appropriate scales.

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