Economics and "Sustainability": Balancing Trade-offs and Imperatives

Michael A. Toman

ABSTRACT. *The concept of "sustainability" has been increasingly invoked in scholarly and public policy debates. Discussion has been hampered, however, by uncertainty and lack of uniformity in the meaning of sustainability. This paper seeks to identify some common ground among economists, ecologists, and environmental ethicists. Two issues seem salient: requirements for intergenerational equity and the definition of "social capital" to be provided to future generations. A concept of "safe minimum standard," which has received at least some recognition in the ecology, philosophy, and economics literatures, may provide the beginnings of a common ground for debate about sustainability.* (*JEL* Q2)

I. INTRODUCTION

The concept that use of natural resources, environmental services, and ecological systems somehow should be "sustainable" has become one of the most widely invoked and debated ideas in the area of resource and environmental management. It was a basic theme in the 1992 "Earth Summit," the United Nations Conference on Environment and Development (UNCED), and in the World Bank's 1992 *World Development Report* on environment and development. It is an issue discussed not just in professional journals but also in newspaper articles and in basic textbooks (see, e.g., Pearce and Turner 1990 and Tietenberg 1992). It is a principle behind the founding of a professional organization, the International Society for Ecological Economics, many of whose members question the sufficiency or even the validity of conventional economic approaches to resource and environmental management problems.

Despite the frequency with which the term is invoked, the concept of sustainability remains surprisingly ambiguous. It is clear from examining various usages of the term that writers have very different meanings in mind.[1] For example, the use of the term in the 1992 *World Development Report* seems to refer primarily to the application of existing neoclassical principles of efficient resource and environmental management in developing countries. This is very different than the ideas expressed by Herman Daly (see, e.g., Daly 1990, 1991), who argues that use ("throughput") of energy and materials must be sharply curtailed to avoid ecological catastrophe. Sustainability also is interpreted very differently by many economists, who see the natural environment as one of many fungible assets that can be deployed in satisfying human demands, and by many ecologists and ethicists, who express greater concern for both ecological integrity and the interests of future generations (compare Ehrlich 1989 and Solow 1993a, 1993b, for example).

The goal of this paper is to provide some vocabulary and grammar that may be useful for this ongoing debate among economists, ecologists, and ethicists. We begin, as do many others, with the statement about sustainability from the report of the "Brundt-

Senior Fellow, Resources for the Future.

Earlier versions of this paper were presented at meetings of the International Society for Ecological Economics and the American Economic Association, and at seminars at the World Bank, the Agency for International Development, and the University of Maryland. I owe a large debt to Pierre Crosson, Bryan Norton, and John Pezzey, whose insights played a substantial role in clarifying my understanding of the issues raised in the paper. I also appreciate helpful conversations with Geir Asheim, Doug Bohi, Allen Kneese, and Jeff Krautkraemer, and perceptive comments by Tom Tietenberg, Scott Gordon, Tim Brennan, and an anonymous referee on earlier drafts.

[1]See also Pezzey (1989) and Pearce, Markandya, and Barbier (1989), who catalogue scores of sometimes vague and conflicting sustainability definitions. Dixon and Fallon (1989) discuss how sustainability has been transformed from a condition on steady-state management of specific resources to an expression of broad ecological concerns.

Land Economics • November 1994 • 70(4): 399–413

land Commission," the World Commission on Environment and Development (WCED). That report described sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987, 43). The threat to future generations perceived in the report arise from potentially large-scale and irreversible degradation of natural systems in the course of global economic development, particularly in poorer countries.

The Brundtland statement thus focuses attention on two issues that seem to be central themes in any conception of sustainability: the nature of the current generation's responsibility to future generations, and the degree of substitutability between "natural capital" and other forms of social capital—physical investment and investment in knowledge and institutions as embodied in human capital.[2] The next two sections of the paper examine alternative views on these two issues to show how they lead to different conceptions of sustainability. In the fourth section of the paper these alternative conceptions are related to each other through a "two-tier" model of resource management based on the idea of "safe minimum standard." The fifth and last section of the paper contains concluding remarks.

II. INTERGENERATIONAL FAIRNESS

There is an enormous literature, spanning over two millennia, on concepts of distributive justice including fairness across generations. Unfortunately, there is not yet a conception of distributive justice that commands wide intellectual support. Nevertheless, there are several points of view that have attracted considerable attention in discussions of sustainability.[3] The discussion that follows emphasizes issues of intergenerational fairness even though these issues cannot be entirely divorced from the subject of the next section, substitution possibilities among components of society's wealth endowment.

One fundamental partitioning of justice concepts separates theories based on maximization of an independently defined good (teleological theories) from theories based more on innate rights and obligations (deontological theories). A further categorization can be made based on theories that emphasize the current generation and its immediate descendants—"presentist" theories—and theories that put greater emphasis on the "further future." Yet another distinction, particularly in nonpresentist theories of justice, concerns justice concepts that emphasize individuals and more "organicist" conceptions that put greater weight on community interests.

The typical criterion of discounted intertemporal welfare maximization in applied welfare economics occupies one point in the continuum of alternative justice conceptions. This criterion not only emphasizes preference satisfaction over rights; it also is highly presentist, since with *any* positive intergenerational discount rate the welfare of individuals living one generation in the future is scarcely relevant to current decision making. Many writers have suggested that the presentist focus of the present-value (PV) criterion implies an influence of the current generation over the circumstances of its more distant descendants that seems, at least intuitively, to be ethically questionable (Kneese and

[2] In emphasizing these themes we are placing ourselves within the anthropocentric stream of debate about sustainability, in which the needs and wants of people are central, as opposed to an "ecocentric" perspective that asserts the intrinsic worth of the natural environment. We also are sidestepping, without in any way minimizing, the issue of how the state of the environment may be connected to income distribution within generations—in particular, connections between poverty and environmental degradation. See Pearce, Barbier, and Markandya (1990) and World Bank (1992) for discussion of these issues. Finally, we consider sustainability primarily in the context of resource management to meet identified human needs, as opposed to the broader "co-evolutionary" perspective discussed in Norgaard (1988), which emphasizes the mutual interactions between social actions and goals.

[3] See Pearce and Turner (1990, chap. 15) for a compact summary; Pezzey (1992) provides a wide-ranging survey of motivations for considering sustainability.

Schulze 1985; Norton 1982, 1984, 1989; Parfit 1983b; Page 1977, 1983, 1988).

The debate over the ethical implications of the PV criterion is long-standing and involves a number of considerations that often seem to be misunderstood. One basic issue in this debate is the relationship between the PV criterion and the broader concept of intergenerational economic efficiency as defined by the Pareto criterion, which requires only that it be impossible to improve the welfare of members of one generation without reducing the welfare of members of some other generation. This notion of "no waste" seems desirable in any intergenerational welfare criterion, at least to those who give some weight to the importance of individual preference satisfaction. The difficulty with the PV criterion thus is not that it requires Pareto efficiency, but rather that it puts weight on the welfare of the current generation in the social welfare function that some regard as excessive.

As Page (1977, 1988) points out, there are infinitely many intergenerational social orderings consistent with the Pareto principle that allow for different sets of intergenerational welfare weights without the "dictatorship" of the current generation embodied in the present value criterion. A number of analysts have explored other social welfare criteria that preserve the Pareto principle without imposing the preferences of the current generation on future generations.[4]

This issue has been carefully considered in a series of papers by Howarth and Norgaard (see Howarth and Norgaard 1990, 1992, 1993 and Howarth 1991a, 1991b). Using an overlapping generations framework, they argue that the problem of intergenerational equity must be viewed as a problem of ethics that is distinct from economic efficiency in the Pareto sense. They further argue that the intergenerational equity problem should be approached as one that involves a fair distribution of property rights between current and future generations. This argument is a simple but powerful intergenerational extension of a standard result in welfare economics: "The choice of distribution of income is the same as the choice of an allocation of endowments, and this in turn is equivalent to choosing a particular welfare function" (Varian 1984, 209; see also Bromley 1989). In particular, Howarth and Norgaard show that while purely "egoistic" utility concerns will motivate some savings to benefit the (short-term) future (since people live more than one period and may also have concerns for their own immediate descendants), purely egoistic savings will not in general be adequate to optimize a social welfare function that includes more altruistic concerns (e.g., the well-being of the entire next generation or individuals further into the future). Howarth's and Norgaard's arguments also have important implications for analyses of environmental valuation, discount rates, and policy design (e.g., pollution taxation), since all of these are affected by the income distribution.

Howarth and Norgaard do not investigate the range of intergenerational social welfare functions that might plausibly be invoked in connection with intergenerational equity. In their analysis they are concerned primarily with the egalitarian "maximin" criterion discussed below as an alternative to maximizing the present value of utility streams.[5] In addition, trying to achieve intergenerational equity solely through savings that transfer endowments across

[4]See in particular Page (1977), Pearce (1983), and Burton (1993) for discussions of intergenerational discounting. These analyses suggest that a positive discount rate to reflect the growth of the economy is compatible with a zero rate of pure time preference in the social welfare function on ethical grounds. The arguments in Sandler and Smith (1976, 1977, 1982), Bishop (1977), and Cabe (1982) indicate that the assumption of a uniform discount rate may not be consistent with intertemporal Pareto efficiency, particularly with intertemporal public goods.

[5]Howarth (1992) derives this social welfare criterion from a more restricted maximin ethic between just parents and their children. He shows that if parental altruism extends only to the direct *consumption* of the next generation, there is no assurance that utility levels will be maintained or increase over time; but if the current generation is concerned about the capacity of its descendants to exercise *their* bequest motive as well, the result is concern about the equity of welfare across all generations.

generations may not always be effective. Randall and Farmer (1993) argue that when the two-generation analyses of Howarth and Norgaard are extended to a setting with three or more generations, a kind of Coasian result obtains: the ultimate equilibrium allocation is not that sensitive to the initial distribution of property rights. Randall and Farmer argue for an approach to sustainability based on preservation rules like the safe minimum standard discussed subsequently in this paper.

The problem of intergenerational equity has received considerable attention in the economics literature through the application of a Rawlsian (1971) "maximin" concept of intergenerational rights (see, e.g., Solow 1974, 1986 and Norton 1989, as well as the work by Howarth and Norgaard cited above). The Rawlsian approach has been criticized as posing too harsh a trade-off between equity and welfare maximization, since a strict application of the Rawlsian criterion leads to the outcome that all generations must be equally well (or badly) off—that is, there is no scope for the current generation to pursue improvements in future conditions. However, more recent analyses of the Rawlsian social welfare problem suggest that this trade-off need not be so harshly drawn. In particular, Asheim (1988, 1991) shows that when individual preferences include some altruistic concern for immediate descendants, but there is also a social agreement to follow a Rawlsian ethic involving concern for the indefinite future, it is possible within the context of social welfare maximization to have economic growth coupled with a requirement that future generations be no worse off than the present.

As Pezzey (1989, 1994a) points out, there are a number of alternatives to the maximin criterion for social welfare orderings that could be used to reflect intergenerational equity concerns. Pezzey (1994b) analyzes in some detail the implications of a criterion based on the maximization of the present value of per-capita utility subject to an ethical constraint that per-capita utility not decline over time. Like Asheim, Pezzey finds that this criterion allows for concern for future welfare without necessarily sacrificing all growth possibilities. A weaker version of this criterion would accord intergenerational equity (as indicated by nondeclining utility over time) some *finite* weight in the social welfare function, allowing for well-defined trade-offs between maximum present value and fairness (see, e.g., Broome 1992).

The discussion thus far has concerned mainly individualistic conceptions of what is good or right. Even the individualistic point of view gives rise to deep controversy. On the one hand, critics raise objections to the capacity of utilitarianism, or even the concept of human preferences, to adequately describe human interests (see, e.g., Sen 1982; Parfit 1983b; Sagoff 1988; and Norton 1992).[6] Defenders of deontological theory, on the other hand, point out the difficulties in assigning rights to future generations (e.g., Broome 1991). Even those who do not necessarily espouse utilitarianism agree that there are some deep logical difficulties in assigning standing to "potential" future persons whose circumstances not only are largely unknown to the present generation but also are endogenous to the set of choices made by the current generation (see, e.g., Baier 1984; Barry 1977; Golding 1972; Passmore 1974; and Parfit 1983a).

One approach to this problem has been the development of organicist arguments that invoke an obligation to the entire context of future human life—the species as a whole, and the ecological systems that surround it—rather than just to potential future individuals (see, e.g., Leopold 1949; Lovelock 1988; Callicott 1989; Norton

[6] Some critics argue that the conventional approach to specifying preference orderings in economics is deficient on both empirical and moral grounds, since it does not distinguish "lower" or "higher" impulses, or "self-interest" and "community-motivated" interests. The solution, it is argued, is some hierarchical representation of preferences. However, Brennan (1989) argues that this approach does not really solve any problems associated with conventional preference reasoning in economics; and in particular, that moral deficiencies associated with the outcomes of economic logic should be directly confronted as such, rather than attempting to reframe that logic.

1982, 1986, 1989; Page 1983, 1991; Nash 1989; Weiss 1989). This "stewardship" perspective emphasizes the safeguarding of the large-scale ecological processes that support all facets of human life, from biological survival to cultural existence. The stewardship perspective does not deny the relevance of human preferences, but it asserts the existence of larger societal concerns that members of society will feel (in varying degrees) beyond individualistic preferences.

The organicist position raises the interesting and as-yet unanswered question of whether there are important social values that simply cannot be captured in an individualistic resource valuation, no matter how broad and sophisticated the valuation methods are. The difficulty in addressing this issue is that the two perspectives are based on different fundamental axioms. The organicist position seems to avoid some of the difficulties in extending individualistic fairness concepts to intergenerational circumstances. On the other hand, a nonindividualistic perspective is a two-edged sword in that many of humankind's most cherished economic, political, and other social institutions derive fundamentally from giving high respect to individual rights. Organicism without constraints leads to supremacy of the group over the individual, a form of social order that history shows to be very dangerous and destructive. The two-tier system described subsequently in the paper seeks to provide a venue for considering the balance between individual trade-offs and social imperatives.

III. RESOURCE SUBSTITUTABILITY

Assuming one accepts some obligation to consider the well-being of future generations, what bundles of social capital should succeeding generations make available to their descendants? The answer to this question depends critically on one's assumptions regarding the degree of substitutability between the services provided by natural capital (material resources, waste absorption, other ecological functions, aesthetic and cultural values) and other forms of capital (plant, equipment, knowledge, skills, social institutions).

One view, to which many economists would be inclined, is that all resources are relatively fungible sources of well-being. This view appears to be influenced heavily by a number of classic and more recent applications of aggregate growth models with natural resources. A number of familiar theorems come out of this literature. In the standard growth model without natural resource constraints, the modified Golden Rule indicates that per-capita consumption and utility will grow over time provided the economy is not already saturated with capital. Clearly, sustainability presents no challenge in this world, even with positive discounting of future utilities. The same outcome obtains with natural resources provided these resources are in some sense "augmentable"—capable of being renewed or of having damages offset by compensatory investments (for a recent exposition of this see van Geldrop and Withagen 1993). Even with exhaustible resources or some other irreversible degradation of the services provided by the natural environment (such as accumulative pollution), it is possible for consumption and welfare to grow if there is sufficient substitutability between natural resources and capital accumulation, or technical progress sufficient to offset the depletion/degradation of natural resource services (Dasgupta and Heal 1974; Solow 1974, 1986; Stiglitz 1974; Baumol 1986; Dasgupta and Mäler 1991; see also the surveys in Asheim 1989, Pezzey 1992, and Toman, Pezzey, and Krautkraemer forthcoming).

From this point of view, then, large-scale damages to ecosystems such as degradation of environmental quality, loss of species diversity, or destabilization from global warming are not intrinsically unacceptable. The question is whether compensatory investments for future generations in other forms of capital are feasible and are undertaken. This is the essence of the argument advanced by Solow (1986) and Mäler (1991), based on previous work by Hartwick (1977), that investments of resource rents in other forms of capital provide the means to sustain consumption possibilities over time. Investments in human knowledge, techniques of production and social organization are especially pertinent in humankind's efforts to outrace any increases in the scarcity of services provided by the natural environment.[7]

An alternative view, embraced by many ecologists and some economists, is that such compensatory investments often are infeasible as well as ethically indefensible. Physical laws are seen as limiting the extent to which other resources can be substituted for scarce natural resources or ecological degradation. In particular, physical capital cannot be substituted for scarce energy without limit because there are minimum energy requirements for accomplishing any transformation of matter. In addition, because matter is conserved, waste is an inherent part of any economic activity; and natural limits may constrain the capacity of the environment to process these wastes.[8] Healthy ecosystems, including those that provide genetic diversity in relatively unmanaged environments, offer resilience against unexpected changes that preserve options for future generations.[9] For natural life-support systems no practical substitutes are possible, and degradation may be irreversible. In such cases (and perhaps in others as well), compensation cannot be meaningfully specified.[10]

The question of physical scale is central to this debate. If substitutability is relatively easy, then the total scale of human activity relative to the natural environment is of limited significance relative to efficient use of resources and, depending on one's ethical perspective, the adequacy of society's total savings for the future. The notion of "carrying capacity," so often invoked in sustainability debates, then would be at most ephemeral and at worst meaningless outside its traditional ecological usage. Critics of this view turn the entire argument around by claiming that physical limits cannot be ignored and then putting much more emphasis on scale issues (see, e.g., Goodland, Daly, and El Serafy 1991 and Costanza 1991).

A related issue that sometimes is overlooked is the distinction between local and global impacts when considering substitution possibilities. Local resource depletion and ecological degradation, while often having serious consequences, may be more easily compensated for by trade, economic diversification, and migration than regional

---

[7] As pointed out recently by Asheim (1994) and Pezzey (1994b), Hartwick's reinvestment rule has been widely misinterpreted as an instant test of the future sustainability of an arbitrary economy. Although an economy with constant utility over time must satisfy the Hartwick Rule (as Hartwick proved), observing that investment currently happens to be greater than or equal to the resource rent measured at market prices does *not* imply that at least the current level of utility can be maintained by imposing Hartwick's Rule from now onwards. The intuition behind this result is that an economy which is depleting its natural resources too fast for sustainability will drive resource prices and hence resource rents too low, and investment at such a level does not ensure sustainability. The correct indicator of permanent sustainability would be resource rents as measured by shadow prices which reflect the sustainability constraint (which includes the constraint of the current resource stock). This poses a challenge for those interested in developing empirical indicators of sustainable development.

[8] Concern over these issues in the economics literature has been expressed by Ayres and Kneese (1969), Kneese, Ayres, and d'Arge (1971), Ayres and Miller (1980), Perrings (1986), Anderson (1987), Barbier and Markandya (1990), Gross and Veendorp (1990), Victor (1991), Daly (1992), Townsend (1992), and Common and Perrings (1992); see also the survey in Toman, Pezzey and Krautkraemer (forthcoming).

[9] A related argument at the macro level is that environmental quality may complement capital growth as a source of economic progress, particularly for poorer countries (Pearce, Barbier, and Markandya 1990).

[10] The importance of the substitutability issue can be illustrated in connection with the debate over allocating responsibility for greenhouse gas control. If one accepts the view that investments in adaptation to climate change have limited scope for effectiveness, then the atmosphere's capacity to absorb greenhouse gases also is a depletable resource with limited substitution potential. In this case cumulative past greenhouse gas emissions can be a simple metric for assessing a fair distribution of control obligation: greater cumulative emissions by industrialized countries imply greater responsibility. However, if one sees the investment in economic productive capacity and thus in global adaptive capacity by industrial nations as having provided significant benefits that do compensate for depletion of the atmosphere's capacity for greenhouse gas absorption, then the responsibility of industrialized countries is less clear-cut.

or global adversities. On the other hand, trade distortions (e.g., discrimination against manufactured exports by developing countries) may limit national capacities to develop sustainably, and individual countries may appear to develop sustainably by "exporting" unsustainable resource use to other nations that supply materials.

The discussion in this section and the previous one suggests that, at the risk of some caricature, three alternative polar conceptions of sustainability can be identified:

1. *Neoclassical presentism.* This position does not place much emphasis on sustainability as an issue distinct from efficient resource use. The standard present value criterion is adopted for intergenerational welfare comparisons, and natural capital scarcity is assumed to be remediable (given appropriate price signals and/incentives) through substitution and technical advance.
2. *Neoclassical egalitarianism.* This view is the same as (1) with respect to assumptions about managing natural capital scarcity, but it also maintains a concern about a potential shortfall in total savings for the future that is not encompassed in the present value criterion.
3. *Ecological organicism.* In contrast to (1) and (2), this view emphasizes limits on substitution between natural capital and other assets. Like (2), this view includes a concern for intergenerational fairness, but that concern is not entirely individualistic; it also encompasses concerns for ecological systems and the human species as a whole.[11]

To be sure, views on sustainability that are composites of these positions also can be defined. The model discussed in the next section allows for a continuum of views about intergenerational fairness and resource substitutability.

IV. AN EXTENDED "SAFE MINIMUM STANDARD"

In this section a simple conceptual framework is outlined that can be used in considering how individualistic resource trade-offs might be balanced against social imperatives for safeguarding against large-scale, irreversible degradation of natural capital. The framework is not intended to imply a specific decision rule. Instead, its purpose is to indicate the implications of different sustainability conceptions and to provide some common ground for consideration of differences in conceptions among economists, ecologists, and ethicists. In broad outline, the framework is a two-tier system in which standard economic trade-offs (market and nonmarket) guide resource assessment and management when the potential consequences are small and reversible, but these trade-offs increasingly are complemented or even superseded by socially determined limits for ecological preservation as the potential consequences become larger and more irreversible. The framework is an extension of the logic of safe minimum standard promulgated by Ciriacy-Wantrup (1952) and Bishop (1978). Variants of this two-tier approach have been suggested by a number of writers from different disciplines (see, e.g., Norton 1982, 1992; Page 1983, 1991; and Randall 1986).

To begin the discussion, suppose for simplicity that all potential human impacts on the natural environment can be characterized by their prospective "cost" and "irreversibility." Prospective cost can be interpreted in several ways. It can be thought of as an (individualistic) economic measure of expected opportunity cost, as an ecological measure of predicted physical impact, or as some hybrid of individualistic or organicist concerns including social values like political freedom and justice. The

[11] It would be possible to identify a fourth position, ecological presentism, but this view could be internally contradictory and in any event it seems to hold little interest.

framework does not require a particular definition of cost, though some precision on what is counted as a cost is needed in practice when interpreting alternative conceptions of the safe minimum standard.

Similarly, irreversibility can be seen in terms of an ecological assessment of system function or as an economic construct involving the feasibility of restorative or compensating investment. Economic irreversibility here is taken to be the same as nonsubstitutability. Of course, considerable uncertainty exists regarding both the cost and irreversibility of particular human impacts. This uncertainty is in fact central to the concept of safe minimum standard.

One question that needs to be addressed is why two metrics are needed for gauging impacts and determining social responses. Economists are accustomed to valuing consequences of irreversibility in an uncertain setting (see, e.g., Krutilla 1967; Krutilla and Fisher 1985; and Fisher and Hanemann 1987), so this dimension to some extent is redundant. Indeed, the prospective cost measure could be thought of as including premiums reflecting risks that can be monetized. The concept of systemic scale in ecological research also may forge links between the severity and irreversibility of impacts (Norton and Ulanowicz 1992). This research suggests that damages to ecological systems that are larger in spatial scale or higher up in the hierarchy of natural processes—more complex, consisting of more component subsystems—is both more harmful and harder to reverse because of the complexity and slower time of adaptation in these systems.

Nevertheless, there are reasons for distinguishing the metrics. Monetizing all irreversibility suggests that compensatory investment for any environmental degradation is feasible and ethical.[12] This seems debatable, as already noted. Analytically, it rules out by assumption the ecological organicist position on sustainability defined above. To avoid this, we must retain both the cost and irreversibility dimensions.

The cost and irreversibility dimensions can be brought together in a single "sample universe" as shown in Figure 1.[13] Individuals can, in this theory, locate different impacts on the natural environment (e.g., a 5-degree global mean temperature rise or a 50 percent loss of tropical forest) in the square, depending on their own assessments of cost and irreversibility. Because of uncertainties, these assessments will reflect subjective judgments including attitudes toward known or potential risks (in other words, the cost and irreversibility assessments generally will not reflect just subjective mean or median values). Individual judgments inherently will reflect not just factual information but also personal values about the nature of the obligation to future generations. A variety of social institutions, notably the political process, education, and mass communication, presumably generate some synthesis of individual impact assessments at the societal level. The synthesis is dynamic in that it reflects a variety of forms of social learning (e.g., improvements in production technique and social organization).

We can now combine this construct with an extension of the safe minimum standard logic to indicate how individualistic tradeoffs and social imperatives regarding the natural environment might be balanced. The safe minimum standard originally was developed in the context of individual species preservation (see Bishop 1978 and Ciriacy-Wantrup 1952). The logic in this setting is that standard benefit-cost comparisons may be inadequate if the long-term cost of species loss is highly uncertain (in the Knightian sense of having probabilities that are difficult to gauge) but possibly quite substantial. Proponents of a safe minimum standard argue that with low information but high potential asymmetry in the loss function, the evenhanded assessment of benefit-cost analysis should give way to a greater presumption in favor of species

[12] This discussion leaves aside important practical problems of measurement that arise in any approach to irreversibility.

[13] This diagrammatic approach was originally developed by Bryan Norton (see Norton 1992). The figure shown here is an adaptation of Norton's schema.

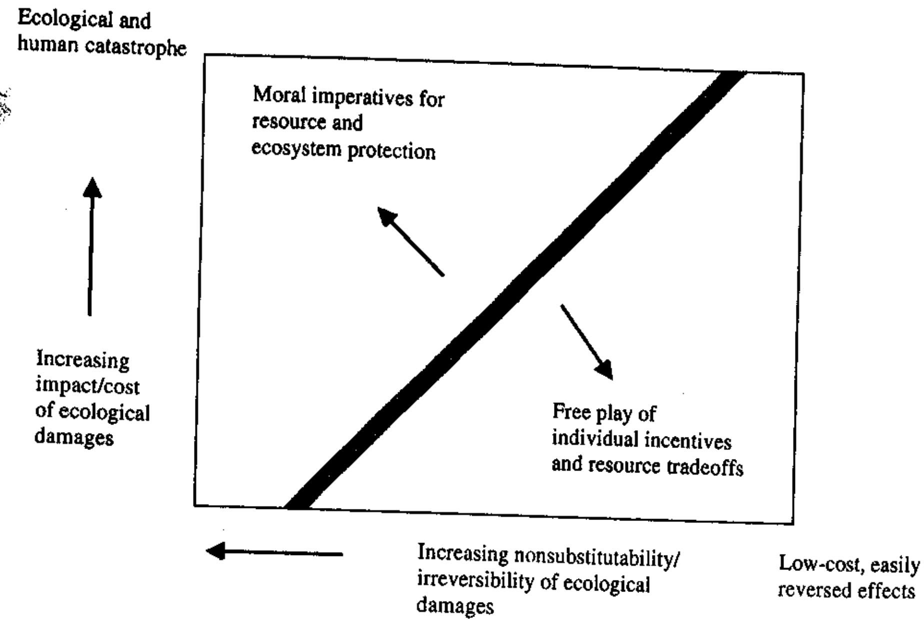

FIGURE 1
ILLUSTRATION OF THE SAFE MINIMUM STANDARD FOR BALANCING NATURAL RESOURCE TRADE-OFFS AND IMPERATIVES FOR PRESERVATION

preservation unless society judges that the cost of preservation is "intolerable."[14]

In Figure 1 we extend this logic to a continuum of potential impacts on the natural environment in the following way. First, impacts in the lower-right portion of the box involve both modest cost and a high degree of reversibility. In this area there is little threat of substantial lasting damage to the interests of future generations, and it is reasonable to rely upon individualistic valuations and trade-offs as reflected in benefit-cost analysis. Individual incentives for efficient resource use can be achieved through markets and incentive-based policies to correct "conventional" externalities.

Toward the upper-right corner of the box the costs become higher but still are relatively reversible. Here the primary concern in addition to efficient resource use might be to ensure that the current generation meets obligations to the future through general compensation for environmental degradation. On the other hand, impacts located toward the lower-left corner of the box are relatively irreversible but low in cost, so they presumably can be absorbed without too much detrimental effect on the future.

It is in considering impacts toward the upper-left corner of Figure 1 that the safe minimum standard assumes prominence. Here the long-term costs are likely to be high and substitution options likely to be low, making the impacts irreversible. Moreover, uncertainty is likely to be substantial since the impacts in question involve large-scale ecological systems and functions that remain poorly understood.

Under these conditions even individualistic, presentist valuations can provide a considerable impetus toward resource preservation. However, the logic of the safe minimum standard suggests that this impetus alone may not fully satisfy reasonable obligations to future generations, particularly when the negative effects involve

[14] See Bishop (1979) and Smith and Krutilla (1979), as well as Castle and Berrens (1993) for further discussion of the distinction between the safe minimum standard and benefit-cost analysis. This reasoning is another way of highlighting the need for considering cost and irreversibility as distinct metrics of impact.

large-scale ecological systems and long gestation periods. One can imagine that the closer one moves to the northwest corner of the box, the more entirely individualistic valuation ciriteria are supplemented by other expressions of community interest in the form of a priori social rules of a "constitutional" nature for preserving natural capital. This is illustrated by the fuzzy demarcation line in Figure 1. Such socially determined criteria could be changed if the members of society deem the cost of preserving natural capital to be excessive, but a higher burden of proof would be placed on arguments favoring acceptance of high-cost, irreversible impacts than on acceptance of smaller impacts.

As already noted, individual perceptions of natural impacts and thus individual assessments of where the fuzzy line should be located depend strongly on individual values and knowledge. Figure 1 can be used to illustrate the different positions on sustainability summarized in the previous section of the paper. Generally speaking, ecologists with a primary concern for natural function and resilience might be more inclined than economists to emphasize the irreversibility dimension and to draw a more vertical fuzzy line, limiting even lower-cost irreversible effects; economists with greater concern for cost and more confidence in substitutability might be more inclined toward a horizontal line. Neoclassical presentists might put little or no area to the northwest of the dividing line (or even dismiss the whole construct), while ecological organicists would take a contrary view. Neoclassical egalitarians might take a middle ground, drawing a close to horizontal line but placing more area above it to limit high-cost burdens on future generations.

It should be emphasized again that there is a distinct difference between the safe minimum standard approach and the standard prescriptions of resource and environmental economics, which involve getting accurate valuations of resources in benefit-cost assessments and using economic incentives to achieve efficient allocations of resources given these valuations. Whether a resource-protection criterion is established through application of the safe minimum standard concept or entirely by trade-offs through cost-benefit analyses, that criterion can be achieved cost-effectively by using economic incentives. However, for impacts on the natural environment that are uncertain but may be large and irreversible, the safe minimum standard posits an alternative to relying just on comparisons of expected economic benefits and costs for developing resource-protection criteria.[15] It places greater emphasis on scale issues involving potential damages to the natural system than on the sacrifices experienced from curbing ecological impacts, which are seen as likely to be smaller and more readily reversible. On the other hand, the arguments in this section do not require that either the safe minimum standard as a social decision rule, or individual preferences for environmental preservation, be rigidly hierarchical. The safe minimum standard can be seen as a social compact for expressing agreed-upon moral sentiments in the face of high ecological uncertainty and potential loss asymmetry, even with egoistic consumption, bequest, and time preferences that are entirely neoclassical.[16]

The arguments in this section are somewhat similar to those developed by Vatn and Bromley (1994) regarding environmental decision making and economic valuation. Briefly, these authors argue that large-scale environmental assets or risks are inherently difficult to value meaningfully in a conventional economic sense. This is not just because of limited information about these assets and risks, which causes individual preferences to be poorly defined, but also because large-scale environmental con-

[15] See also Pezzey (1989, 1994a), who shows with a simple example that efficient management of externalities over time may not generate sustainable welfare distributions.

[16] Tim Brennan suggests (in private communication) that the safe minimum standard also can be seen as a social decision strategy that economizes on costly information-gathering and enforcement activities relative to theoretically preferred marginal evaluations and policies.

siderations are bound up in social mores that condition individual preferences. Vatn and Bromley argue that people must be seen as dualistic, behaving as citizens as well as consumers, and that many social institutions for environmental management—including the norms surrounding government of the environment—must be seen as ways that societies have attempted to circumvent the informational and "contextual" problems surrounding individualistic valuation. This point of view justifies in particular the imposition of safe minimum standards determined through political discourse and other complex social processes.

V. CONCLUDING REMARKS

Sustainability ultimately is intimately wrapped up with human values and institutions, not just ecological functions. An entirely ecological definition of sustainability is inadequate; guidance for social decision making also is required. It must be recognized that human behavior and social decision processes are complex, just as ecological processes are. At the same time, economic analysis without adequate ecological underpinnings also can be misleading. The sustainability debate also should remind economists to carefully distinguish between efficient allocations of resources—the standard focus of economic theory—and socially optimal allocations that may reflect other intergenerational (as well as intragenerational) equity concerns.

The tension between ecological and economic perspectives on sustainability suggests several ways in which both economists and ecologists could adapt their research emphases and methodologies to make the best use of interdisciplinary contributions. For ecologists, the challenges include providing information on ecological conditions in a form that could be used in economic assessment.[17] Ecologists also must recognize the importance of human behavior, particularly behavior in response to economic incentives—a factor often given short shrift in ecological impact analyses. Economists for their part could expand analyses of resource values to consider the function and value of ecological systems as a whole, making greater use of ecological information in the process. Both methodological research and case studies are needed to synthesize ecological and economic perspectives. Research by economists and other social scientists (psychologists and anthropologists) also could help to improve understanding of how future generations might value different attributes of natural environments.

From the standpoint of economic theory, an important direction for further research is the consideration of how both physical limits and ethical constraints on resource use may affect the time paths and shadow values of natural capital stocks, relative to the results found in standard theory. The literature on economic growth with natural resources is beginning to address these issues, and there is a lot of basic methodology that can be exploited for this purpose.[18]

One example is the work by Asheim (1988, 1991) and Pezzey (1989, 1994a, 1994b) alluded to earlier. Asheim shows that if we accept the idea of two-tiered social preferences, in which individuals have limited altruism for the next generation but also subscribe to a broader conception of intergenerational social justice, socially preferred outcomes can promote justice without sacrificing growth. In particular, this argument provides a more basic justification for the criterion of nondecreasing utility assumed in Pezzey's sustainability analysis.[19]

Another set of examples concerns the issue of resource substitution. A number of

[17] Carpenter (1992) argues that the current state of biophysical measurement for assessing the sustainability of human impacts on ecological systems is too weak to effectively operationalize the concept of natural capital; only gross unsustainability can be detected.

[18] For further discussion see Toman, Pezzey, and Krautkraemer (forthcoming).

[19] Because of the obvious importance of uncertainty in dealing with long-term environmental change, for a complete analysis it is necessary to explicitly reflect this uncertainty in social welfare orderings. This issue is tackled in Asheim and Brekke (1993).

papers have explored the consequences for present-value-maximizing paths of including stocks in utility functions as a reflection of some sort of "amenity" value (see, e.g., Krautkraemer 1985, 1988 and Tahvonen and Kuuluvainen 1993). In these analyses, preservation of some positive level of environmental attribute is not assured; achieving preservation in the steady state requires some combination of large initial capital accumulation and unbounded disutility from environmental degradation. Barbier and Markandya (1990), in particular, consider the consequences of requiring a threshold level of environmental preservation to stave off irreversible environmental disaster. Common and Perrings (1992) go further in discussing the basic differences between economic and ecological sustainability, and the difficulties in bringing these ideas together in a single model.

Despite its continued abuse as a buzzword in policy debates, the concept of sustainability is becoming better established as a consequence of studies in economics, ecology, philosophy, and other disciplines. With a better understanding of the interdisciplinary theoretical issues, and a better empirical understanding of both ecological conditions and social values, sustainability also can evolve to the point of offering more concrete guidance for social policy.

References

Anderson, C. L. 1987. "The Production Process: Inputs and Wastes." *Journal of Environmental Economics and Management* 14 (Mar.):1–12.

Asheim, G. B. 1988. "Rawlsian Intergenerational Justice as a Markov-Perfect Equilibrium in a Resource Technology." *Review of Economic Studies* 55 (July):469–84.

———. 1989. "Intergenerational Conflicts in the Management of Natural and Environmental Resources: Sustainability in a Growth-Theoretic Perspective." Center for Applied Research, Draft Manuscript, Norwegian School of Economics and Business Administration (Oct.).

———. 1991. "Unjust Intergenerational Allocations." *Journal of Economic Theory* 54 (Aug.):350–71.

———. 1994. "Net National Product as an Indicator of Sustainability." *Scandinavian Journal of Economics* 96 (June):257–65.

Asheim, G. B., and K. A. Brekke. 1993. "Sustainability When Resource Management Has Stochastic Consequences." Central Bureau of Statistics, Discussion Paper No. 86, Oslo (Mar.).

Ayres, R. U., and A. V. Kneese. 1969. "Production, Consumption, and Externalities." *American Economic Review* 69 (June): 282–97.

Ayres, R. U., and S. Miller. 1980. "The Role of Technological Change." *Journal of Environmental Economics and Management* 7 (Dec.):353–71.

Baier, A. 1984. "For the Sake of Future Generations." In *Earthbound: New Introductory Essays in Environmental Ethics*, ed. T. Regan. New York: Random House.

Barbier, E. B., and A. Markandya. 1990. "The Conditions for Achieving Environmentally Sustainable Development." *European Economic Review* 34 (May):659–69.

Barry, B. 1977. "Justice Between Generations." In *Law, Morality, and Society: Essays in Honour of H. L. A. Hart*, eds. P. M. S. Hacker and S. J. Rax. Oxford: Clarendon Press.

Baumol, W. J. 1986. "On the Possibility of Continuing Expansion of Finite Resources." *Kyklos* 39:167–79.

Bishop, R. C. 1977. "Intertemporal and Intergenerational Pareto Efficiency: A Comment." *Journal of Environmental Economics and Management* 4 (Sept.):247–57.

———. 1978. "Endangered Species and Uncertainty: The Economics of the Safe Minimum Standard." *American Journal of Agricultural Economics* 60 (Feb.):10–18.

———. 1979. "Endangered Species, Irreversibility and Uncertainty: A Reply." *American Journal of Agricultural Economics* 61 (May): 376–79.

Brennan, T. J. 1989. "A Methodological Assessment of Multiple Utility Frameworks." *Economics and Philosophy* 5:189–208.

Bromley, D. W. 1989. "Entitlements, Missing Markets and Environmental Uncertainty." *Journal of Environmental Economics and Management* 17 (Sept.):181–94.

Broome, J. 1991. *The Intergenerational Aspects of Climate Change*. Bristol, UK: University of Bristol.

———. 1992. *Counting the Cost of Global Warming*. Cambridge: White Horse Press.

Burton, P. S. 1993. "Intertemporal Preferences and Intergenerational Equity Considerations in Optimal Resource Harvesting." *Journal of Environmental Economics and Management* 24 (Mar.):119–32.

Cabe, R. A. 1982. "Intertemporal and Intergenerational Pareto Efficiency: An Extended Theorem." *Journal of Environmental Economics and Management* 9 (Dec.):355–60.

Callicott, J. B. 1989. *In Defense of the Land Ethic*. Albany: State University of New York Press.

Carpenter, R. A. 1992. "Can Sustainability Be Measured." Paper presented at the 2nd Meeting of the International Society for Ecological Economics, Stockholm, Sweden, Stockholm University, August 3–6.

Castle, E. N., and R. P. Berrens. 1993. "Endangered Species, Economic Analysis, and the Safe Minimum Standard." *Northwest Environmental Journal* 9:108–30.

Ciriacy-Wantrup, S. V. 1952. *Resource Conservation*. Berkeley: University of California Press.

Common, M., and C. Perrings. 1992. "Towards an Ecological Economics of Sustainability." *Ecological Economics* 6 (July):7–34.

Costanza, R., ed. 1991. *Ecological Economics: The Science and Management of Sustainability*. New York: Columbia University Press.

Daly, H. 1990. "Toward Some Operational Principles of Sustainable Development." *Ecological Economics* 2 (Apr.):1–6.

———. 1991. "Ecological Economics and Sustainable Development: From Concept to Policy." Environment Department Working Paper No. 1991–24, The World Bank.

———. 1992. "Is the Entropy Law Relevant to the Economics of Natural Resource Scarcity?—Yes, of Course It Is!" *Journal of Environmental Economics and Management* 23 (July):91–95.

Dasgupta, P. S., and G. M. Heal. 1974. "The Optimal Depletion of Exhaustible Resources." In *Review of Economic Studies, Symposium on the Economics of Exhaustible Resources*. Edinburgh, Scotland: Longman Group Limited.

Dasgupta, P. S., and K.-G. Mäler. 1991. "The Environment and Emerging Development Issues." In *Proceedings of the World Bank Annual Conference on Development Economics 1990*. Washington, DC: The World Bank.

Dixon, J. A., and L. A. Fallon. 1989. "The Concept of Sustainability: Origins, Extensions, and Usefulness for Policy." *Society and Natural Resources* 2:73–84.

Ehrlich, P. R. 1989. "The Limits to Substitution: Meta-Resource Depletion and a New Economic-Ecological Paradigm." *Ecological Economics* 1 (Feb.):9–16.

Fisher, A. C., and W. M. Hanemann. 1987. "Quasi-Option Value: Some Misconceptions Dispelled." *Journal of Environmental Economics and Management* 14 (June):183–90.

Golding, Martin P. 1972. "Obligations to Future Generations." *The Monist* 56:85–99.

Goodland, R., H. Daly, and S. El Serafy, eds. 1991. "Environmental Sustainable Economic Development Building on Brundtland." Environment Department, Environment Working Paper No 46, The World Bank (July).

Gross, L. S., and E. C. H. Veendorp. 1990. "Growth With Exhaustible Resources and a Materials-Balance Production Function." *Natural Resource Modeling* 4 (Winter): 77–94.

Hartwick, J. M. 1977. "Intergenerational Equity and the Investing of Rents from Exhaustible Resources." *American Economic Review* 67 (Dec.):972–74.

Howarth, R. B. 1991a. "Intergenerational Competitive Equilibria under Technological Uncertainty and an Exhaustible Resource Constraint." *Journal of Environmental Economics and Management* 21 (Nov.):225–43.

———. 1991b. "Intertemporal Equilibria and Exhaustible Resources: An Overlapping Generations Approach." *Ecological Economics* 4 (Dec.):237–52.

———. 1992. "Intergenerational Justice and the Chain of Obligation." *Environmental Values* 1 (Summer):133–40.

Howarth, R. B., and R. B. Norgaard. 1990. "Intergenerational Resource Rights, Efficiency and Social Optimality." *Land Economics* 66 (Feb.):1–11.

———. 1992. "Environmental Valuation under Sustainability." *American Economic Review* 82 (May):473–77.

———. 1993. "Intergenerational Transfers and the Social Discount Rate." *Environmental and Resource Economics* 3 (Aug.):337–58.

Kneese, A. V., and W. D. Schulze. 1985. "Ethics and Environmental Economics." In *Handbook of Natural Resource and Energy Economics,* Vol. 1, eds. A. V. Kneese and J. L. Sweeney. Amsterdam: North-Holland.

Kneese, A., R. Ayres, and R. d'Arge. 1971. *Economics and the Environment*. Baltimore, MD: Johns Hopkins University Press for Resources for the Future.

Krautkraemer, J. A. 1985. "Optimal Growth, Resource Amenities and the Preservation of Natural Environments." *Review of Economic Studies* 52 (Jan.):153–70.

———. 1988. "The Rate of Discount and the Preservation of Natural Environments." *Natural Resource Modeling* 2 (Winter): 421–37.

Krutilla, J. V. 1967. "Conservation Reconsidered." *American Economic Review* 54 (Sept.):777–86.

Krutilla, J. V., and A. C. Fisher. 1985. *The Economics of Natural Environments: Studies in the Valuation of Commodity and Amenity Resources*, 2d ed. Washington, DC: Resources for the Future.

Leopold, A. 1949. *A Sand County Almanac*. New York: Oxford University Press.

Lovelock, J. 1988. *The Ages of Gaia*. New York: Norton.

Mäler, K.-G. 1991. "National Accounts and Environmental Resources." *Environmental and Resource Economics* 1:1–16.

Nash, J. A. 1989. "Ecological Integrity and Christian Political Responsibility." *Theology and Public Policy* 1 (Fall):32–48.

Norgaard, R. B. 1988. "Sustainable Development: A Co-Evolutionary View." *Futures* 20 (Dec.):606–20.

Norton, B. G. 1982. "Environmental Ethics and the Rights of Future Generations." *Environmental Ethics* 4 (Winter):319–30.

———. 1984. "Environmental Ethics and Weak Anthropocentrism." *Environmental Ethics* 6 (Summer):131–48.

———. 1986. "On the Inherent Danger of Undervaluing Species." In *The Preservation of Species*, ed. B. G. Norton. Princeton, NJ: Princeton University Press.

———. 1989. "Intergenerational Equity and Environmental Decisions: A Model Using Rawls' Veil of Ignorance." *Ecological Economics* 1 (May):137–59.

———. 1992. "Sustainability, Human Welfare, and Ecosystem Health." *Environmental Values* 1 (Summer):97–111.

Norton, B. G., and R. E. Ulanowicz. 1992. "Scale and Biodiversity Policy: A Hierarchical Approach." *Ambio* 21 (May):244–49.

Page, T. 1977. *Conservation and Economic Efficiency*. Baltimore, MD: Johns Hopkins University Press for Resources for the Future.

———. 1983. "Intergenerational Justice as Opportunity." *Energy and the Future*, eds. D. MacLean and P. G. Brown. Totowa, NJ: Rowman and Littlefield.

———. 1988. "Intergenerational Equity and the Social Rate of Discount." In *Environmental Resource and Applied Welfare Economics*, ed. V. K. Smith. Washington, DC: Resources for the Future.

———. 1991. "Sustainability and the Problem of Valuation." In *Ecological Economics: The Science and Management of Sustainability*, ed. R. Constanza. New York: Columbia University Press.

Parfit, D. 1983a. "Energy Policy and the Further Future: The Identity Problem." In *Energy and the Future*, eds. D. MacLean and P. B. Brown. Totowa, NJ: Rowman and Littlefield.

———. 1983b. "Energy Policy and the Further Future: The Social Discount Rate." In *Energy and the Future*, eds. D. MacLean and P. B. Brown. Totowa, NJ: Rowman and Littlefield.

Passmore, J. 1974. *Man's Responsibility for Nature*. New York: Scribner's.

Pearce, D. W. 1983. "Ethics, Irreversibility, Future Generations and the Social Rate of Discount." *International Journal of Environmental Studies* 21:67–86.

Pearce, D., and R. Turner. 1990. *Economics of Natural Resources and the Environment*. Baltimore, MD: Johns Hopkins University Press.

Pearce, D., A. Markandya, and E. Barbier. 1989. *Blueprint for a Green Economy*. London: Earthscan.

Pearce, D. W., E. Barbier, and A. Markandya. 1990. *Sustainable Development: Economics and Environment in the Third World*. London: Earthscan.

Perrings, C. 1986. "Conservation of Mass and Instability in a Dynamic Economy-Environment System." *Journal of Environmental Economics and Management* 13 (Sept.):199–211.

Pezzey, J. 1989. *Economic Analysis of Sustainable Growth and Sustainable Development*. World Bank, Environment Department Working Paper No. 15. Now reprinted as Pezzey, J. 1992. *Sustainable Development Concepts: An Economic Analysis*. World Bank Environment paper No. 2. Washington, DC: World Bank.

———. 1992. "Sustainability: An Interdisciplinary Guide." *Environmental Values* 1 (Mar):321–62.

———. 1994a. "Sustainability, Intergenerational Equity, and Environmental Policy." Draft manuscript, University College London (April).

———. 1994b. "The Optimal Sustainable Depletion of Nonrenewable Resources." Draft manuscript, University College London (May).

Randall, A. 1986. "Human Preferences, Economics, and the Preservation of Species." In *The Preservation of Species*, ed. B. G. Norton. Princeton, NJ: Princeton University Press.

Randall, A., and M. C. Farmer. 1993. "Policies for Sustainability: Lessons from an Overlapping Generations Model." Draft manuscript, Columbus: The Ohio State University (Jan.).

Rawls, J. 1971. *A Theory of Justice*. Cambridge: Harvard University Press.

Sagoff, M. 1988. *The Economy of the Earth*. New York: Cambridge University Press.

Sandler, T., and V. K. Smith. 1976. "Intertemporal and Intergenerational Pareto Efficiency." *Journal of Environmental Economics and Management* 2 (Feb.):151–59.

———. 1977. "Intertemporal and Intergenerational Pareto Efficiency Revisited." *Journal of Environmental Economics and Management* 4 (Sept.):252–57.

———. 1982. "Intertemporal and Intergenerational Pareto Efficiency: A Reconsideration of Recent Extensions." *Journal of Environmental Economics and Management* 9 (Dec.):361–65.

Sen, A. K. 1982. "Approaches to the Choice of Discount Rates for Social Benefit—Cost Analysis." In *Discounting for Time and Risk in Energy Policy*, eds. R. C. Lind et al. Washington, DC: Resources for the Future.

Smith, V. K., and J. V. Krutilla. 1979. "Endangered Species, Irreversibilities, and Uncertainty: A Comment." *American Journal of Agricultural Economics* 61 (May):371–75.

Solow, R. M. 1974. "Intergenerational Equity and Exhaustible Resources." In *Review of Economic Studies, Symposium on the Economics of Exhaustible Resources*. Edinburgh, Scotland: Longman Group Limited.

———. 1986. "On the Intergenerational Allocation of Natural Resources." *Scandinavian Journal of Economics* 88 (June):141–49.

———. 1993a. "An Almost Practical Step Toward Sustainability." *Resources Policy* 19 (Sept.):162–72.

———. 1993b. "Sustainability: An Economist's Perspective." In *Selected Readings in Environmental Economics*, ed. R. Dorfman and N. Dorfman, 3rd ed. New York: Norton.

Stiglitz, J. 1974. "Growth with Exhaustible Natural Resources: Efficient and Optimal Growth Paths." In *Review of Economic Studies, Symposium on the Economics of Exhaustible Resources*. Edinburgh, Scotland: Longman Group Limited.

Tahvonen, O., and J. Kuuluvainen. 1993. "Economic Growth, Pollution, and Renewable Resources." *Journal of Environmental Economics and Management* 24 (Mar.):101–18.

Tietenberg, T. 1992. *Environmental and Natural Resource Economics*, 3rd ed. New York: Harper Collins.

Toman, M. A., J. Pezzey, and J. Krautkraemer. Forthcoming. "Neoclassical Economic Growth Theory and 'Sustainability'." In *Handbook of Environmental Economics*, ed. D. W. Bromley. Oxford: Basil Blackwell.

Townsend, K. N. 1992. "Is the Entropy Law Relevant to the Economics of Natural Resource Scarcity? Comment." *Journal of Environmental Economics and Management* 23 (July):96–100.

van Geldrop, J., and C. Withagen. 1993. "Natural Capital and Sustainability." Draft Manuscript, Department of Mathematics and Computing, University of Technology, Eindhoven, Netherlands.

Varian, H. 1984. *Microeconomic Analysis*, 2d ed. New York: Norton.

Vatn, A., and D. W. Bromley, 1994. "Choices without Prices without Apologies." *Journal of Environmental Economics and Management* 26 (Mar.):129–48.

Victor, P. A. 1991. "Indicators of Sustainable Development: Some Lessons from Capital Theory." *Ecological Economics* 4 (Dec.): 191–213.

Weiss, E. B. 1989. *In Fairness to Future Generations*. Dobbs Ferry, NY: Transnational Publishers.

World Bank. 1992. *World Development Report 1992: Development and the Environment*. New York: Oxford University Press.

World Commission on Environment and Development (WCED). 1987. *Our Common Future*. New York: Oxford University Press.