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The Economics of Sustainability

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I. INTRODUCTION

Few topics in recent years have dominated popular concern and stimulated scientific writing, especially in the literature on resource and environmental economics and ecology, more than sustainability. A great many economists have taken the subject seriously, generating an impressive amount of literature. Hardly a month goes by that one does not learn of a new public sector program to promote sustainability, either in this country or someplace around the globe.[2]

Customarily, articles on sustainability and sustainable development begin by making reference to the 1987 "Bruntland Report" issued by The World Commission on Environment and Development.[3] The report implies that if humankind will make the correct decisions, a choice need not be made between conservation and development-we can have both. The report's well-known definition of sustainable development reads as follows: "Sustainable development is development that meets the needs of the present without compromising the ability of the future to meet their own."[4] This statement or definition constitutes a normative judgment about the welfare of those who live in the future relative to

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2. Natural Resources Defense Council et al., DIRECTORY OF NATIONAL COMMISSIONS ON SUSTAINABLE DEVELOPMENT (1st. ed., 1994).

3. World Commission on Environment and Development, OUR COMMON FUTURE. Oxford University Press. 1987. In this essay sustainability and "sustainable development" are used interchangeably. There are now many alternative definitions of each concept. The roots of these terms date at least to Boulding's "Spaceship Earth" metaphor in Kenneth I. Boulding, The Economics of Spaceship Earth, in ENVIRONMENTAL QUALITY IN A GROWING ECONOMY 3-14 (Henry Jarrett ed., 1966). "Sustained yield" has been used in renewable resource management at least since the 1950s. *See* Michael A. Toman, *Economics and Sustainability: Balancing Trade-offs and Imperatives*, 70 LAND ECONOMICS 399-413 (1994). Paul Samuelson traces a reference to sustained yield in forestry management back to 1788 in *Economics of Forestry in an Evolving Society*, 14 ECONOMIC INQUIRY 466-92 (1976).

4. Bruntland report *supra* note 3, at 43.

those who live in the present.[5] It establishes an alternative goal or objective for economic analysis and, at base, is not an economic efficiency concept. It is an ethical commitment to the welfare of future generations.[6] Further, the report calls attention to the importance of access to resources and the distribution of costs and benefits.

This article presents summaries of widely cited positions concerning sustainability and then evaluates these positions in the context of uncertainty. It then presents three alternative world views and discusses the policy implications of each. The article also describes subsystem sustainability and speculates about probable future developments.

Finally, this article argues that sustainability should not be associated with stability (little or no change) or with an equilibrium condition between natural and human processes. The article takes the position that such conditions should not be imposed or assumed. Human and natural history is about change and adjustment, not about static or equilibrium conditions. The concept of sustainability may be of greater value in guiding change and adaptation than it is in establishing once-and-for-all, fully synoptic, adjustments.

II. ON THE NATURE OF SUSTAINABILITY

Extreme positions are often helpful in evaluating controversy; this appears to be especially true of the economics of sustainability. Such positions provide alternative perspectives, or world views, concerning the protection of society's capital assets or what each generation passes on to the next.[7] At one extreme, there is the view that human development has reached the point where natural, rather than man-made, capital is the binding constraint on human welfare. Under this view, sustainable

5. *See* Robert M. Solow, Sustainability: An Economist's Perspective, J. Seward Johnson Lecture, Woods Hole Oceanographic Institution, Marine Policy Center, Woods Hole, MA (1991), transcript available from Woods Hole Oceanographic Institution, Marine Policy Center, Woods Hole, MA and An Almost Practical Step Toward Sustainability, Resources For the Future 40th Anniversary Lecture, Washington, D.C. (1992), transcript available from Resources For the Future, 1655 Massachusetts Avenue, Washington, D.C.

6. For further discussion *see* Richard B. Howarth and Richard B. Norgaard, *Environmental Valuation under Sustainable Development*, 82 AMERICAN ECONOMIC REVIEW 473-77 (1992); David W. Pearce and R. Kerry Turner, ECONOMICS OF NATURAL RESOURCES AND THE ENVIRONMENT (1991); and Richard B. Howarth, *Sustainability under Uncertainty: A Deontological Approach*, 71 LAND ECONOMICS 417-27 (1995).

7. Definitions of total capital often provide for components consisting of (i) man-made (reproducible, physical) capital (ii) human (cultural) capital and (iii) natural (renewable and nonrenewable resources) capital.

development is defined in terms of constant or non-declining natural capital.[8]

The writings of Herman Daly on this subject, many of which predate the Bruntland Report, emphasize that the relationship between man-made and natural capital is best described as one of complements rather than substitutes.[9] Daly argues that the scale of human development has already reached the assimilative and regenerative capacity of the natural world. The formation and growth of the International Society of Ecological Economics (ISEE) reflects similar concerns. The ISEE wishes to extend and integrate economics and ecology to assist in the management of environmental systems. It states that such integration is necessary because conceptual and professional isolation has led to mutually destructive environmental policies over the long term. Some writers who call for a different emphasis in the economic literature believe that different questions than those addressed in mainstream economics need to be asked.[10] They argue that the processes which have led to global markets have the effect of enriching only the wealthy elite even as the natural environment declines. They see human-created capital as having no commitment to place or people.

At the other extreme of the discussion is the judgment that much human progress, especially that made during the past two centuries, has stemmed from the substitution of man-made for natural capital. In this view, the commitment is to human capacity to satisfy future needs or wants, not to particular natural resources. Exceptions are made for those unique natural resources for which there is no good gauge of value. Man-made and natural resources are considered to be substitutes, not complements. This view is considered more mainstream or orthodox than Daly's. The writings of Robert Solow are in this tradition.[11]

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8. The provision of non-declining natural capital does not imply that the current generation should never diminish the stock of nonrenewable resources (e.g. fossil fuels). Rather, if nonrenewable resources are used they must be replaced by renewable resources so that the total stock of natural capital will not decline. This point is discussed in INVESTING IN NATURAL CAPITAL: THE ECOLOGICAL ECONOMICS APPROACH TO SUSTAINABILITY (Ann-Mari Jansson et al. eds., 1994).

9. Recent statements by Herman Daly can be found in Operationalizing Sustainable Development by Investing in Natural Capital, in INVESTING IN NATURAL CAPITAL: THE ECOLOGICAL ECONOMICS APPROACH TO SUSTAINABILITY (Ann-Mari Jansson et al. eds., 1994) and Robert Costanza & Herman Daly, *Natural Capital and Sustainable Development*, 6 CONSERVATION BIOLOGY 37-46 (1992). For Daly, complementarity between natural and man-made capital means we need both and the maintenance of natural capital is a priority condition for sustainability.

10. *See, e.g.*, David Korten, *Sustainable Development* in WORLD POLICY JOURNAL 157-190 (Winter 1991-1992).

11. See Solow, *supra* note 5.

It is important to consider fundamental sustainability conditions when evaluating the two extreme positions. Multiple generations are involved and the analysis must deal with events which will occur far into the future. Incomes, preferences and technology will not be the same across generations and thus many important variables are uncertain. It is therefore not possible to assign probabilities to particular future values. In other words, extreme uncertainty prevails even though this is not indicated by the two extreme views.

As uncertainty increases, the probability of the correctness of a particular world view decreases, which in turn increases the probability of incurring the cost of an incorrect decision. Thus, if either extreme case is chosen as a basis for decision-making and proves to be incorrect, the cost of that choice becomes an important public policy variable.

Consider first the world view which holds that man-made and human capital are not substitutes. If provision is made for non-declining natural capital and if natural capital proves not to be a limiting resource, economic welfare will be sacrificed. In aggregate, the people of both the current and future generations will be rendered worse off than it would be possible for them to be. This is a major consideration in addressing the needs of the poor, whether in this or in succeeding generations.

Consider next the extreme position which maintains that, in general, natural and man-made capital are substitutes. The costs, if this world view should prove incorrect, also have the potential of being very high. For example, if a species which could have provided a cure for cancer is permitted to become extinct, the loss of human lives which results should be considered a cost of the incorrect decision to consider natural and man-made capital as substitutes.

The issue of which extreme position is more likely to be correct is an empirical one that can be resolved only with the passage of time.[12] Unfortunately, decisions will have to be made before this knowledge becomes available.

An important segment of the literature on the economics of sustainability implicitly or explicitly rejects these opposed world views. Ciriacy-Wantrup was one of the early exponents of this approach. He recognized the need to avoid irreversibilities and advanced the notion of safe minimum standards (SMS) for renewable resources.[13] Since the

12. *See* Bryan G. Norton, *Evaluating Ecosystem States: Two Competing Paradigms*, 14 ECOLOGICAL ECONOMICS 127-33 (1995); Michael Toman, *Economics and Sustainability: Balancing Tradeoffs and Imperatives*, 70 LAND ECONOMICS 399-413 (1994).

13. A statement of the SMS can be found in Sigfried Von Ciriacy-Wantrup, RESOURCE CONSERVATION: ECONOMICS AND POLICIES (1952). The writings of Ciriacy-Wantrup have undergone a recent revival and reference to the SMS can be found frequently in sustainability literature. Recent discussion of the SMS can be found in Richard Bishop,

early 1970s, economists have written extensively about the value of maintaining flexibility in decision-making and of avoiding irreversible decisions.[14] The literature on the economics of sustainability can now be classified in terms of its consistency with one of the three world views identified in the previous section:

1. Natural and man-made resources will not substitute in the future (World View I).
2. Natural and man-made resources are generally substitutes (World View II).
3. Uncertainty is the dominant economic condition describing the relationship of natural to man-made resources in the distant future. The nature of the substitution relationship between man-made and natural capital in the distant future is unknown (World View III).

Most of the emerging literature on sustainability has not given explicit recognition to uncertainty, but much is implicitly consistent with

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Economics, Efficiency, Sustainability and Biodiversity, 22 AMBIO 69-73 (19913) and Michael Toman, *Economics and Sustainability: Balancing Tradeoffs and Imperatives*, 70 LAND ECONOMICS 399-413 (1994). When Wantrup advanced the concept of SMS, he was attempting to provide a practical guide for public policy. He explicitly rejected the notion that a societal optimum could be achieved in natural resource management. He was interested in practical approximations that would move society in the correct direction. He explicitly recognized that public policy natural resource decision-making occurred under great uncertainty. *Id.* at 251. Wantrup believed that avoiding irreversibilities in natural resource management under uncertainty was desirable and practical. Thus, society should maintain flexibility by avoiding irreversibilities unless it would be very costly to do so. He advanced the flow concept of a "critical zone" in renewable resource management which exists when a further decrease in flow cannot be reversed economically under presently foreseeable conditions. *Id.* at 253. He recognized that economic irreversibility would occur prior to technological irreversibility. Wantrup introduced the concept of a Acritical zone to serve as a warning against carrying resource use so far that economic irreversibility would occur. He recognized, however, that economic irreversibility might well happen and that the costs of reversing direction might become "immoderate." He warned of safeguarding the barn door after the horse has been stolen. *Id.* at 266. If a decision is made to avoid depletion by reducing use of natural resources, potential wealth is being transferred forward in time to different beneficiaries. This clearly involves an equity issue which cannot be addressed exclusively with economic concepts. Economists have not yet learned how to make interpersonal utility comparisons within a time period or generation; it should not be surprising that they cannot do so intergenerationally. While economic analysis can inform such a decision, in the final analysis more than economics is involved.

14. *See, e.g.*, John Krutilla, *Conservation Reconsidered*, 57 AMERICAN ECONOMIC REVIEW 777-86 (1967); Kenneth Arrow & Anthony C. Fisher, *Environmental Preservation, Uncertainty, and Irreversibility*, 88 QUARTERLY JOURNAL OF ECONOMICS 312-19 (1974). A survey of work in this area may be found in Avinash K. Dixit & Robert S. Pindyck, INVESTMENT UNDER UNCERTAINTY (1994).

World View III.[15] This literature has the following distinctive characteristics:

1. It does not attempt to resolve the question of whether man-made and natural capital will be substitutes or complements in the future.
2. It argues that cultural capital, including human institutions (e.g., legal entitlement structures), are an important part of the total capital stock. The literature on adaptive management and two-tiered decision models is in this tradition and is consistent with social experimentation and social learning.
3. It further states that not all natural capital is likely to be, or can be, preserved. An important part of sustainability policy involves decisions as to what should be preserved or sacrificed. Effort is needed to identify "critical" natural capital.
4. Finally, there is often implicit recognition of evolutionary processes in both the economic and ecological spheres.[16]

It would be inaccurate to classify all economists who believe that human and man-made resources are generally substitutes in production and consumption as rigidly adhering to World View II. Further, it is inaccurate to suggest or imply that those who lean toward World View I believe that there are no possibilities for the substitution of one class of resources for another. Nevertheless, certain policy positions follow logically from each world view based on these extreme positions. The purpose of this article is to bring these policy issues into the open.

III. PUBLIC POLICY AND SUSTAINABILITY

A. World View I

World View I argues that man-made and natural resources are complements rather than substitutes. These authors believe that the

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15. For a recent example, *see* David Pearce & Jeremy Warford, WORLD WITHOUT END: ECONOMY, ENVIRONMENT AND SUSTAINABLE DEVELOPMENT (1993). Earlier writers include Kenneth Boulding, The Economics of the Coming Spaceship Earth in ENVIRONMENTAL QUALITY IN A GROWING ECONOMY 3-14 (Henry Jarrett ed., 1966) and Kenneth Boulding, EVOLUTIONARY ECONOMICS (1981); Sigfried Von Ciriacy-Wantrup, RESOURCES CONSERVATION: ECONOMICS AND POLICIES (1952); and Edgar S. Dunn, ECONOMICS AND SOCIAL DEVELOPMENT: A PROCESS OF SOCIAL LEARNING (1971).

16. *See* Paul Christensen, *Driving Forces, Increasing Returns and Ecological Sustainability* in ECOLOGICAL ECONOMICS: THE SCIENCE AND MANAGEMENT OF SUSTAINABILITY 75-87 (Robert Costanza ed., 1991) and The Return to Increasing Returns (James N. Buchanan & Yong J. Yoon eds., 1994) and Gene M. Grossman and Elhanan Helpman, *Endogenous Innovation in the Theory of Growth*, 8 JOUR. OF ECONOMIC PERSPECTIVE 23-44 (1994).

natural environment is finite and nearly fully utilized-a "full world" view. Public policy measures should be designed to facilitate accommodation to the finite natural environment. Such accommodation will include demand adjustment both in population growth and economic development.

Economic growth will be limited to technical change that will reduce natural resource use by the economic system. Clearly the policy implications of this view are far-reaching and dramatic. Because these authors believe that existing economic systems are taking society in the wrong direction, economic analysis based on the existing distribution of income, wealth, and decentralized markets does not play a major role in their public policy determinations. Daly has summarized his policy prescriptions for an environmental macroeconomics as follows:

1. Human activity should be limited to a level which, if not optimal, is at least within carrying capacity and therefore sustainable.
2. Economic growth should be dependent on the kind of technical change that will reduce natural resource use by the economic system.
3. Renewable resources should not be driven to extinction because they will become more important as non-renewable resources are exhausted. Specifically, this means that a) use rates should not exceed regeneration rates; and b) waste emissions should not exceed the renewable assimilative capacity of the environment.
4. Non-renewable resources should be exploited, but only at a rate equal to the creation of renewable substitutes.[17]

B. World View II

World View II provides a much more prominent place for conventional economic analysis. Sustainability imposes the constraint that present needs may not dominate those of the future. Writers arguing for World View II recognize that unique natural resources such as the Grand Canyon constitute an exception, rather than the rule. These acknowledged exceptions pertain to unique amenity resources rather than more functionally transparent ecosystem services (e.g., biodiversity and biogeochemical cycling). Because future and present needs are of equal importance, some efficient solutions will not be sustainable. To carry this analysis forward it is necessary to include non-market as well as market valuations in economic analysis. If this is done, and "public good"

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17. *See* Herman Daly, *Elements of Environmental Macroeconomics* in ECOLOGICAL ECONOMICS: THE SCIENCE AND MANAGEMENT OF SUSTAINABILITY 44-45 (Robert Costanza ed., 1991).

exceptions are taken into consideration, natural resources can be subjected to benefit-cost tests. Because man-made and natural resources are substitutes, there is no concern about exhausting natural resources so long as a policy of capacity building is in place.

Any means that enhances the substitution of man-made for natural resources is included as a part of general capacity enhancement. Capacity may be enhanced *technically,* for example, by the discovery of an improved seed (plant variety) which increases yield more than it increases resource use. Capacity may also be enhanced by increased human knowledge which permits humans to better manage the natural environment. Institutional innovation may also enhance capacity. An example of this is the adoption of an incentive system that encourages reduced resource use instead of a government program which subsidizes natural resource exploitation.

C. World View III

An explicit recognition of uncertainty has considerable public policy implications. It means that there must be a rejection of the notion that either complements or imperfect substitutes necessarily exist. Because it cannot be known in the present whether complements or substitutes will prevail in the future, plans are needed for either eventuality. While optimality may underlie public policy analysis and planning under the assumption of substitutes, no such construct will serve a world of great uncertainty. Under World View III an attempt is made to avoid actions with high social costs if the assumptions on which these actions are based are incorrect. Rather than attempting to discover an optimal plan for sustainability, this approach attempts to avoid actions that will lead to costly mistakes in the form of expensive irreversibilities.

In addition, the debate concerning the possible substitution of man-made for natural resources in the future is not of great interest because World View III recognizes that the debate cannot be resolved in the present. Thus, it would be hazardous to adopt public policies that assume otherwise. This approach directs attention toward human (cultural) capital because it places emphasis on human adaptation to conditions of uncertainty. Both individual and group adaptations become of great importance.

With traditional benefit-cost analysis the discount rate is the preferred device to link generations and resolve issues concerning the allocation of resources across generations. The appropriate discount rate is the opportunity cost of using resources now rather than in the future. In practice this rate cannot be known and must be approximated by using estimates based on discount rates prevailing in actual markets.

It has been written, however, that concepts of sustainability should set constraints on markets.[18] Once this has been done, one should discount at normal rates. We believe this is consistent with World View III. This makes no attempt to discover an economic equilibrium condition which will provide intergenerational equity. Instead, policies and actions are taken consistent with prevailing ethical judgments about intergenerational equity (fairness across generations). Discount rates then emerge which are consistent with these policies and actions. Conceivably a discount rate might be used to evaluate public sector investments and policies that affect resource use in the distant future. Even so, there is no feasible way to impose an "optimal" discount rate on the private sector even if one could be discovered.

Figure 1 illustrates the policy implications of the three alternative world views. World View I, which holds that natural and man-made resources are not substitutes, calls for non-declining natural capital policies. It discourages indiscriminate economic growth but permits technical change that would make more efficient use of natural resources. It universally avoids irreversibilities in the use of natural capital.

World View II requires a policy of general capacity building. Under this approach, technical change and education are awarded equal status with natural resource preservation. Natural resources with positive benefit-cost ratios, as measured in the contemporary economy, and certain unique natural resources would be preserved.

18. Talbot Page, *Sustainability and the Problem of Valuation* in ECOLOGICAL ECONOMICS: THE SCIENCE AND MANAGEMENT OF SUSTAINABILITY 69 (Robert Costanza, ed. Columbia University Press 1991)

Figure 1:

Policy Responses to Alternative World States

	World View I Man-made and Natural Capital are not Substitutes	*World View II* Man-made and Natural Capital are Substitutes	*World View III* Uncertainty
Avoid Irreversibilities in Natural Capital	Everywhere Non-declining natural capital	Not necessarily a) B/C > 1 b) Public goods	Selectively a) B/C > 1 b) Opportunity cost of flexibility c) Public goods
General Capacity Building	Would not emphasize	Emphasize	Emphasize
General Economic Growth	Would limit	Would welcome	Would evaluate incrementally
Adaptive Management	No[19]	No	Yes

However, public policies to preserve natural resources predicted to be in short supply for future generations might well be adopted. This would require assumptions about preferences, incomes, technologies, and scarcities far into the future.

World View III, which emphasizes uncertainty, generates different policy responses. This approach would provide for public goods and preserve natural resources with positive benefit-cost ratios. It would avoid irreversibilities in natural resource use, but permit some resources to disappear. The costs of avoiding irreversibility in terms of the

19. As a practical matter, no thoughtful person would disavow all aspects of adaptive management. But if the substitution relationship between man-made and natural resources is presumed known, there is much less to be learned from experience than if uncertainty is expected to prevail.

contemporary economy can be estimated by use of the techniques of economic methodology.[20] Under World View III there is no single objective rule for specifying which resources will be preserved and which will be sacrificed. The uncertainty approach does not emphasize a market-driven or benefit-cost definition of sustainability. Rather, it calls attention to the cost of preservation in the context of the contemporary economy-the opportunity cost. There is no absolute measure of when such a cost becomes excessive.

World View III emphasizes adaptability and requires that social institutions be evaluated from that perspective. Neither of the other world views emphasizes adaptability because they assume that the future is known. Thus, World View III policies would probably constrain contemporary economic growth more than those of World View II, but less than those of World View I.

The specific example of endangered species policy and the conservation of biological diversity will serve to illustrate the way different world views affect particular resource management problems. Under World View I, species are a part of natural capital to be preserved. "The 1973 Endangered Species Act"-16 U.S.C. (Secs.) 1531 to 1544 is, at least in part, consistent with World View I. Sections 7-16 U.S.C. (Sec.) 1536 (no-jeopardy) and Section 9-16 U.S.C. (Sec.) 1538 (no-takings) of the act prohibit actions that will harm species, regardless of the consequences.[21] The writing of biologists Edward O. Wilson and Paul Ehrlich are consistent with this point of view.[22] A clear expression of the need to preserve species is given by David Ehrenfeld.[23]

In World View II it is neither necessary nor perhaps desirable to conserve all species. Conversion of natural habitats for human use may

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20. *See* Avinash K. Dixit & Robert S. Pindyck, INVESTMENT UNDER UNCERTAINTY (1994), and Emery N. Castle & Robert P. Berrens, *Endangered Species, Economic Analysis and the Safe Minimum Standard*, 9 NORTHWEST ENVIRONMENTAL JOURNAL 108-30 (1993).

21. Exceptions to both sections exist. For example, the Endangered Species Committee may grant an exception to section 7 and allow an action to proceed event though it may harm an endangered species. Endangered Species Act of 1973. God Squad exemptions-U.S.C. (sec.) 1536(h). As amended through the 100th Congress. However, the committee has rarely been called upon to act.

22. Paul R. Ehrlich & Edward O. Wilson, *Biodiversity Studies: Science & Policy*. 253 SCIENCE, 758-62 (1991).

23. "Long standing existence in Nature is deemed to carry with it the unimpeachable right to continued existence. Existence is the only criterion of the value or Nature, and diminution of the number of existing things is the best measure of decrease of what we ought to value. That is, as mentioned, an ancient way of evaluating" conservability and by rights ought to be named the "Noah Principle after the person who was one of the first to put it into practice." David Ehrenfeld, *The Arrogance of Humanism* as quoted in Christopher L. Mann & Mark L. Plummer NOAH'S CHOICE: THE FUTURE OF ENDANGERED SPECIES (1995), at 135-36.

cause extinctions but may increase production and may be judged to improve human welfare.[24] Substitutes for specific species or for the goods and services provided by them may be found. Much of the work of trying to value particular species or ecosystem services can be interpreted in light of the question: how much compensation, in terms of money or other goods, is needed to replace the loss of this particular species or ecosystem service?

Uncertainty and potential irreversibilities are at the center of World View III and its perspective on the conservation of species. For example, one argument in support of conserving species is that some species will be found to contain a key ingredient for a new pharmaceutical drug or some other as yet unknown future benefit, (e.g., the Pacific yew and taxol). If the species become extinct these potential future benefits will be lost. The recent literature on measures of biological diversity and genetic prospecting analyzes conserving species in order to preserve genetic information that may have great value in the future.[25] Not all species need to be conserved but those that are unique, genetically or otherwise, may be given higher priority for conservation.

IV. SUB-SYSTEM SUSTAINABILITY

The concept of sustainability has been used to evaluate forest management practices for many decades. As applied to natural resource management, the term may have originated in forestry.[26] The forestry literature emphasizes sustained timber yields, although there are numerous references in this literature to values not related to timber management. The current use of the term "sustainability" requires that sub-systems be considered in the context of the larger systems of which they are a part. For example forestry, farming, grazing, and fishing are all part of larger ecosystems. In general, it is possible to sustain a

24. *See, e.g.*, Gardner M. Brown & Joseph Swierzbinski, *Optimal Genetic Resources in the Context of Asymmetric Public Goods* in ENVIRONMENTAL RESOURCES AND APPLIED WELFARE ECONOMICS: ESSAYS IN HONOR OF JOHN V. KRUTILLA 91-118 (V. Kerry Smith ed., 1988): "Yet not all species should be preserved. We should actively seek to preserve only those for which the expected net benefits are positive."

25. Work on this topic includes: Stephen Polasky Et al. *Searching for Uncertain Benefits and the Conservation of Biological Diversity*, 3 ENVIRONMENTAL AND RESOURCES ECONOMICS 171-81 (1991); Stephen Polasky & Andrew Solow, *On the Value of a Collection of Species*, 29 JOUR. OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT 298-303 (1995), and R. David Simpson, Et al. *Valuing Biodiversity for Use in Pharmaceutical Research*, JOURNAL OF POLITICAL ECONOMY, 104:163-83 (1996).

26. *See* Toman & Samuelson, *supra* note 3.

sub-system for a long time if resources, either from the larger system or from some external source, are used to sustain the sub-system.

Forestry, farming, grazing, and fishing are industries that obtain their definition from the economy, not from ecology. Their purpose is to satisfy human needs. The behavior of these industries cannot be understood in isolation from the economy of which they are a part. If we wish to modify the performance of these industries for ecological effect, the economic and political context which provides their definition and the rationale for their existence must also be modified. Recently there has been considerable change in practices for improved ecological effect. Some of these changes may have been politically induced. Others may have been motivated by genuine concern about ecological consequences of past practices. Whatever the motivation, justification and modification of industry practices cannot be divorced from the objectives of the industry from which they arise.

The world views identified in this article establish the framework within which system sustainability can be considered. The view that man-made and natural resources are not substitutes may give rise to the hope that relatively permanent sustainable sub-system practices can be discovered. Even so, technology will change, and social values are mutable. And, of course, human expectations of natural resources change as well. For example, when "sustainable" forestry was invented, timber production was considered to be the primary output of the forestry sub-system. Amenity values were viewed as a by-product. Social expectations have now changed so that amenity values often exceed timber values. Perhaps the greatest change over time has come from the substitution of man-made capital for natural capital. Under World View II, the primary emphasis will be on the capacity of the economy to maintain or improve production rather than natural resource conservation.[27] Under World View III, practices would be modified as dictated by changes in social expectations, technological improvements, and increased knowledge of ecosystem behavior.

Even though consumption and production practices can be expected to change under each of the world views, the choice criterion will differ. With World View I, preservation of natural capital is of the greatest importance. World View II uses a constrained economic optimization model to ensure that present needs will not be satisfied at the expense of future needs. Under World View III, minimizing the cost of maintaining flexibility becomes of great importance. This view, rather

27. Vernon W. Ruttan, for example, notes that none of the three traditional, historically sustainable farming systems have the capacity to respond to even moderate growth in demand. *See* Vernon W. Ruttan, *Constraints on the Design of Sustainable Systems of Agricultural Production*, 10 ECOLOGICAL ECONOMICS 209-19 (1994).

than attempting to discover indefinitely sustainable practices, places emphasis upon practices that will be relatively more sustainable than those currently in use. It concerns itself with the resource use attributes that should be sustained. Questions about forestry and agricultural practices have often been asked by people outside of these industries who are concerned about consumption, not production. For example, clear-cutting may be the best way to produce some timber but often destroys scenic values.

A great deal of effort is currently being expended to discover and apply "sustainable" practices in forestry, grazing, fishing, and farming. The assumption seems to be that sustainable practices are "out there" and the trick is to find them and persuade people to use them. At any given time there well may be practices which are more resource conserving than those currently in use. The techniques of production in a society such as ours are always in a state of flux and current investment in such practices can rapidly become obsolete. Obsolescence may stem from larger system change in either the man-made or the natural environment, or from human knowledge. Some of the effort currently being devoted to the "discovery" of sustainable practices might be better spent attempting to understand current farming, fishing, grazing, and forestry systems and developing techniques and institutions that provide for adaptation and change.

V. DISCUSSION

There has been an enormous bureaucratic and public sector response both domestically and internationally to sustainability concepts. No doubt sustainability has struck a responsive chord because of widespread general concern about environmental matters. Given the public sector investment in sustainability programs, it is likely there will be continued interest in sustainability for a long time. In the near term, the benefits of maintaining the approach will be greater than the costs. Continued use of the sustainability concept will depend on how it fares as it is subjected to intensive intellectual scrutiny.

There can be no doubt that recent analysis of sustainability issues has stimulated a re-examination of the economics of conservation. It requires a fundamental reformulation of the economics of intergenerational natural resource management. This includes (1) the distribution of resources and property rights within the current generation and across future generations; (2) the availability and protection of critical natural capital assets; (3) the effects on the carrying capacity of life supporting ecological systems from increases in the scale of human activities; (4) methods of policy analysis. For example, the basis of keeping national accounts of production and consumption would be

revised significantly if sustainability were to become a priority policy objective. It is not within the scope of this paper to evaluate "ecological economics" as such, but its existence and close relation to sustainability issues is significant.

One cannot argue that the welfare of future generations has been ignored by mainstream, orthodox, resource and environmental economics. There is significant literature about intergenerational equity and intergenerational discount rates.[28] In addition, however, the Bruntland Report[29] introduced a specific intergenerational goal-that the needs of the present should not be satisfied at the expense of future needs. This requires that a constraint be built into the traditional system of analysis, if sustainability is to be accommodated. The result is that some of the possible efficient resource allocations under a more general system are not sustainable. There seems to be little doubt that the mainstream economics model, properly constrained, can, in theory, yield sustainable resource allocations. If one wishes to make empirical applications of such a model, possible market failures need to be investigated and some type of benefit-cost analysis of such interventions adopted. This includes the estimation of nonmarket values, including existence values.[30]

VI. CONCLUSIONS

It is our opinion that the response to sustainability issues in the economics literature has been useful. But when we consider the large uncertainties associated with intergenerational issues, we question the value of empirical work designed to estimate "socially optimal" natural resource allocations across generations. To do so requires that great dependence be placed on the assumptions of modern equilibrium economics with both positive and normative implications. Further, it places a heavy burden on techniques such as contingent valuation for the estimation of existence values.

The sustainability issue has stimulated renewed discussion of the substitution of man-made for natural capital. Even though it will never be possible to resolve this question decisively, it is useful to re-visit it. An

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28. *See* Robert C. Lind et al., DISCOUNTING FOR TIME AND RISK IN ENERGY POLICY (1982).

29. *Supra* note 3.

30. Nonmarket values for unpriced environmental goods typically include use values (outdoor recreation) and nonuse values; the archetypal nonuse value is the existence value associated with simply knowing that some desirable environmental asset or set of conditions continues to exist. The survey-based contingent valuation method is the only technique economists have to assign nonuse and existence values. Recent debate on the acceptability of the method has been polemic. For a review *see* Paul Portney, et al., 8(4) JOURNAL OF ECONOMIC PERSPECTIVES (1994).

articulation of particular views of how the world is, and will likely be, permits different policy approaches to the management of the natural environment over time to be stated and compared. Nevertheless, sustainability is only one component of a comprehensive resource and environmental policy.

Standing alone, a sustainability objective is a blunt instrument with limited usefulness in policy formation. Daly[31] demonstrated that achieving sustainability meets a necessary condition, but is not sufficient for a comprehensive policy. The introduction of a sustainability constraint into a social optimization model will render some outcomes not sustainable that would otherwise be efficient. Under an adaptive management model consistent with World View III, judgments can be made among alternatives that preserve more, rather than fewer, natural resources. Nevertheless, this correlates only the "needs" of future generations with resource endowments and does not provide an unambiguous choice criterion.

As useful as the conceptual work on sustainability has been, it is not clear that it will serve as a fruitful research paradigm in economics far into the future. Conceptual issues remain to be resolved, but it is not clear that they will be of great policy significance. Work on sub-system sustainability issues will continue. Here, the economist can play a useful role by directing attention to, and organizing, information that bears on the following issues: (1) The exogenous forces that influence the performance of a sector such as farming, forestry, grazing or fishing with respect to use of the natural environment over time;[32] (2) how particular practices compare in protecting resource endowments for future generations; (3) the opportunity costs, in the context of the contemporary economy, that are associated with those practices isolated in (2) above; and (4) the institutional design and legal entitlement structures which promote flexibility and adaptation.

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31. *Supra* note 9.

32. An example, suggested by an anonymous reviewer, involves the pulp and paper industry. Of relevance are the effects of product specification (e.g., advertising, institutional rules) on natural resource use.