PN-ABI-902

Energy and Natural Resources Division

Resources for the Future/Washington, D.C.

PN-ABI-902

ENR91-05

ECONOMICS AND "SUSTAINABILITY:" BALANCING TRADEOFFS AND IMPERATIVES

by

Michael A. Toman

Pierre Crosson

Resources for the Future
1616 P Street, NW
Washington, D.C. 20036
(202) 328-5000

January 1991

Earlier versions of this paper were presented at the International Society for Ecological Economics/World Bank/AID Conference "The Ecological Economics of Sustainability," Washington, D.C., May 21-23, 1990, and at the American Economic Association annual meetings, Washington, DC, December 1990. The authors gratefully acknowledge helpful conversations with Douglas Bohi, Tim Brennan, Allen Kneese, Jeff Krautkraemer, and John Pezzey, and perceptive comments by Tom Tietenberg on an earlier draft. We especially appreciate the contributions by Bryan Norton in helping to shape our understanding of the subject.

©1991 Resources for the Future. All rights reserved. No portion of this paper may be reproduced without permission of the authors.

Discussion papers are materials circulated for information and discussion. They have not undergone formal peer review as have RFF books and studies.

ECONOMICS AND "SUSTAINABILITY:" BALANCING TRADEOFFS AND IMPERATIVES

by

Michael A. Toman and Pierre Crosson

Abstract

The concept of "sustainability" has been increasingly invoked in scholarly and public policy debates since the 1987 publication of the World Commission on Environment and Development Report that asserted the need for "...development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Discussion has been hampered, however, by uncertainty and lack of uniformity in the meaning of sustainability. In particular, economists and ecologists generally have very different interpretations of sustainability. The result is misunderstandings and lost opportunities for narrowing scholarly or policy differences.

In this paper we seek to clarify the disparities between economists and ecologists in the interpretation of sustainability, and to begin identifying some common ground between the two disciplines. We consider three issues that seem salient in the debates between ecologists and economists: requirements for intergenerational equity, the definition of "social capital" -- the legacy to be provided to future generations -- and the total scale of human resource-using activity relative to global resource capacities.

We propose that a concept of "safe minimum standard," which has received at least some recognition in both the ecology and economics literatures, may provide the beginnings of a common ground for debate about the sustainability literature.

ECONOMICS AND "SUSTAINABILITY:"

BALANCING TRADEOFFS AND IMPERATIVES

Concerns about the possible misuse of natural resources (including the environment) and about the natural legacy being left for future generations are becoming drawn together under the heading of "sustainability." The concept of sustainability has been increasingly invoked in scholarly and public policy debates since the publication in 1987 of a report by the World Commission on Environment and Development (WCED, known less formally as the "Brundtland Commission"). That report asserted the need for "...development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987, p. 43). Since the issuance of that report there has been growing discussion of this objective and of different ways it might be achieved.[1]

Discussion has been hampered, however, by uncertainty and lack of uniformity in the meaning of sustainability. The ambiguity is perhaps understandable since, as Norgaard (1988) and Dixon and Fallon (1989) point out, the term initially referred to the physical condition of specific resources (e.g., sustained-yield timber cutting) but is now being used to address broad concerns of entire socioeconomic and ecological systems. However, the ambiguity seems to go deeper than this. As we argue in the next section of the paper, economists and ecologists generally have very different interpretations of sustainability. These differences are poorly

---

1. The September 1989 issue of Scientific American, entitled "Managing Planet Earth," was devoted to sustainability issues. The journal Futures also had a special issue (December 1988) on sustainable development, and the concept now is found in textbooks on resource and environmental economics (see, e.g., Tietenberg 1988 and Pearce and Turner 1990).

understood by partisans on the two sides. The result is misunderstandings and lost opportunities for narrowing scholarly or policy differences.

In this paper we seek to clarify the disparities between economists and ecologists in the interpretation of sustainability, and to begin identifying some common ground between the two disciplines. Our hope is that by at least providing some common vocabulary, unnecessary divisiveness can be avoided. Our underlying premise is that sustainability is an important issue for both research and policy, though (contrary to some partisans) we do not believe all the directions for policy are clear. Without a better understanding of the concept, statements about policy action become at least somewhat suspect and the concept is threatened with being seen as trivial.[2]

Three issues seem salient in the debates between ecologists and economists. The first is the nature of the responsibility to future generations, i.e., the requirements for intergenerational equity.[3] The second is the definition of what we term "social capital" -- the legacy to be provided to future generations. The third concerns the total scale of human resource-using activity relative to global resource capacities.

These issues, which clearly are interrelated, are discussed in the next section of the paper. In the third section we propose that a concept of "safe minimum standard," which has received at least some recognition in both the ecology and economics literatures, may provide the beginnings of a

---

2. The problems stemming from fuzzy definition seem well illustrated here by the following quotation, taken from a recent conference report: "We need a more clear understanding of sustainable development, both in concept and in practice. But both concept and practice can move in parallel. There are development and environmental projects underway which are fully consistent with sustainable development."

3. Questions of intragenerational equity also figure prominently in many discussions of sustainability. However, these debates are more familiar, and to keep the paper more manageable we do not address them here.

common ground for debate about the sustainability literature. The fourth section of the paper attempts to illustrate the preceding conceptual discussion by making reference to sustainability issues in agriculture. The fifth and concluding section offers suggestions for further research.

Before developing our arguments further we offer some caveats regarding their scope. As already noted, sustainability has come to mean many things to many people. Our concern is with the issue at a fairly abstract level, with a focus on global prospects over the very long (multigenerational) term. We do not directly address the other context in which the term sustainability often is used, that of individual developing countries with a more immediate (one-generation-ahead) time horizon. However, we believe our discussion also has relevance for such issues. The other main caveat is that we approach the issue of sustainability from the standpoint of economic well-being, broadly defined. Some writers (e.g., Norgaard 1988, White in press) suggest that addressing global change and sustainability ultimately requires considering a wide range of issues that cut across social and biological sciences. Whatever the merits of such an approach, it is well beyond the scope of the present paper.

KEY ISSUES IN A SUSTAINABILITY DEFINITION

Intergenerational Equity

The previously given quotation from the Brundtland Commission Report suggests that intergenerational equity is a critical issue in defining sustainability. However, economists and ecologists tend to have very different views of this issue. The familiar approach to this issue in economics extends the logic of time preference for members of one generation to an intergenerational preference ordering in which the utilities of future

generations are discounted.[4] This approach is broadly consistent with an important philosophical principle known as "methodological individualism," which underlies both utilitarian value systems and contractarian (rights-based) value systems undergirding democratic political liberalism. According to this principle, it is logically difficult if not impossible to assess benefits and harms, and thus define rights or obligations, for amorphous future individuals whose very being is determined by our actions. It follows that while rights and obligations can be defined for members of the present generation, the obligations of the present to potential future individuals (and the reciprocal rights of these individuals) become more attenuated, the farther into the future we consider the obligation and the less "identifiable" future individuals become.[5]

Despite its grounding in methodological individualism, a strict application of intergenerational discounting seems to run afoul of some basic intuitive notions of fairness. The criterion can imply ruination of future generations exposed to the prospect of resource exhaustion (in the absence of countervailing technological progress) or the risk of large, irreversible, long-gestation environmental damages (Dasgupta and Heal 1979; Kneese and Schulze 1985; Pezzey 1989). Page (1977, 1983, 1988) has shown that the discounted present value criterion for intergenerational welfare is

---

4. The papers in Lind (1982) provide a wide-ranging discussion of intragenerational and intergenerational discounting. The discussion continues in a compilation of papers published as part of the March 1990 Journal of Environmental Economics and Management.

5. See Baier (1984) for further discussion of methodological individualism. The logical difficulty of assigning rights to future individuals is referred to in the philosophy literature as identity problem or Parfit's Paradox (Parfit 1983a). Philosophers such as Passmore (1974) and Golding (1972) have concluded that we cannot define obligations of the present to distant future generations. Even proponents of a greater current responsibility to the future recognize the difficulty of making inability this case solely on the basis of individual rights (see, e.g., Norton 1982).

dictatorial in the Arrow (1963) sense, giving absolute power over resource use to the current generation. This can lead to a sort of intergenerational dynamic inconsistency in plans for resource use, in that future generations would seek to revise the plans of the current generation if they were able to. These observations are troubling, since the requirements that an intergenerational social preference ordering be nondictatorial and dynamically consistent (in the sense just described) would seem to be reasonable requirements for fairness.

A sharply contrasting view to methodological individualistic logic is expressed by "organicist" philosophers, ecologists, and a few economists. Adherents to the organicist view acknowledge the logical difficulty of assigning rights to potential individuals in the distant future, but they see the obligations of the present as going beyond individual rights to entail protection of entire systems -- ecological systems and the human species as a whole (Leopold 1949, Lovelock 1988, Callicott 1989, Page 1983, Norton 1982, 1986, 1989). This position emphasizes the safeguarding of evolutionary, ecological processes which contribute to human survival and advancement, quite apart from the consumption or existence values individuals might place on specific resources. It is relatively hostile to intergenerational discounting of all values (Parfit 1983b).

The organicist position also has been justified by extending the logic of Rawls' (1971) "veil of ignorance" (see Norton 1989). In Rawls' original thought experiment, individuals who did not know what position in life they might occupy would adopt a social contract to protect the least well off. Extending this reasoning to an intergenerational time frame, if individuals do not know what generation they might occupy, and whether that generation might face resource impoverishment or ecological catastrophe (even nonexistence) as a result of its predecessors' actions, they will seek to

protect a viable ecological system and a resource base capable of meeting human needs (allowing for the possibility of technical progress to increase natural resource productivity and otherwise economize on use of the most scarce resource inputs).[6]

Note that this view does not imply the necessity of eschewing discounting across generations. However, discounting would be limited to the rate of growth in the capacity of the resource base to support economic activity, through augmentation of renewable and technical advance (see Page 1977). Greater discounting would imply excessive resource use in the present.

Protection of the ecological system and resource base is a different criterion for social planning than the Rawlsian "maximin" criterion which has been explored in the resource economics literature (e.g., Solow 1974, Hartwick 1977), despite some similarities. The maximin approach is concerned with the distribution of individual utility levels across generations and thus confronts the problems posed by methodological individualism which we discussed above.[7] In contrast, the organicist approach is (in varying degrees) nonindividualistic, emphasizing the state of natural systems and the preservation of options for the future rather than a specific utility distribution.

The organicist approach also has significant limitations. One important one is that since market-oriented, democratic societies are built

---

6. See also Weiss (1989), who argues for an intergenerational social contract for resource preservation.

7. A strict application of the maximin approach also has the drawback of implying an equal distribution of individual utilities across generations -- what Solow (1986) refers to as a prescription for stagnation. Pezzey (1989) illustrates how this problem can be avoided by requiring individual utilities to be nondecreasing over time, so that the future can be better than the past.

upon basically individualistic institutions, nonindividualistic obligations to the future may not be easily expressed by such institutions (especially markets). The principle of resource base preservation also is a coarse filter that begs many questions. While it may screen out ecological catastrophes, how do we cope with smaller-scale harms? And how are threats of ecological degradation to be balanced against the threats of economic stagnation which may result from excessive risk aversion in resource use?

We return to these points in subsequent parts of the paper. For the moment, it suffices to say that despite much study and debate, neither the economics, philosophy, or ecology literatures provide a concept of intergenerational equity which commands widespread agreement, let alone means for implementation. There is a need for much additional work in this area.

The Composition of Social Capital

The legacy of resources left by the current generation to its descendants consists of many things -- natural resources and the environment, physical capital (objects created by human beings), and human knowledge and abilities. This diversity requires us to contemplate which resources will be used up, saved, and augmented. Ecologists and economists also tend to have differing views on this issue.

Consistent with the organicist perspective, many ecologists emphasize the need for special protection of natural resources, and natural systems, in order to safeguard ecological robustness and thus the continuation and quality of human life. In this view there is particular concern with damages that not only are large but also are irreversible. Again, this view goes beyond the value of natural resources and the environment in satisfying human consumptive demands. It asserts a basic lack of fungibility between

ecological resources and other components of social capital. This view also maintains a skepticism about the importance of technical innovation in augmenting social capital.[8]

The standard approach in resource economics, as illustrated in a recent paper by Dasgupta and Maler (1990), emphasizes the value of social capital rather than the size of any components. A comprehensive definition of "national income" can be made which includes both the value of current economic flows and the value of changes in components of social capital. Where market data are not applicable, the valuation of stock changes is done using shadow prices which reflect the present value of future consumption changes resulting from the stock changes. Thus, if current consumption degrades the environment the cost can be netted out of current income flows.[9]

Through its use of a criterion based on the present value of utility from consumption, this approach to defining social capital is methodologically individualistic. But the more important contrast with the organicist view is that the standard economic approach singles out no component of social capital for special consideration; rather it allows the maximum scope for tradeoffs among capital components including growth in human knowledge and ability. Thus, for example, special concern over environmental degradation would be warranted because its shadow cost is high relative to the cost of amelioration -- which may indeed be true for

---

8. In addition to its adherents among ecologists and philosophers, this view is supported by a small number of economists (see Daly 1990, Daly and Cobb 1989).

9. In more technical terms, this approach entails constructing a Hamiltonian function for (utilitarian) social welfare where the state variables are components of social capital and the co-state variables are the shadow prices.

nonmarket environmental resources -- but not because environmental resources have some larger fundamental importance.[10]

One consequence of these differences in perspective is that economists and ecologists often operate at different levels of aggregation when considering social capital and sustainability.[11] The use of (market or shadow) prices to define a common value metric for capital in the standard economic approach tends to lead to aggregation across resources, regions, and time. In contrast, even when expressing concern about global sustainability, ecologists often emphasize specific resources (e.g., soils) or specific regions (e.g., poor agricultural developing countries).

Aside from their differences, both attitudes toward the definition of social capital confront serious implementation problems. The problems with the organicist approach already have been noted -- it is a coarse filter, with difficulties in clearly identifying exactly which components of social capital should command special attention. The practical problems in integrating ecological processes into income accounting and adequately assessing shadow values of social capital components are no less daunting.[12]

---

10. We should note that efforts have been made to find a middle ground between the extremes described in the text. For example, Pearce, Markandya, and Barbier (1989) claim a special role for natural resources because of their limited substitutability with physical capital (it takes the former to make the latter) and their significance in the development of poorer countries. The authors discuss how benefit-cost calculations might be altered to reflect sustainability goals (as they define them) together with the special role of natural resources. However, many of the policy prescriptions involve changing prices to internalize externalities, especially those associated with nonmarket goods. These recommendations would be embraced by many economists with little specific concern for sustainability (and they might well be viewed as irrelevant by more partisan ecologists). As Pezzey (1989) has shown, internalizing environmental externalities is not a sufficient condition for sustainability.

11. We thank Tom Tietenberg for drawing our attention to this point.

12. Daly and Cobb (1989, Appendix) attempt to construct a new national welfare measure, the Index of Sustainable Economic Welfare. Their
(continued next page)

Both approaches are hampered by deep uncertainties about those elements of social capital which more distant generations are likely to more highly value.

The Scale of Human Activity

This area of controversy between economists and ecologists is in many ways a corollary of disagreements about intergenerational equity and the resource legacy to be left to the future. At one extreme, Daly and Cobb (1989) and Page (1990) are convinced that human demands on the total ecological system's "carrying capacity" already threaten human well-being, even before allowing for the large added demands on carrying capacity that will result from future population growth. This view is shared by many ecologists as well. The conclusion which follows from this perspective is the need for great efforts to rein resource use as well as population.

The response by many resource economists to this argument is that global ecological "carrying capacity" is not an exogenous datum but depends on a host of human interactions, not least of which is technical progress to augment productivity of the resource base by reduced waste and input substitution. Consequently, the scale of human activity is not inexorably bound by current resource availability. "Resources do not exist, they become" is one version of the hoary aphorism; in particular, human behavior will respond to resource scarcity appropriately registered in a price system. This line of thinking is illustrated by Baumol (1986), who discusses how "effective" consumption of a nonrenewable resource might be maintained or even expanded over time by technical innovation, even while

---

(continued from previous page)
discussion reveals the difficulty in any calculations (including their own) in extending conventional income accounts to reflect degradation of the resource base.

physical use of the resource is declining. Simon (1981) is an even more forceful advocate of the view that resource limits are not a serious issue.

A middle ground in this debate is illustrated by the work of Ayres and Kneese (1969, 1989). These authors also hold a concern about resource depletion and degradation. They note that the overall economic-ecological is a closed system with respect to materials use, so more rapid use of resources enlarges the stream of residuals back into the environment. Because of the second law of thermodynamics, the components of this residuals stream inherently are of lower quality than the resource stocks prior to use. Thermodynamic constraints also limit substitution between resources and physical capital. For these reasons, Ayres and Kneese favor less "dissipative" patterns of materials use.

On the other hand, they note that the earth is not a closed system with respect to energy availability, but rather receives net energy input from the sun. This net solar flux is the key, they argue, to ameliorating the thermodynamic constraints discussed above. While energy availability does impose some ultimate limit on carrying capacity, the effective capacity can indeed be enlarged by technical progress in reducing thermodynamic waste in energy use and in using energy to exploit lower-grade materials while preserving environmental conditions. Ayres and Kneese are not prepared to accept the more apocalyptic vision of Daly and others, but they acknowledge that forestalling ecological constraints will require unprecedented rates of increase in technical ingenuity -- particularly with a burgeoning population.

Differences in level of aggregation typically divide economists and ecologists in assessing the scale issue, just as they do in assessing social capital. Economic analyses tend to emphasize not only resource substitution but spatial mobility of resources and people. As we note below in our

discussion of agricultural and sustainability, taking into account such mobility tends to shift the debate toward global sustainability of the resource base while deemphasizing constraints on sustainability faced by specific regions. In contrast, ecologists tend to place more weight on the autonomous sustainability of particular regions or resource sectors. This view seems to reflect a combination of concerns about anthropological and other noneconomic values (e.g., protection of indigenous culture), intrinsic concerns about specific resources, and other factors.

This discussion of the scale problem sets the stage for our introduction of the safe minimum standard concept and for our illustrative observations concerning sustainable agriculture in the next two sections of the paper. For the moment we simply note that the scale problem cannot be fully treated without relating it to the issue of intergenerational obligations. If our concern were solely for resource adequacy and welfare of the present generation, then problems of resource degradation could be viewed just as (possibly subtle or vexing) problems of market failure. It is the introduction of concern over intergenerational fairness where there is a (albeit a highly uncertain one) of irreversible ecological harm to the future, and resource demands may be expected to grow over time, which makes the issue so complex.

RECONCILING TRADEOFFS AND IMPERATIVES

In this section we seek to provide some common vocabulary for economists and ecologists to use in debates over resource protection. Our focus here is on issues related to the composition of social capital and the scale of human activity, as discussed above. The issue of intergenerational responsibility also is central to the concept of sustainability, as we have

noted, but the philosophy literature seems to be providing the needed language for addressing this concern.

The discussion in the previous section suggests that many ecologists and environmental philosophers are more willing than economists generally would be to invoke moral imperatives limiting individual opportunities for resource use. Resource economists would acknowledge the existence of externalities (related to individualistic resource valuations) which require correcting price signals, but once such price corrections are made they would generally favor leaving resource use decisions to be determined by individual incentives. In an effort to bridge this gap, we sketch below a version of the "safe minimum standard" approach to resource protection which we believe has credibility for both disciplines. This approach does not by any means resolve disagreements about "where to draw the line" in resource preservation, but it does seem to offer a useful framework in which the questions can be considered.

To begin the exposition we note that the future impacts on the resource base and ecological system of current human activity can be characterized by many criteria. Economists tend to consider opportunity cost, risk, and sometimes uncertainty. Ecologists tend to be concerned with diminution of a natural system's physical attributes (size, performance, robustness) and with the reversibility of negative impacts.

For our illustration of the safe minimum standard approach, we focus on two attributes of impact. One is expected cost, where cost can be interpreted as opportunity cost by economists or a physical measure by ecologists. The other is irreversibility, which can be seen as implicitly reflecting uncertainty about future system performance and value to humans

as well as reflecting our current expectations about foreclosing options.[13] These attributes seem to be a simplified but reasonable representation of ecologists' concerns which also carry meaning for economists.

Figure 1 brings together these two dimensions. Heuristically, different broad categories of impacts can be thought of regions in this two-dimensional space.[14] The shape of these regions reflects at least some substitutability between cost and reversibility: human society and the ecological system can bear more irreversible impacts if the expected costs are lower. Damage to the future -- and thus, the potential violation of responsibility to the future -- increases as one moves from southeast to northwest in the diagram. The northwest corner represents extinction of the species, while the southeast corner reflects minor, short-term impacts which both the ecological system and the economy can routinely manage. In between are different gradations of impacts, as shown.

Where a particular impact is located in the diagram depends on the observer's assessment of cost and reversibility, and these assessments will depend on the observer's value judgments about future interests and circumstances as well as external facts. Nevertheless, it is generally true that as one moves from southeast to northwest in the diagram, the case for unfettered individual resource tradeoffs and individualistic allocations (especially through markets) becomes more attenuated, while the case for applying overarching moral imperatives to constrain resource use and protect the ecological base grows. One can imagine a (fuzzy) line that divides the

---

13. A more detailed treatment would include uncertainty as a separate dimension, but for our present purposes the simple dichotomy in the text should suffice. We are grateful to Bryan Norton for suggesting this diagrammable approach.

14. This diagram is purely heuristic; no effort is being made to indicate even an ordinal ranking of impacts, let alone a cardinal ranking.

box into two regions, as shown in Figure 2. To the northwest of this line the imperatives operate, while to the southeast individual incentives and tradeoffs (including discounting) are given a relatively free rein (externalities would still be internalized in the price system in this region).

We have thus sketched the broad outlines of a two-tier conceptual model for considering intergenerational resource management and preservation. The first step involves drawing the line in Figure 2 by identifying those resource systems and impacts in the northwest sector which require more protection than even an efficient market allocation will provide in order to protect fundamental interests of future generations, and determining the level of protection to be accorded. The second step allows the normal processes of market exchange and individual political interest-seeking to operate in the southeast portion of the diagram.

The procedure we have sketched responds to ecologists' concerns that the existence of critical resources be acknowledged, and it provides a means by which questions about the carrying capacity of the entire ecological-economic system can be brought into sharper focus. The approach also can command some respect among economists. In particular, this kind of critical resource or system demarcation is similar to the safe minimum standard (SMS) of conservation originally proposed for protecting individual resources (see Bishop, 1978 and Ciriacy-Wantrup, 1952). The SMS establishes for resources identified as critical a presumption in favor of preservation, unless the cost of doing so is intolerably high.[15] Evidence of the potential appeal of a two-tier approach is provided by the fact that one can find in the

---

15. The exchange between Bishop (1979) and Smith and Krutilla (1979) highlights the difference between a safe minimum standard and a benefit-cost assessment, where there is less of a presumption in favor of preservation with the latter approach.

literature a number of suggestions for such procedures by resource economists, ecologists, and environmental philosophers, though they differ in their details.[16]

The framework by itself does not offer answers to the key conceptual questions regarding sustainability we have identified.[17] The categorization of impacts and the location of the safe minimum standard demarcation in Figure 2 depend on individual values and perceptions. Terms like "critical resource" and "intolerably high" are vague. These terms gain meaning only in the context of individual valuations and the reconciliation of differing values in the political process.

For example, some ecologists may be more concerned about the potentially irreversible consequences of human actions than with the expected costs. For them the demarcation line may be essentially vertical. On the other hand, some economists may be more concerned about costs while having faith in society's ability to adapt even when the impacts are irreversible. These beliefs make the demarcation line closer to horizontal.[18] And for those who feel less of an obligation to future generations, and therefore place less emphasis on both cost and irreversibility, the demarcation will be further to the northwest than in the organicist view. The framework we have sketched does not address how these differences are to be adjudicated or reconciled and how individual

---

16. See e.g., Norton (1984), Randall (1986), Page (1983), and Daly and Cobb (1989).

17. The framework also is silent regarding the means to be used for implementation. In democratic societies the collective decision to locate the safe minimum standard line presumably would flow from the political process, but the details of how this would work are not clear. The specific policies to be used for resource protection also would need to be identified.

18. We are grateful to Tim Brennan for suggesting these points.

values may be changed by this process. Nor does it address the specific protective measures that should be undertaken.

The framework we have sketched also is static and thus incomplete. With increasing knowledge about natural processes and possibilities for social organization, technical and institutional options for mitigating and adapting to changes in the resource base or ecological system may increase. This would tend to shift the demarcation line to the northwest (subject to some ultimate natural limits). In effect, carrying capacity becomes a dynamic concept, as noted previously. Values also may shift over time. More research on the concepts we have presented is needed to draw out these points.

Lastly, the application of the framework depends on the spatial frame of reference, an issue where we already have noted the potential for disagreement between economists and ecologists. Our focus has been on global sustainability. The conditions for sustainability for a specific region are likely to be different, the differences increasing as the region under consideration diminishes in size. As already noted, the more regionally mobile are people and resources into and out of a region, the less stringent may be the conditions for sustainability of total economic activity in the region (though different sectors may prosper and decline). This point recurs in our discussion of agriculture and sustainability, to which we now turn.

SUSTAINABLE AGRICULTURE: AN ILLUSTRATION

In this section we illustrate sustainability issues through discussion of tradeoffs and imperatives in natural resource and environmental management in agriculture. This is appropriate because much of the discussion of sustainability focuses on agriculture.

Agricultural sustainability raises all the conceptual issues discussed above. Intergenerational equity demands that each generation manage its agricultural resources so as to indefinitely meet demands for food and fiber at economic and environmental costs consistent with maintaining per capita welfare through time. Those concerned that the intergenerational obligation may not be met argue that current systems of agricultural production threaten irreversible losses of land and water resources and of biological diversity, that the systems are excessively dependent on exhaustible sources of energy, and that agricultural research will prove unable to develop new technologies and management practices which can adequately substitute for these various resources as they become more scarce. In this view, current agricultural systems are operating so far in the northwest portion of Figure 1 as to pose a serious threat to intergenerational equity in provision of food and fiber and other social values affected by management of agricultural resources.

This view about the threat to agricultural sustainability rests on two implicit assumptions: (1) that on a per capita basis future generations will value food and fiber, and the environmental values at risk in agricultural production, in roughly the same ways that our generation does; and (2) that land, water, biological diversity, energy, and technology will continue to play major roles in satisfying future demands for food and fiber. In terms of the conceptual framework developed above, these resources are judged to be key parts of the social capital whose value must be preserved, or enhanced, to assure agricultural sustainability.

Discussion of agricultural sustainability must also address the scale issue. Projections by the United Nations (1989) indicate that the present 5 plus billion people inhabiting the earth could grow to some 10 billion by the middle of the next century. Ninety percent of this growth would be in

the developing countries of Asia, Africa, and Latin America where aspirations for increasing per capita income are high and relatively high proportions of additional income are spent on food. The combination of population and per capita income growth in these countries, plus slow but still positive population growth in the developed countries, could increase global demand for food three to four times between now and the middle of the next century. The issue for world agriculture, therefore, is not whether it could indefinitely meet existing demands for food and fiber but the potentially much more difficult question of whether it could accommodate several multiples of present demands within the next five or six decades.

An assessment of the sustainability of agriculture illustrates two other aspects of sustainability highlighted in our conceptual discussion: (1) the importance of specifying the spatial, or regional, dimensions of sustainability, and (2) of defining the institutional conditions which determine the relationships among the regions. World trade in food and fiber is highly developed, and people move both within and across national borders in response to changing perceptions of economic opportunity. If one assumes -- as we do here -- that the global institutional setting will continue to permit large-scale movements of resources and people, then an assessment of the sustainability of agriculture must take a global perspective. The system may not be sustainable in any particular region, but this would be irrelevant if it is sustainable on a global scale and people, food, and fiber can move among regions.

In the rest of this section we briefly consider the conditions for sustainably expanding global agricultural production in response to rising demand for food and fiber. The focus is on the adequacy of land, water, and fossil energy resources, on biological diversity, and on the issue of

substituting technology for these resources. We also consider the relationship between sustainability and efficiency in the growth of agricultural capacity.

Land resources. Although there still is uncultivated arable land in the world, there is a consensus among agricultural development specialists that most of the future increases in agricultural output will have to come from rising yields on land already in production. The long-term yield effects of soil erosion, therefore, are a major concern. Conversion of land from trees or grass to crops inevitably increases soil erosion by wind and water. Overgrazing of grassland can have the same effect; and irrigation almost inevitably generates increasing salt loads which, unless properly managed, will build up in the soil, reducing its capacity for plant growth.

All of these forms of land degradation are widely observed around the world. Soil erosion, however, probably is most important, and is the focus of attention here.

The literature on world agricultural development routinely features soil erosion as a major threat to agricultural sustainability (e.g., Brown et al., 1990). Assertions to this effect are frequently made about the situation in the United States, Canada, Australia, eastern Europe and the Soviet Union, and the developing countries of Asia, Africa, and Latin America. Despite this, careful reviews indicate that except for the United States, very little is known about either the amount of soil erosion occurring around the world or its productivity effects (Texas Tech Workshop, 1989; Dregne, 1989; Stocking, 1984). (Discussions of resource depletion effects of agriculture in western Europe emphasize contamination of ground and surface waters by fertilizers and animal wastes. Soil

erosion gets little attention, suggesting that it is not viewed as a serious problem in that region.)

The United States first acquired reliable, comprehensive estimates of erosion with the 1977 National Resources Inventory (NRI). A second, more intensively sampled NRI taken in 1982 confirmed the 1977 data. The NRI data were used in models developed by the U.S. Department of Agriculture (Colacicco et al., 1989), by soil scientists at the University of Minnesota (Pierce et al., 1984), and at Resources for the Future (Crosson, 1987), to estimate the effect on crop yields of 100 years of cropland erosion at 1982 rates. The results showed that in the one-hundredth year, yields would be 3 to 10 percent below what they otherwise would be. Crosson (forthcoming) estimated that at the higher end of this range, cumulative crop production costs over the 100 years would be about 5 percent higher than they otherwise would be. This estimate takes account not only of the erosion-induced loss of yield but also the cost of the additional fertilizer needed to replace soil nutrients, and the cost of the additional energy needed to plow less tillable land.

The reviews cited above indicate that information about erosion and its productivity effects in parts of the world other than the United States is anecdotal. Reports of visual observation suggest that in many areas, particularly mountainous ones such as Nepal, erosion is very high. And one might easily infer that the resulting losses of soil productivity must also be high. Research done on experimental plots in parts of Africa and elsewhere also indicate that on some soils and under some systems of agricultural practices, erosion and productivity losses can be high. These studies are few in number, however, and highly site specific. They, and the other anecdotal information, are insufficient to support general conclusions about either the amount of soil erosion or its productivity

consequences across major agricultural producing regions of the world outside of the United States.

Water resources. Two-thirds of global crop production is rainfed, the rest being on irrigated land (Postel, 1989). Global warming and related changes in climate are expected to increase global precipitation and probably to change its distribution among regions around the world. What these events might imply about the supply of water in regions now engaged in rainfed agriculture is highly uncertain. In view of this, it probably makes sense to assume that on global balance, water in the future will be no more limiting in presently rainfed areas than it is now.

The situation in the presently irrigated areas that account for one-third of the world's crop output likely will be quite different. A significant amount of irrigation water is pumped from nonrechargeable aquifers, for example, the Ogallala Aquifer which underlies much of the American Great Plains. As the depth to the water table increases the cost of pumping rises. Even if the aquifer is not exhausted, the cost of taking water from it could rise so high that additional pumping could be justified only at crop prices so high as to raise a question about agricultural sustainability.

Perhaps a more compelling limit to future supplies of irrigation water will be increasing competition for water for nonagricultural uses, including water needed to protect instream ecological values. This competition already is increasing in the American West and elsewhere around the world. Typically, the marginal value of water in these nonagricultural uses is several times its value for irrigation. Again, the crop prices required to permit agriculture to compete effectively for this water likely would be so high as to be considered inconsistent with sustainable agriculture.

Energy. Fossil energy resources drive most farm machinery presently used in agriculture and are the main source of nitrogen fertilizers and chemical pesticides. These resources are nonrenewable. It is possible that in the medium-term future they may become so scarce as to virtually exclude their use for all but the most highly valued goods and services. In this case agriculture could not compete effectively for these resources except with prices of food and fiber rise so high as to raise a question about agricultural sustainability. Indeed, we have no hesitation in asserting that because of its dependence on fossil energy resources mainstream agriculture as currently practiced is not sustainable over the very long term. Unless economical sources of energy continue to be available, either from further advances in the use of fossil fuels or development of renewable substitutes, agriculture will not be able to accommodate the three-to-four fold increase in global demand for food and fiber which plausibly could occur by the middle of the next century.

Biological diversity. Our ability to maintain and expand the supply of agricultural output used for food and fiber depends in a fundamental way on the diversity of the genetic stock embodied in plants and animals. This diversity sets limits to the ability of scientists to develop new crop varieties and animal traits which increase productivity and provide increased protection to plants and animals against insects and disease.

It sometimes is argued that mainstream agriculture as it is practiced in the developed countries, and increasingly in the developing countries also, poses a threat to plant genetic diversity because it relies on a relatively narrow genetic base of high-yielding crop varieties. The sustainability issue, however, is not the genetic diversity of the crops in production at any one time but the diversity of the genetic stock which scientists can tap into as needed to develop new varieties. The genetic

diversity represented in crop gene "banks" in the United States and a few other places around the world is far greater than the diversity represented in the crops grown in mainstream agriculture. The proper sustainability question is whether the amount of diversity held in the gene banks is sufficient to meet future needs. The answer is controversial, but a statement by Duvick (1986, p. 196) implicitly gives some grounds for optimism:

> "Manipulated evolution in the breeding nursery can successfully counter natural evolution in disease and insect populations on the farm. Breeders thus can furnish genetic diversity over time to supplement the relatively small amount of genetic diversity in the farmers' fields at any single point in time." (Emphasis added)

The thrust of this statement is that mainstream agriculture is not a threat to plant genetic diversity despite the narrowness of the genetic base represented on farmers' fields. The statement does not address what probably is the main threat to genetic diversity: tropical deforestation (Wilson, 1989). This threat, however, is not primarily from mainstream agriculture but from traditional slash and burn agriculture in tropical areas, cutting of trees for firewood, and from commercial logging (Repetto, 1989).

Conclusion about natural resource adequacy. The discussion points to the conclusion that in the absence of continuing advances in agricultural technology (here defined to include management improvements) the land, water, and energy resources now used in agriculture will be inadequate to accommodate the prospective increase in global demand for food and fiber at socially acceptable economic and environmental costs. Threats to biological diversity support this conclusion. Put more succinctly, with

the stock of natural and technical capital now at its command, the existing global agricultural system is not indefinitely sustainable.

The conclusion rests on the widely accepted fact that the potential for increasing the present stock of natural resource capital employed in agriculture is small relative to the prospective increase in global demand for food and fiber. The stocks of land and water could be increased some, but probably not much, by reducing degradation of these resources. In the United States, for example, erosion-induced losses of soil productivity are so low that reducing them to zero would add little to the stock of agricultural land relative to future demands likely to be placed on American agriculture. While no one knows how much productivity is lost to soil erosion in the rest of the world, it could be double or triple the rate of loss in the United States and still be small relative to the possible tripling or quadrupling of global demand for food and fiber over the next sixty years.

The situation with respect to degradation of irrigation water appears comparable to that of land degradation. Postel (1989) presents an estimate that 24 percent of the world's irrigated land is damaged by salts in irrigation water. The effect in reducing irrigated production is substantially less than 24 percent because most of this land remains in production, although with reduced yields. Since the effect of saline water in reducing irrigated production is less than 24 percent, and since irrigated production is only one-third of global crop production, eliminating all salinity problems in irrigation water would increase the supply of water by only a small amount relative to the prospective increase in global demand for food and fiber.

Technology as a resource. Because the potential for increasing the quantities of land and water is small, they will contribute adequately to

sustaining future agricultural output only if their yield, or productivity, is increased adequately. This is the role of technological advance, here defined to include all advances in knowledge relevant to agricultural production. Technology also is the key to overcoming increasing fossil fuel scarcity as a threat to agricultural sustainability. There is a consensus among energy specialists that with improvements in management fossil fuels can be used more efficiently than at present, thus extending the economic life of the stock of these resources. And although judgments differ widely about how fast and at what cost we will learn how to substitute other energy resources for fossil fuels, few doubt that it can be done.

It is not clear that technological advance can augment biological diversity, but we already know much about the threats to diversity and how to contain them. What now is critically needed is knowledge of how to overcome the political and institutional obstacles to protection of biological diversity where it is under threat.

The argument here rests on the hypothesis that the supply of knowledge -- here called technology -- relevant to agricultural production is vastly more elastic than the supply of natural resources used in production. The validity of the hypothesis is critical to an assessment of the sustainability of alternative patterns and scales of global development (not just in agriculture), and of the policies needed to achieve sustainability. Investigation of the hypothesis should be among the high priority components of any agenda for research on sustainability.

Hayami and Ruttan (1985) have argued, persuasively in our judgment, that emerging scarcities of the resources used in agriculture induce research to develop new technologies to overcome the scarcities. The validity of the argument, however, depends on the existence of strong

signals correctly identifying the increasingly scarce resources. Market prices can provide the signals where markets exist. But markets are weak or completely absent for some key resources, particularly biological diversity. And even where well-functioning markets exist resource prices may not properly reflect the interests of future generations in resource management.

The implication is that if technology is to adequately serve the full range of social interests in assuring the sustainability of global agriculture it must receive the strong and steady attention of governments and international institutions charged with responsibility for agricultural research.

Sustainability and efficiency. It is easy to imagine sustainable patterns of agricultural development which are socially inefficient. That is, a pattern may provide adequately for new technologies to overcome emerging scarcities of land, water, and fossil energy while also adequately protecting biological diversity, yet generate externalities which make the social product less than it could be. For example, technologies which adequately increase the productivity of the land may, nonetheless, result in costs of downstream damages to water quality from sediment which are greater than the costs of reducing the damages. The costs of damage may not be high enough to pose a significant threat to sustainability, but high enough to raise a significant efficiency issue. The damages persist because the institutions regulating farmers' use of their land permit them to ignore off-farm costs that their operations may impose.

Similarly, concern about the threat to sustainability from emerging scarcities of fossil fuels may result in "crash" policies to develop substitutes which are more costly than a less-intensive, longer-term approach which, nevertheless, would deal adequately with the problem.

The point here is that although any development path which is not sustainable is necessarily inefficient, some sustainable paths likely will be more costly than others. It is important to keep this distinction in mind, both for clarity in trying to understand problems of agricultural sustainability and in formulating policies to achieve it at the lowest social cost.

CONCLUDING REMARKS

Our purpose in this paper has been to identify key uncertainties and disagreements in the concept of sustainability as seen by ecologists and economists, and to begin sketching a framework in which such disagreements can be better understood and mediated. We believe that there is much to be gained from bridging gaps in the approach to sustainability. Economists can learn valuable lessons from ecologists and philosophers concerned with ecological issues, and vice versa.[19]

For economists, one important lesson in our view is the legitimacy of sustainability as an intellectual issue (albeit one with many open questions, contrary to the position taken by a number of ecologists). It is becoming more difficult to refer to an "optimal intertemporal allocation of resources" without some recognition that issues of intergenerational equity, scale of human activity in the biosphere, and potential nonfungibility of resources are not adequately addressed by a criterion of Pareto efficiency based on present value maximization. In particular, discounting does give rise to moral dilemmas, though simply setting discount rates equal to zero is not an attractive solution either. A two-tier procedure like that

---

19. We thank Tom Tietenberg for drawing the following points to our attention.

sketched in this paper may be a useful conceptual starting point for grappling with these issues.[20]

It is just as important for ecologists to recognize the enormous importance of economic incentives in seeking to protect threatened resources. As we have noted, the safe minimum standard approach faces serious operational obstacles as well as conceptual uncertainties in determining where the line of demarcation should be drawn. The greater the degree to which markets can be used to guide resource use, after adjusting prices to reflect social interests that transcend market values such as environmental degradation, the greater the ease with which resource protection can be implemented. Market incentives also can provide a valuable impetus for technical innovation.

We have alluded to many research needs remaining to be filled in better understanding the requirements of sustainability and how they might be met in practice. To conclude this paper we briefly outline an agenda of possible topics for further research.[21]

Further Clarification of Meaning

As already noted, there are numerous unanswered questions still remaining about the basic definition of sustainability. These concern the nature of the assumed obligation to future generations, the basic values

---

20. In summarizing proposed recommendations for a discount rate policy to be followed, the U.S. General Accounting Office (1990) notes that special approaches to mitigate the effects of discounting in valuing human life impacts across generations may be needed. This recognition is an interesting illustration of our point that simple intergenerational discounting procedures may be inadequate.

21. As we noted at the beginning of the paper, sustainability also encompasses a number of shorter-term issues involving resource and environmental management in developing countries. There are many important research topics related to these issues which lie beyond the scope of this review.

those generations may hold, the delineation of consequences from natural resource use as sketched in Figure 1, and the incorporation of dynamic economic and ecological responses. To illustrate, seeking to provide the means for nondecreasing per-capita well-being across generations, as suggested by the Brundtland Commission report, may seem to be a laudable goal. However, our knowledge of future resource requirements and technical opportunities, and our capacity to shelter the future from risks, may be very limited. A more modest objective of resource protection which attempts to guard against catastrophic declines in living standards and seeks to provide minimum acceptable individual living standards may be more achievable.[22]

Examination of Microtheoretic Issues

The imposition of an intertemporal sustainability constraint is likely to affect theoretical conclusions devised from many models of natural resources and economic growth. There is a small but growing technical literature concerned with sustainability, and a larger body of existing literature in resource economics which can be used to address sustainability issues.[23] Building on this literature, it is important to better understand how a sustainability constraint could affect optimal paths and policies in more complex but more realistic settings that include multiple resources with substitution, uncertainty, and endogenous technical change. At the same time, since sustainability derives from a concern about ecological

---

22. The minimum acceptable living standards could be well above current or threatened standards for the world's poorest inhabitants.

23. Pezzey (1989) provides an excellent survey of the literature, particularly papers dealing with resources and economic evolution over time. Other recent papers include Anderson (1987), Barbier and Markandya (1989), Gross and Veendorp (1990), Howarth and Norgaard (1990), and Krautkraemer (1990).

limits it is important to formulate these extended models to include operative physical limits on resource and material substitution (e.g., some bound on the ability of capital to substitute for energy).

Empirical Assessments

Ultimately, policy discussions about sustainability require a complete empirical analysis of the issue than has been conducted to date. Better knowledge is required about both physical systems and social institutions. Our illustration of sustainability issues with reference to agriculture points out many unanswered empirical questions in that area. Issues related to energy -- the extent of long-term substitution possibilities and the transition toward renewable sources -- are another key area for empirical research. An overarching topic is a better empirical understanding of how technical progress can facilitate the achievement of sustainable paths. The policy process also will require assessing the overall impacts on the economy (costs and benefits) of sustainability measures.

As part of the clarification of what sustainability means, there are significant opportunities for collaborative research among economists, ecologists, philosophers, anthropologists, and other scientists. For example, one important unanswered question in the political and cultural arena is the extent to which the current generation has a substantial concern for the well-being of the more distant future. The other two research components listed above are more specifically economic in nature, but answering such microtheoretic and empirical economic questions should help to put sustainability issues and policies in sharper focus.

Figure 1. Categorization of Impacts

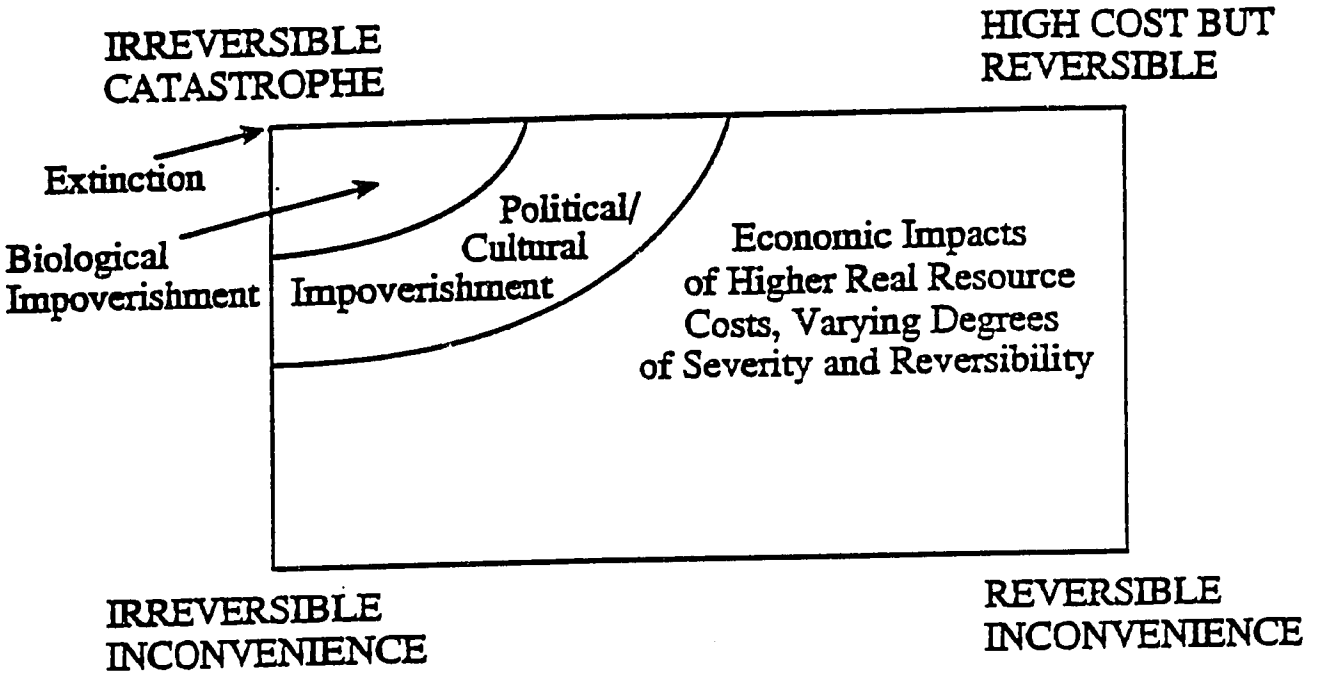
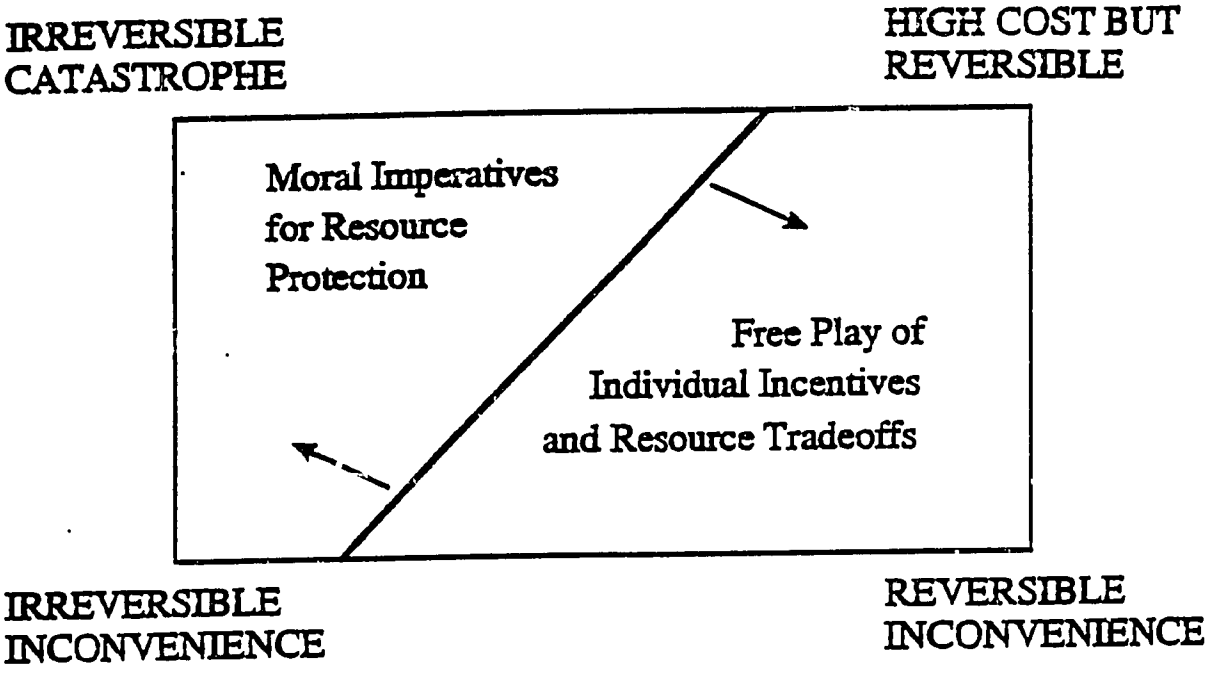


Figure 2. The "Safe Minimum Standard"



REFERENCES

Anderson, C. L. 1987. "The Production Process: Inputs and Wastes," Journal of Environmental Economics and Management vol. 14, no. 1 (March), pp. 1-12.

Arrow, K. J. 1963. Social Choice and Individual Values, 2nd edition (New Haven, Yale University Press).

Ayres, R. U. and A. V. Kneese. 1969. "Production, Consumption, and Externalities," American Economic Review vol. 69, no. 3 (June), pp. 282-297.

Ayres, R. U. and A. V. Kneese. 1989. "Externalities: Economics and Thermodynamics," in F. Archibugi and P. Nijkamp, eds., Economy and Ecology: Towards Sustainable Development (Dordrecht, Kluwer).

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

Barbier, E. B. and A. Markandya. 1989. "The Conditions for Achieving Environmentally Sustainable Development." International Institute for Environment and Development Paper 89-01 (London).

Baumol, W. J. 1986. "On the Possibility of Continuing Expansion of Finite Resources," Kyklos vol. 39, no. 2, pp. 167-179.

Bishop, R. D. 1978. "Endangered Species and Uncertainty: The Economics of the Safe Minimum Standard," American Journal of Agricultural Economics vol. 60, no. 1 (February), pp. 10-18.

Bishop, R. D. 1979. "Endangered Species, Irreversibility and Uncertainty: A Reply," American Journal of Agricultural Economics vol. 61, no. 2 (May), pp. 376-379.

Brown, L. 1990. State of the World 1990 (Worldwatch Institute, Washington, D.C.).

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

Ciriacy-Wantrup, S. V. 1952. Resource Conservation (Berkeley, University of California Press).

Colacicco, D., T. Osborn, and K. Alt. 1989. "Economic Damages from Soil Erosion," Journal of Soil and Water Conservation vol. 44, no. 1 (January-February), pp. 35-39.

Crosson, P. 1987. "Soil Erosion and Policy Issues" in T. Phipps, P. Crosson, and K. Price (eds.), Agriculture and the Environment, Resources for the Future, Washington, D.C.).

Crosson, P. (Forthcoming). The Long-Term Adequacy of Agricultural Land in the United States: Economic and Environmental Issues (Resources for the Future, Washington, D.C.

Daly, H. 1990. "Toward Some Operational Principles of Sustainable Development," Ecological Economics vol. 2, no. 1 (April), pp. 1-6.

Daly, H. and J. Cobb. 1989. For the Common Good (Boston, Beacon Press).

Dasgupta, P. S. and G. M. Heal. 1979. Economic Theory and Exhaustible Resources (Cambridge, MA., Cambridge University Press).

Dasgupta, P. and K.-G. Maler. 1990. "The Environment and Emerging Development Issues." Presented at the World Bank Annual Conference on Development Economics, Washington, D.C., April.

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

Dregne, H. 1989. "Informed Opinion: Filling the Soil Erosion Data Gap," Journal of Soil and Water Conservation vol. 44, no. 4 (July-August), pp. 303-305.

Duvick, D. 1986. "Summary and Assessment of the Papers on Breeding," in P. Hazell (ed.), Summary Proceedings of a Workshop on Cereal Yield Variability (International Food Policy Research Institute, Washington, D.C.).

General Accounting Office (GAO). 1990. "GAO's Discount Rate Policy: Proposed Recommendations." Draft manuscript, Office of the Chief Economist (Washington, D.C., GAO, June).

Golding, M. 1972. "Obligations to Future Generations," The Monist vol. 56, pp. 85-99.

Gross, L. S. and E. C. H. Veendorp. 1990. "Growth With Exhaustible Resources and a Materials-Balance Production Function," Natural Resource Modeling vol. 4, no. 1 (Winter), pp. 77-94.

Hartwick, J. M. 1977. "Intergenerational Equity and the Investing of Rents from Exhaustible Resources," American Economic Review vol. 67, pp. 972-974.

Hayami, Y. and V. Ruttan. 1985. Agricultural Development (The Johns Hopkins University Press, Baltimore and London).

Howarth, R. B. and R. B. Norgaard. 1990. "Intergenerational Resource Rights, Efficiency, and Social Optimality," Land Economics vol. 66, no. 1 (February), pp. 1-11.

Kneese, A. V. and W. D. Schulze. 1985. "Ethics and Environmental Economics," in A. V. Kneese and J. L. Sweeney, eds., Handbook of Natural Resource and Energy Economics, vol. I (Amsterdam, North-Holland).

Krautkraemer, J. A. 1990. "Neoclassical Economics and Sustainability." Presented at the American Economic Association annual meetings, Washington, D.C., December.

Leopold, A. 1949. A Sand County Almanac (New York, Oxford University Press).

Lind, R. C., ed. 1982. Discounting for Time and Risk in Energy Policy (Washington, D.C., Resources for the Future).

Lovelock, J. 1988. The Ages of Gaia (New York, Norton).

Norgaard, R. B. 1988. "Sustainable Development: A Co-Evolutionary View," Futures vol. 20, no. 6 (December), pp. 606-620.

Norton, B. G. 1982. "Environmental Ethics and the Rights of Future Generations," Environmental Ethics vol. 4, no. 4 (Winter), pp. 319-330.

Norton, B. G. 1984. "Environmental Ethics and Weak Anthropocentrism," Environmental Ethics vol. 6 (Summer), pp. 131-148.

Norton, B. G. 1986. "On the Inherent Danger of Undervaluing Species," in B. G. Norton, ed., The Preservation of Species (Princeton, NJ, Princeton University Press).

Norton, B. G. 1989. "Intergenerational Equity and Environmental Decisions: A Model Using Rawls' Veil of Ignorance," Ecological Economics vol. 1, pp. 137-159.

Page, T. 1977. Conservation and Economic Efficiency (Baltimore, Johns Hopkins University Press for Resources for the Future).

Page, T. 1983. "Intergenerational Justice as Opportunity," in D. MacLean and P. G. Brown, eds., Energy and the Future (Totowa, NJ, Rowman and Littlefield).

Page, T. 1988. "Intergenerational Equity and the Social Rate of Discount," in V. Kerry Smith, ed., Environmental Resource and Applied Welfare Economics (Washington, D.C , Resources for the Future).

Page, T. 1990. "Sustainable Resource Targets: A Response to Four Lessons from Biology." Draft manuscript (June).

Parfit, D. 1983a. "Energy Policy and the Further Future: The Identity Problem," in D. MacLean and P. G. Brown, eds., Energy and the Future (Totowa, NJ, Rowman and Littlefield).

Parfit, D. 1983b. "Energy Policy and the Further Future: The Social Discount Rate," in D. MacLean and P. G. Brown, eds., Energy and the Future (Totowa, NJ, Rowman and Littlefield).

Passmore, J. 1974. Man's Responsibility for Nature (New York, Scribner's).

Pearce, D., and R. Turner. 1990. Economics of Natural Resources and the Environment (Baltimore, Johns Hopkins University Press).

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

Pezzey, J. 1989. "Economic Analysis of Sustainable Growth and Sustainable Development." Environment Department Working Paper No. 15 (Washington, D.C., World Bank, March).

Pierce, F., R. Dowdy, W. Larson, and W. Graham. 1984. "Productivity of Soils in the Corn Belt: An Assessment of the Long Term Impact of Erosion," Journal of Soil and Water Conservation vol. 39, no. 2 (March-April), pp. 131-136.

Postel, S. 1989. Water for Agriculture: Facing the Limits (Worldwatch Institute, Washington, D.C.).

Randall, A. 1986. "Human Preferences," Economics, and the Preservation of Species," in B. G. Norton, ed., The Preservation of Species (Princeton, Princeton University Press).

Rawls, J. 1971. A Theory of Justice (Cambridge, Harvard University Press).

Repetto, R. 1990. "Deforestation in the Tropics," Scientific American, vol. 262, no. 4, pp. 36-42.

Simon, J. 1981. The Ultimate Resource (Princeton, NJ, Princeton University Press).

Smith, V. K. and J. V. Krutilla. 1979. "Endangered Species, Irreversibilities, and Uncertainty: A Comment," American Journal of Agricultural Economics vol. 61, no. 2 (May 1), pp. 371-375.

Solow, R. M. 1974. "Intergenerational Equity and Exhaustible Resources," in Review of Economic Studies Symposium on the Economics of Exhaustible Resources (Edinburgh, Longman Group Limited).

Solow, R. M. 1986. "On the Intergenerational Allocation of Natural Resources," Scandinavian Journal of Economics vol. 88, no. 1, pp. 141-149.

Stocking, M. 1984. Erosion and Soil Productivity: a Review, AGLS Consultant's Working Paper No. 1, Food and Agricultural Organization, Rome.

Texas Tech Workshop. 1989. Erosion, Productivity and Sustainable Agriculture, International Center for Arid and Semiarid Land Studies, Texas Tech University, Lubbock, Texas.

Tietenberg, T. 1988. Environmental and Natural Resource Economics, 2nd edition (Glenview, IL, Scott Foresman).

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

White, G. In press. "Greenhouse Gases, Nile Snails, and Human Choice," in R. Jessor, ed., Perspectives on Behavioral Science: The Colorado Lectures (Westview Press).

Wilson, E. 1989. "Threats to Biodiversity," Scientific American vol. 261, no. 3 (September), pp. 108-116.

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

RESOURCES FOR THE FUTURE

DISCUSSION PAPERS

April 1991

The following RFF discussion papers are currently in print. The cost of each is indicated. Prepayment is required for discussion papers for which there is a charge. This charge covers postage. Checks should be made out to Resources for the Future. Orders should be addressed to Publications, Resources for the Future, 1616 P Street, N.W., Washington, D.C. 20036.

ENERGY AND NATURAL RESOURCES DIVISION

ENR88-01	ALTERNATIVE AGRICULTURE: A REVIEW AND ASSESSMENT OF THE LITERATURE. Pierre Crosson and Janet Ekey (1988)	$5.00
ENR88-03	AN ASSESSMENT OF FERC PROPOSALS FOR REFORMING WHOLESALE GENERATION MARKETS. Michael A. Toman and Joel Darmstadter (REV. 1989)	$5.00
ENR88-04	ANALYZING U.S. OIL AND GAS EXPLORATION: A JOINT-PRODUCTS RATIONAL EXPECTATIONS FRAMEWORK. Margaret A. Walls (1988)	$5.00
ENR89-01	CHANGES IN ELECTRICITY MARKETS AND IMPLICATIONS FOR GENERATION TECHNOLOGIES. Hadi Dowlatabadi and Michael Toman (1989)	$5.00
ENR89-02	MANAGEMENT OF WATERSHEDS FOR AUGMENTED WATER YIELDS--PLUMAS NATIONAL FOREST. John V. Krutilla, Michael Bowes, and Thomas B. Stockton (1989)	$5.00
ENR89-03	TEMPORAL AGGREGATION IN FORPLAN LINEAR PROGRAMS. Michael D. Bowes (1989)	$5.00
ENR89-05	POLICY OPTIONS FOR ADAPTATION TO CLIMATE CHANGE. Norman J. Rosenberg, Pierre Crosson, William E. Easterling III, Kenneth Frederick, and Roger Sedjo (1989)	$5.00
ENR89-06	WILL NUCLEAR POWER RECOVER IN A GREENHOUSE? John F. Ahearne (1989)	$5.00
ENR89-07	ETHANOL FUEL AND NON-MARKET BENEFITS: IS A SUBSIDY JUSTIFIED? Margaret A. Walls, Alan J. Krupnick, and Michael A. Toman (1989)	$5.00
ENR90-01	AGRICULTURE IN A CHANGING ENVIRONMENT. Pierre Crosson and Norman J. Rosenberg (1989)	$5.00
ENR90-02	THE NATION'S WATER RESOURCES: PAST TRENDS AND CURRENT CHALLENGES. Kenneth D. Frederick (1989)	$5.00
ENR90-03	THE NATION'S CROPLAND AND SOILS: PAST TRENDS AND CURRENT CHALLENGES. Pierre Crosson (1990)	$5.00
ENR90-04	RANGELANDS. B. Delworth Gardner (1990)	$5.00
ENR90-05	IS REGULATION WHAT REGULATORS DO? Charles G. Stalon (1990)	$5.00
ENR90-06	RECENT INTERNATIONAL DEVELOPMENTS IMPACTING UNITED STATES FOREST PRODUCTS TRADE. A. Clark Wiseman (1990)	$5.00

ENR90-07	THE NATION'S FOREST RESOURCES. Roger A. Sedjo (1990)	$5.00
ENR90-08	FROM BAD TO WORSE; IMPACTS OF THE 1986 OIL PRICE COLLAPSE. Margaret A. Walls and Andrew S. Jones (1990)	$5.00
ENR90-09	AN ANALYSIS OF OIL AND GAS SUPPLY MODELING TECHNIQUES AND A SURVEY OF OFFSHORE SUPPLY MODELS. Margaret A. Walls (1990)	$5.00
ENR90-10	TAXATION, DEPLETION, AND WELFARE: A SIMULATION STUDY OF THE U.S. PETROLEUM RESOURCE. Robert T. Deacon (1990)	$5.00
ENR90-11	POPULATION GROWTH, SOIL FERTILITY, NONCONVEXITIES, AND AGRICULTURAL INTENSIFICATION. Jeffrey A. Krautkraemer (1990)	$5.00
ENR90-12	CONTINUOUS AND CYCLICAL FARMING STRATEGIES FOR SOIL MANAGEMENT FOR SUSTAINABLE AGRICULTURE. Jeffrey A. Krautkraemer (1990)	$5.00
ENR90-13	RENT-SEEKING AND THE COMMON POOL. Robert T. Deacon and Jon Sonstelie (1990)	$5.00
ENR90-14	U.S. WASTEPAPER RECYCLING POLICIES: ISSUES AND EFFECTS. A. Clark Wiseman (1990)	$5.00
ENR90-15	PROSPECTS FOR REDUCED CO_2 EMISSIONS IN AUTOMOTIVE TRANSPORT. Joel Darmstadter and Andrew Jones (1990)	$5.00
ENR91-01	DESIGNING PRICE CAPS FOR GAS DISTRIBUTION SYSTEMS. Thomas P. Lyon and Michael A. Toman (1990)	$5.00
ENR91-02	LESSONS FROM OTHER INTERNATIONAL AGREEMENTS FOR A GLOBAL CO_2 ACCORD. Peter M. Morrisette, Joel Darmstadter, Andrew J. Plantinga, and Michael A. Toman (1990)	$5.00
ENR91-03	HOW THE CO_2 ISSUE IS VIEWED IN DIFFERENT COUNTRIES. Peter M. Morrisette and Andrew J. Plantinga (1990)	$5.00
ENR91-04	UTILITY INVESTMENT BEHAVIOR AND THE EMISSION TRADING MARKET. Douglas R. Bohi and Dallas Burtraw (1991)	$5.00
ENR91-05	ECONOMICS AND "SUSTAINABILITY:" BALANCING TRADEOFFS AND IMPERATIVES. Michael A. Toman and Pierre Crosson (1991)	$5.00
ENR91-06	THE ECONOMIC COST OF CO_2 MITIGATION: A REVIEW OF ESTIMATES FOR SELECTED WORLD REGIONS. Joel Darmstadter (forestry contribution by Andrew Plantinga) (1991)	$5.00
ENR91-07	EQUITY AND INTERNATIONAL AGREEMENTS FOR CO_2 CONTAINMENT. Dallas Burtraw and Michael A. Toman (1991)	$5.00
ENR91-08	THE NASA BUDGET: FOR WHOM, FOR WHAT, AND HOW BIG? Molly K. Macauley (1991)	$5.00
ENR91-09	DOMESTIC EARMARKS AS TRADE POLICY: AN APPLICATION TO U. S. LOG EXPORTS. Clark Wiseman, Kenneth S. Lyon, and Roger A. Sedjo (1991).	$5.00
ENR91-10	U. S. ENERGY AND ENVIRONMENTAL POLICIES: PROBLEMS OF FEDERALISM AND CONFLICTING GOALS. Margaret A. Walls (1991).	$5.00
ENR91-11	ECONOMIC CONSIDERATIONS IN SUPPLYING EARTH OBSERVATION DATA FROM SPACE. Molly K. Macauley and Michael A. Toman (1991).	$5.00

QUALITY OF THE ENVIRONMENT DIVISION

QE88-02	ENFORCEMENT LEVERAGE WHEN PENALTIES ARE RESTRICTED. Winston Harrington (1988)	$2.25
QE88-04	ECONOMICS AND NUTRIENT REDUCTIONS IN THE CHESAPEAKE BAY. Alan J. Krupnick (1988)	$2.25
QE88-05	TEMPORAL AND SPATIAL CONTROL OF AMBIENT OZONE. Alan J. Krupnick (1988)	$2.25
QE88-06	MOMENT-BASED TESTS FOR POISSON AND RELATED COUNT DATA MODELS. John Mullahy (1988)	$2.25
QE88-08	POLICIES FOR THE MITIGATION OF ACID RAIN: A CRITIQUE OF EVALUATION TECHNIQUES. Hadi Dowlatabadi and Winston Harrington (1988)	$2.25
QE88-09	ACID DEPOSITION: SCIENCE AND POLICY. Winston Harrington (1988)	$2.25
QE88-10	THE HEALTH AND AGRICULTURAL BENEFITS OF REDUCTIONS IN AMBIENT OZONE IN THE UNITED STATES. Alan J. Krupnick and Raymond J. Kopp (1988)	$2.25
QE88-11	NATURAL RESOURCE ECONOMICS. Allen V. Kneese (1988)	$2.25
QE88-12	ENVIRONMENTAL STRESS AND POLITICAL CONFLICTS: SALINITY IN THE COLORADO RIVER. Allen V. Kneese (1988)	$2.25
QE88-13	EFFICIENCY PROPERTIES OF SOURCE CONTROL POLICIES FOR AIR POLLUTION CONTROL: AN EMPIRICAL APPLICATION TO THE LOWER DELAWARE VALLEY. Walter O. Spofford, Jr. (1988)	$2.25
QE89-01	AMBIENT OZONE AND ACUTE HEALTH EFFECTS: EVIDENCE FROM DAILY DATA. Alan J. Krupnick, Winston Harrington, and Bart Ostro (1988)	$2.25
QE89-02	MARKET SEGMENTATION AND VALUING AMENITIES WITH HEDONIC MODELS: THE CASE OF HAZARDOUS WASTE SITES. R. Gregory Michaels and V. Kerry Smith (1988)	$2.25
QE89-03	TRAVEL COST RECREATION DEMAND METHODS: THEORY AND IMPLEMENTATION. V. Kerry Smith (1988)	$2.25
QE89-05	SIGNALS OR NOISE? EXPLAINING THE VARIATION IN RECREATION BENEFIT ESTIMATES. V. Kerry Smith and Yoshiaki Kaoru (1988)	$2.25
QE89-07	TRADABLE NUTRIENT PERMITS AND THE CHESAPEAKE BAY COMPACT. Alan J. Krupnick (1989)	$2.25
QE89-08	VALUING INDIVIDUALS' CHANGES IN RISK: A GENERAL TREATMENT. A. Myrick Freeman III (1989)	$2.25
QE89-09	BENEFIT ESTIMATION GOES TO COURT: THE CASE OF NATURAL RESOURCE DAMAGE ASSESSMENTS. Raymond J. Kopp and V. Kerry Smith (1989)	$2.25
QE89-10	MOMENT-BASED ESTIMATION AND TESTING OF STOCHASTIC FRONTIER MODELS. Raymond J. Kopp and John Mullahy (1989)	$2.25
QE89-11	THE SOCIAL COST OF ENVIRONMENTAL QUALITY REGULATIONS: A GENERAL EQUILIBRIUM ANALYSIS. Michael Hazilla and Raymond J. Kopp (1989)	$2.25
QE89-12	PUBLIC CHOICES AND PRIVATE RISKS: THE ROLE OF ECONOMIC ANALYSIS. V. Kerry Smith (1989)	$2.25

QE89-13	BENEFIT-COST ANALYSIS OF POLICIES TOWARD RISK. A. Myrick Freeman III (1989)	$2.25
QE89-14	MEASURING WELFARE VALUES OF PRODUCTIVITY CHANGES. A. Myrick Freeman III and Winston Harrington (1989)	$2.25
QE89-15	UNCERTAINTIES IN ESTIMATES OF THE COSTS AND BENEFITS OF GROUNDWATER REMEDIATION: RESULTS OF A COST-BENEFIT ANALYSIS. Walter O. Spofford, Jr., Alan J. Krupnick, and Eric F. Wood (1989)	$2.25
QE89-16	THE SOCIAL COSTS OF CHRONIC HEART AND LUNG DISEASE. Maureen L. Cropper and Alan J. Krupnick (REV. 1990)	$2.25
QE89-17	THE ECONOMIC ANALYSIS OF AGRICULTURAL CHEMICAL REGULATION: THE CASE OF PHENOXY HERBICIDES AND WHEAT. Leonard P. Gianessi, Raymond J. Kopp, and Cynthia A. Puffer (1989)	$2.25
QE89-18	NOTES ON SYSTEMS OF FRONTIER FACTOR DEMAND EQUATIONS. Raymond J. Kopp and John Mullahy (1989)	$2.25
QE89-19	WEIGHTED LEAST SQUARES ESTIMATION OF THE LINEAR PROBABILITY MODEL, REVISITED. John Mullahy (1989)	$2.25
QE89-20	THE EFFECTS OF UNCERTAINTY ON POLICY INSTRUMENTS: THE CASE OF ELECTRICITY SUPPLY AND ENVIRONMENTAL REGULATIONS. Hadi Dowlatabadi and Winston Harrington (1989)	$2.25
QE89-21	REGULATING PESTICIDE USE: SOCIAL COSTS, POLICY TARGETING AND ECONOMIC INCENTIVES. Leonard P. Gianessi, Raymond J. Kopp, and Cynthia A. Puffer (1989)	$2.25
QE89-21-B	A DATA APPENDIX TO REGULATING PESTICIDE USE: SOCIAL COSTS, POLICY TARGETING AND ECONOMIC INCENTIVES. Leonard P. Gianessi, Raymond J. Kopp, and Cynthia A. Puffer (1989)	$2.25
QE89-22	LONGITUDINAL PATTERNS OF COMPLIANCE WITH OSHA HEALTH AND SAFETY REGULATIONS IN THE MANUFACTURING SECTOR. Wayne B. Gray and Carol Adaire Jones (1989)	$2.25
QE89-23	REGRESSION MODELS FOR BETA-DISTRIBUTED OUTCOMES. John Mullahy (1989)	$2.25
QE90-01	VALUING AMENITY RESOURCES UNDER UNCERTAINTY: A SKEPTICAL VIEW OF RECENT RESOLUTIONS. V. Kerry Smith (1989)	$2.25
QE90-02	ESTIMATING RECREATION DEMAND USING THE PROPERTIES OF THE IMPLIED CONSUMER SURPLUS. V. Kerry Smith (1989)	$2.25
QE90-03	TRENDS IN AMERICAN WILDLIFE RESOURCES. Winston Harrington (1989)	$2.25
QE90-04	HOUSEHOLD PRODUCTION FUNCTIONS AND ENVIRONMENTAL BENEFIT ESTIMATION. V. Kerry Smith (1989)	$2.25
QE90-05	ARE OSHA HEALTH INSPECTIONS EFFECTIVE? A LONGITUDINAL STUDY IN THE MANUFACTURING SECTOR. Wayne B. Gray and Carol Adaire Jones (1989)	$2.25
QE90-06	CAN WE MEASURE THE ECONOMIC VALUE OF ENVIRONMENTAL AMENITIES? V. Kerry Smith (1989)	$2.25
QE90-07	USING AN UPPER BOUND ON STAND-ALONE COST IN TESTS OF CROSS SUBSIDY. Karen Palmer (1989)	$2.25

QE90-08	AN ECONOMIC APPRAISAL OF THE D.C. APPEALS COURT RULING ON THE DOI REGULATIONS FOR NATURAL RESOURCE DAMAGE ASSESSMENTS. Raymond J. Kopp, Paul R. Portney, and V. Kerry Smith (1989)	$2.25
QE90-09	UNINTENDED IMPACTS OF PUBLIC INVESTMENTS ON PRIVATE DECISIONS: THE DEPLETION OF FORESTED WETLANDS. Robert N. Stavins and Adam B. Jaffe (1989)	$2.25
QE90-10	ALTERNATIVE RENEWABLE RESOURCE STRATEGIES: A SIMULATION OF OPTIMAL USE. Robert N. Stavins (1989)	$2.25
QE90-11	INNOVATIVE POLICIES FOR SUSTAINABLE DEVELOPMENT IN THE 1990s: ECONOMIC INCENTIVES FOR ENVIRONMENTAL PROTECTION. Robert N. Stavins (1990)	$2.25
QE90-12	ENVIRONMENTAL ECONOMICS: A SURVEY. Maureen L. Cropper and Wallace E. Oates (1990)	$2.25
QE90-13	THE EFFECT OF INFORMATION ON HEALTH RISK VALUATIONS. Alan J. Krupnick and Maureen L. Cropper (1990)	$2.25
QE90-14	VALUING ENVIRONMENTAL HEALTH EFFECTS. Maureen L. Cropper and A. Myrick Freeman III (1990)	$2.25
QE90-15	EMISSIONS TRADING IN THE ELECTRIC UTILITY INDUSTRY. Douglas R. Bohi, Dallas Burtraw, Alan J. Krupnick, and Charles G. Stalon (1990)	$2.25
QE90-16	REAPPORTIONMENT RECONSIDERED. Deanna Marquart and Winston Harrington (1990)	$2.25
QE90-17	CONSISTENT ESTIMATION AND INFERENCE FOR ECONOMETRIC FRONTIER MODELS ESTIMATED BY LEAST SQUARES. Raymond J. Kopp and John Mullahy (1990)	$2.25
QE90-18	THE INCENTIVE CONTRACT FOR STRATEGIC DELEGATION IN BARGAINING. Dallas Burtraw (1990)	$2.25
QE90-19	BARGAINING WITH NOISY DELEGATION. Dallas Burtraw (1990)	$2.25
QE90-20	THE ESTIMATION OF CONSUMER PREFERENCES FOR ATTRIBUTES: A COMPARISON OF HEDONIC AND DISCRETE CHOICE APPROACHES. Maureen L. Cropper, Leland Deck, Nalin Kishor, and Ted McConnell (1990)	$2.25
QE90-21	RISK COMMUNICATION AND ATTITUDE CHANGE: TAIWAN'S NATIONAL DEBATE OVER NUCLEAR POWER. Jin Tan Liu and V. Kerry Smith (1990)	$2.25
QE90-22	(REV) INTERNATIONAL COMPARISONS OF ENVIRONMENTAL REGULATION. Raymond J. Kopp, Paul R. Portney, and Diane E. DeWitt (1990)	$2.25
QE90-23	THE USE OF PRODUCTION INDICES IN PLANNING AND EVALUATING FISHERIES MANAGEMENT PROGRAMS. Danny C. Lee (1990)	$2.25
QE90-24	A TEST FOR CROSS-SUBSIDIES IN LOCAL TELEPHONE RATES: DO BUSINESS CUSTOMERS SUBSIDIZE RESIDENTIAL CUSTOMERS? Karen L. Palmer (1990)	$2.25
QE90-25	THE COST-EFFECTIVENESS AND ENERGY SECURITY BENEFITS OF METHANOL VEHICLES. Alan J. Krupnick, Margaret A. Walls, and Michael A. Toman (1990)	$2.25
QE91-01	ELECTRIC VEHICLES AND THE ENVIRONMENT: CONSEQUENCES FOR EMISSIONS AND AIR QUALITY IN LOS ANGELES AND U.S. REGIONS. Hadi Dowlatabadi, Alan J. Krupnick, and Armistead Russell (1990)	$2.25

QE91-02	"BLACK MAYONNAISE" AND MARINE RECREATION: METHODOLOGICAL ISSUES IN VALUING A CLEANUP. Yoshiaki Kaoru and V. Kerry Smith (1990)	$2.25
QE91-03	THE IMPACT OF PRICING RULES ON ELECTRIC UTILITY EMISSIONS. Hadi Dowlatabadi and Robert W. Hahn (1990)	$2.25
QE91-04	DIVERSIFICATION BY REGULATED MONOPOLIES AND INCENTIVES FOR COST-REDUCING R&D. Karen Palmer (1990)	$2.25
QE91-05	HEALTH CAPITAL, RISK AVERSION, AND THE VARIANCE OF INCOME: ASSESSING SOME WELFARE COSTS OF ALCOHOLISM AND POOR HEALTH. John Mullahy and Jody L. Sindelar (1990)	$2.25
QE91-06	DETECTING HETEROGENEITY AND OVERDISPERSION IN POISSON REGRESSION MODELS VIA GOODNESS-OF-FIT. John Mullahy (1990)	$2.25
QE91-07	IMPROVING SYSTEM PLANNING IN THE COLUMBIA RIVER BASIN: SCOPE, INFORMATION NEEDS, AND METHODS OF ANALYSIS. Danny C. Lee and Charles M. Paulsen (1990)	$2.25
QE91-08	TRANSPORTATION AND AIR POLLUTION IN URBAN AREAS OF DEVELOPED AND DEVELOPING COUNTRIES. Alan J. Krupnick (1991)	$2.25
QE91-09	NATURAL RESOURCE DAMAGE ASSESSMENTS AND THE MINERAL SECTOR: VALUATION IN THE COURTS. V. Kerry Smith (1991)	$2.25
QE91-10	ON SEPARATING DEFENSIBLE BENEFITS TRANSFERS FROM "SMOKE AND MIRRORS". V. Kerry Smith (1991)	$2.25
QE91-11	EVALUATING THE RELATIVE EFFECTIVENESS OF ECONOMIC INCENTIVES AND DIRECT REGULATION FOR ENVIRONMENTAL PROTECTION: IMPACTS ON THE DIFFUSION OF TECHNOLOGY. A. B. Jaffe and R. N. Stavins (1991)	$2.25
QE91-12	WHO BEARS THE BURDEN OF ENERGY TAXES? D. E. DeWitt, H. Dowlatabadi, R. J. Kopp (1991)	$2.25

THE NATIONAL CENTER FOR FOOD AND AGRICULTURAL POLICY

RR87-01	AGRICULTURAL TRADE MODEL COMPARISON: A LOOK AT AGRICULTURAL MARKETS IN THE YEAR 2000 WITH AND WITHOUT TRADE LIBERALIZATION. Rachel Nugent Sarko (1986)	$5.00
FAP87-02	PROMOTING INCREASED EFFICIENCY OF FEDERAL WATER USE THROUGH VOLUNTARY WATER TRANSFER. Richard W. Wahl (1987)	$3.00
FAP89-01	REFLECTIONS FROM THE PAST, CHALLENGES FOR THE FUTURE: AN EXAMINATION OF U.S. AGRICULTURAL POLICY GOALS. Kristen Allen (1988)	$3.00
FAP89-03	ENVIRONMENTAL PROTECTION AND AGRICULTURAL SUPPORT: ARE TRADE-OFFS NECESSARY? Katherine Reichelderfer (1989)	$3.00
FAP89-04	THE CONSUMER'S STAKE IN FOOD POLICY: THE UNITED STATES AND THE EUROPEAN COMMUNITY. Carol S. Kramer and Barbara J. Elliott (1989)	$3.00
FAP89-05	TEN TRUTHS ABOUT SUPPLY CONTROL. Thomas W. Hertel (1989)	$3.00
FAP89-06	PROPOSITION 65 AND THE ECONOMICS OF FOOD SAFETY. Carol S. Kramer and Eileen O. van Ravenswaay (1989)	$3.00

FAP89-07	THE POLITICAL ECONOMICS OF CALIFORNIA'S PROPOSITION 65. Tim T. Phipps, Kristen Allen and Julie A. Caswell (1989)	$3.00
FAP90-01	TARGETING FARM PROGRAMS. Daniel A. Sumner (1989)	$3.00
FAP90-02	THE 1985 FOOD SECURITY ACT AS A BASIS FOR FUTURE FARM LEGISLATION. Robert L. Thompson (1989)	$3.00
FAP90-03	U.S. TRADE POLICY AND THE GATT: IMPLICATIONS FOR AGRICULTURE. David Blandford (1989)	$3.00
FAP90-04	DECOUPLING AND RELATED FARM POLICY OPTIONS. Tim T. Phipps, G. E. Rossmiller, and William H. Meyers (1989)	$3.00
FAP90-05	FOOD SAFETY AND PUBLIC POLICY: WHAT CAN ECONOMISTS CONTRIBUTE? Carol S. Kramer (1990)	$3.00
FAP90-06	FOOD SAFETY: THE CONSUMER SIDE OF THE ENVIRONMENTAL ISSUE. Carol S. Kramer (1990)	$3.00
FAP90-07	TREATING FOOD SECURITY AND FOOD AID ISSUES AT THE GATT. Nicole Ballenger and Carl Mabbs-Zeno (1990)	$3.00
FAP90-08	THE DISTRIBUTION OF DIRECT PAYMENTS TO FARM OPERATORS IN 1987 AND 1988: SOME QUESTIONS ABOUT POLICY OBJECTIVES. James Duncan Shaffer and Gerald W. Whittaker (1990)	$3.00
FAP90-09	MEASUREMENT AND EVALUATION OF THE IMPACTS OF AGRICULTURAL CHEMICAL USE: A FRAMEWORK FOR ANALYSIS. John M. Antle and Susan M. Capalbo (1990)	$3.00
FAP91-01	REVISITING SURPLUS FOOD PROGRAMS AFTER SURPLUSES: THE TEMPORARY EMERGENCY FOOD ASSISTANCE PROGRAM AND ITS ROLE IN THE DISTRICT OF COLUMBIA. Nicole Ballenger and Courtney Harold (1991)	$3.00

CENTER FOR RISK MANAGEMENT

CRM 88-01	REGULATION AND RISK ANALYSIS OF HAZARDOUS MATERIALS TRANSPORTATION ROUTES. John C. Allen and Theodore S. Glickman (1988)	Free
CRM 88-02	AIR POLLUTION, CIGARETTE SMOKING, AND THE PRODUCTION OF RESPIRATORY HEALTH. John Mullahy and Paul R. Portney (Revised 1989)	Free
CRM 89-02	URBAN AIR QUALITY AND CHRONIC RESPIRATORY DISEASE. Paul R. Portney and John Mullahy (1988)	Free
CRM 89-03	THE NET BENEFITS OF INCENTIVE-BASED REGULATION: THE CASE OF ENVIRONMENTAL STANDARD-SETTING IN THE REAL WORLD. Wallace E. Oates, Paul R. Portney and Albert M. McGartland (1988)	Free
CRM 89-04	PROTECTIVE ACTION DECISION-MAKING IN TOXIC VAPOR CLOUD EMERGENCIES. Theodore S. Glickman and Alyce M. Ujihara. (1988)	Free
CRM 89-05	ECONOMICS AND THE RATIONAL MANAGEMENT OF RISK. A. Myrick Freeman III and Paul R. Portney (1989)	Free
CRM 89-06	AN EXPEDITIOUS RISK ASSESSMENT OF THE HIGHWAY TRANSPORATION OF FLAMMABLE LIQUIDS IN BULK. Theodore S. Glickman (1989)	Free

CRM 89-07	RESTRICTING HAZARDOUS MATERIALS ROUTES ON THE NATIONS' RAILROADS: SOME CONSIDERATIONS FOR REGULATORY ANALYSIS. Theodore S. Glickman (1989)	Free
CRM 90-01	A SIMPLE FORMULA FOR CALCULATING THE "MASS DENSITY" OF A LOGNORMALLY-DISTRIBUTED CHARACTERISTIC: APPLICATIONS TO RISK ANALYSIS. Adam M. Finkel (1989)	Free
CRM 90-02	DISCOUNTING AND THE EVALUATION OF LIFE-SAVING PROGRAMS. Maureen L. Cropper and Paul R. Portney (1990)	Free
CRM 90-03	GAUGING THE DEGREE OF CONFIDENCE IN CHOICES BETWEEN RISKY ALTERNATIVES. Theodore S. Glickman and Emily D. Silverman (1990)	Free
CRM 91-01	THE DETERMINANTS OF PESTICIDE REGULATION: A STATISTICAL ANALYSIS OF EPA DECISIONMAKING. Maureen L. Cropper, William N. Evans, Stephen J. Berardi, Maria M. Duchin-Soares, and Paul R. Portney (revised December 1990)	Free
CRM 91-02	POLICIES FOR THE REGULATION OF GLOBAL CARBON EMISSIONS. Wallace E. Oates and Paul R. Portney (1991)	Free
CRM 91-03	THE EPA AT "THIRTYSOMETHING". Paul R. Portney, Katherine N. Probst, and Adam M. Finkel (1991)	Free