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MARKETS AND BIODIVERSITY

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Abstract

I review the nature of biodiversity as an economic commodity, and discuss the extent to which and mechanisms via which markets can be used to conserve biodiversity.

1 Markets for Biodiversity

Biodiversity is being destroyed at a rate which is paralleled only by the rates of destruction in historical episodes such as the extinction of the dinosaurs. Today, however, the driving forces are mainly human economic and social organizations. In particular, markets, and the incentives which they generate, are playing a central role. This observation leads one naturally to question whether there is a basic antipathy between market forces and biodiversity. Can markets in fact capture the social value which resides in biodiversity? Do they provide incentives to maintain and develop this value? Or do we need different forms of economic and social organization to maintain the earth's biological resources intact? In this paper I present a preliminary review of these issues, trying to classify biodiversity as an economic commodity, understand how it fits into the economic system and assess the actual and potential adequacy of market economic systems as institutions for managing the resources of biodiversity.

The earth's biodiversity is a characteristic of its biological resources: by biological resources I mean its total resources of naturally-occurring living entities, such as plants, animals, fish, insects, birds, bacteria, etc.. Biodiversity is a measure of the genetic variance contained within these biological resources: it increase with the number of distinct species. Many populations have critical masses or thresholds: their growth functions are such that once the population falls below a critical number the species is doomed to extinction. So biodiversity is not related simply to the total quantity of biological resources, but to the distribution of these relative to the threshold levels of the populations of the species represented. If all species are well above these levels, an increase in biological resources does nothing for biodiversity. On the other hand, if some are at or near these threshold levels, an increase in biological resources focused on these populations will increase or maintain biodiversity. I make this point so that it is clear that more forests, or more cod, or more tigers, are not per se beneficial to biodiversity: this depends on populations relative to thresholds.

The issue, then, is whether markets help or hinder the preservation of biodiversity. Certain cases come to mind immediately in which markets do in a limited sense place an economic value on biodiversity. Examples of these include

- ecotourism, and in general tourism based on environmental assets such as coral reefs, unspoiled scenery, unique environments, etc.
- biological prospecting - InBio, Shaman Pharmaceuticals, and other attempts to exploit traditional knowledge of the medical properties of plants and insects.
- fisheries and forestry.

Each of these is an example of a market in which one trades goods or services produced from biodiversity. But do these markets provide adequate incentives for the preservation of biodiversity? Do the incentives that they provide cover all important aspects of biodiversity?

The answers to these questions are probably "no" and "no". Nevertheless, markets do provide some incentive to preserve biodiversity, and more intelligent use of market forces can surely be of value in the quest for conservation.

In order to understand the potential and the limitations of market forces in the area of biodiversity, we need to understand two sets of issues. What is the value which resides in biodiversity? And how do these sources of value fit within the general framework of resource-allocation theory? A general review of the relevant aspects of economic theory can be found in Dasgupta and Heal [13] and references there.

2 The Value of Biodiversity

There are (at least) four ways in which biodiversity is a source of value.

1. It may be valuable as sources of knowledge: this is the source which is tapped in biological prospecting and in the famous Merck-InBio deal.[1]

2. Biodiversity may have value in life-support systems: green plants produce oxygen, bacteria clean water and fertilize soil. All of these activities are crucial in the maintenance of human life.

3. Biodiversity such as animals, plants, and even landscapes, may have an intrinsic value, a value in and of themselves independently of their anthropocentric value, and similarly they may have a right to exist independently of their value to humanity.[2]

4. Biodiversity may have cultural and aesthetic values. For example, in certain societies animals or plants have great symbolic value, as with elephants and Hinduism, the bald eagle for the United States and the lily for France. They are part of the cultural identity and heritage. The existence of significant aesthetic value for certain types of biodiversity is clear, even though hard to quantify.

Items 1 and 2 are instrumental values—they may vanish in the unlikely event that find synthetic substitutes for natural resources in these roles. They value the environment as a means rather than as an end. Item 3 differs in that it recognizes an intrinsic, non-instrumental value in biodiversity.[3]

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[1] For details of this and similar deals, see Chichilnisky [6].

[2] A discussion of some of these philosophical issues can be found in Kneese and Schultze [19]. A fascinating recent paper by Ng is also recommended [21].

[3] Explicit recognition of the intrinsic value seems to me an essential element of the concept of sustainability. Formally, this means that utility is derived not just from a flow of consumption that can be produced from the environment, used either as a consumption good or as an input to production, but also from the existence of a stock, so that instantaneous utility at each point in

Some of these sources of value can in principle be quantified. For example, consider the role played by bacteria in a watershed area in purifying water which is collected in a reservoir. Adequate bacteial action may obviate the need for chemical water purification: if the bacteria are destroyed, for example via pesticides running into the soil, then this action is lost and chemical purification plants are needed. For a large city these could involve capital costs several billion dollars and then significant running costs (see Chichilnisky and Heal [10] for details). In such cases, looking at the provision which would have to be made in the absence of certain species can provide a way of valuing the actions of the species. However, there are certainly dimensions of the value of biodiversity which are unquantifiable, such as the intrinsic, aesthetic and cultural values.

3 Efficient Allocation and Biodiversity

Four economic issues are central to an understanding of the extent to which market forces can realize the value of biodiversity. These are property rights, public goods,[4] time horizons, and uncertainty and irreversibility. Each of these represents a dimension of resource-allocation problems in which the unaided market is weak, and which is also central to the management of biodiversity. In fact, biodiversity as an economic commodity strikes directly at the market's weakest links. Strengthening these adequately is not impossible, but is a major challenge for the design of economic institutions.

3.1 Property Rights

One can only buy or sell goods for which property rights are well-defined, i.e., goods that the seller truly owns and has the right to transfer to others. This is the domain of law and economics, and is an issue that is discussed extensively by other contributors to this volume. The problem is, of course, that many biological resources are not owned in the conventional sense, so that they are not readily tradeable. Even when the biological resources are owned, their diversity is not a tradeable commodity. Their owner cannot therefore appropriate their market value, assuming that the market would in principle give them a significant value.

This is a common problem with many natural resources, which are often "fugacious", i.e., prone to move around. The "Conally Hot Oil Act", a landmark piece of U.S. legislation in the establishment of property rights in oil, was intended to establish property rights in oil reserves that could move from one property to another.

time can be expressed as a function $u(c_t, s_t)$ where c_t is a flow of consumption at time t and s_t an environmental stock at that date, as for example in Krautkraemer [20] and in Beltratti Chichilnisky and Heal [3].

[4] A note for the cognoscenti: one might expect externalities to be included in this list. But public goods are a particular form of externalities, which are implicitly included in this category.

So there are precedents for the successful establishment of property rights under apparently unpromising conditions. The papers of Professors Chichilnisky and Stone in this volume develop this point further.

3.2 Public Goods

Biodiversity is a *public good*, that is, a good with the property that if it is provided for one, then it is provided for all. Classic examples of public goods are law and order and defense. A basic proposition of welfare economics is that market economies will if left to themselves under-provide public goods relative to an efficient level: markets work best for private goods (food, housing, consumer durables), not public goods. They work for the private good bread, but not for the public good genetic variation in wheat types: they work for the private good beef, but not for the public good genetic variation in cattle types.

In fact, biodiversity is an interesting and special example of a public good: most public goods are centrally provided, as the adjective in their title and the previous examples indicate. Biodiversity however is different. Our initial stocks of biodiversity, like initial stocks of extractive resources such as oil and coal, are part of the initial conditions of life on earth. We can only subtract from them. We can provide less biodiversity, but we cannot provide more. There is a ratchet effect here, an irreversibility: I shall return to this, as it mandates a particularly great degree of caution. The process of subtraction from our initial stocks of biodiversity, which sets the amount which we have, is not the result of any central decisions, as is the provision of the classic examples of public goods such as defense and law and order. The total biodiversity remaining in the world is the result of millions of independent and decentralized decisions on what to grow, where to grow it, how to grow it, what land to clear, what fuels to burn, etc. Biodiversity is therefore a privately provided public good. Atmospheric composition, and hence climate, is also a privately provided public good (see Chichilnisky and Heal [8] and Chichilnisky Heal and Starrett [11]): it also results from millions of independent decisions on how much fossil fuel to burn. This is a category of goods to which economists have not given much attention. Here we have a field in which environmental issues are forcing economists to sharpen their tools.

3.2.1 Depletion Permits

One of the most attractive economic mechanisms for managing the use of the atmosphere, seen as a privately-produced public good, is the use of "tradeable emission permits". A tradeable emission permit regime is one in which a total acceptable level of emissions is set by a regulatory authority, which then issues a number of permits to emit which can be traded by their owners (for more details, see Chichilnisky and Heal [11]): by analogy, one can envisage "tradeable depletion permits" as a way of managing the use of biodiversity. In fact, to the extent that tradeable emission permits can be earned by the preservation or development of CO_2 sinks such as forests, the two will automatically be related.

Recent work ([8], [11]) suggests that the efficient operation of these markets is particularly sensitive to the distribution of property rights. This is in contrast to the standard results in the welfare economics of competitive markets for private goods, which assert the "orthogonality" of efficiency and distribution. Two key results on the welfare properties of competitive markets for private goods are the first and second theorems of welfare economics, which state respectively that any equilibrium of a competitive market is efficient,[5] and that given any efficient pattern of resource allocation, this can be achieved as the equilibrium of competitive markets for private goods given some suitable distribution of property rights among the people in the economy. In other words, the mapping from distributions of property rights to equilibria is onto efficient patterns of resource allocation. This sensitivity of efficiency to distribution is also in contrast to the so-called Coase Theorem, which asserts that assigning property rights where there initially were none will lead to efficiency independently of to whom the rights are assigned.

The relationship between efficiency and distribution which emerges in the work of Chichilnisky Heal and Starrett (CHS) in the context of permits to emit CO_2 is as follows. Suppose that a regulatory body has decided that it is appropriate for the world as a whole to emit six billion tons, and that this emission will be shared between one hundred countries. It then has to decide how to allot the rights to the six billions tons of emission between the one hundred countries. Several such schemes have been suggested, covering a spectrum which runs from allocation proportional to historical emissions to allocation proportional to population. Clearly the former favors the industrial countries and the latter the developing. The conventional wisdom in economics, based on the first and second welfare theorems outlined above, has always been that from the perspective of attaining efficiency it does not matter what allocation rule is chosen—proportional to pre-existing emissions, to population, or any other rule. The basic result in CHS is that this is not true: that in fact only a small number of ways of allocating the emission rights between countries will lead to efficient outcomes. There is a presumption that these are ways which in some loose sense favor the developing countries.

How does this relate to preservation of biodiversity? There has been no systematic analysis of this issue yet, so that what follows is a very preliminary set of conjectures. It abstracts altogether from the international political agreement which would be needed to implement it. Suppose for the sale of argument that we wish to preserve precisely the existing level of biodiversity: this is of course not obvious, and has to be

[5] The concept of efficiency is Pareto efficiency. A pattern of resource allocation is Pareto efficient is there is no other feasible allocation at which everyone is no worse off and someone is better off. The first and second theorems of welfare economics make certain assumptions in addition to the absence of public goods: see Dasgupta and Heal [13].

justified by reference to the total social costs and benefits of such a decision. Given this target, we next ascertain the relationships between populations and minimum thresholds needed for survival, and categorize populations by their relationships to these thresholds—very much as is done in determining which species are endangered. In fact, what has to be done at this stage is to forecast the relationship between population and threshold that will emerge over the near future, perhaps one or two decades, in the absence of corrective intervention, i.e., on the basis of what is normally called the "business as usual" scenario. So far, then, there is nothing new.

Next we take the species for which there is a danger of population approaching the threshold, and decide on acceptable reductions in these populations. These reductions will be the total "depletion quotas" for these populations. In fact, for certain fisheries this is already standard practice: this is exactly the method used in deciding acceptable catches for each year. Finally, the "depletion quotas" set in this way are allocated amongst possible users, who may trade them in an open market. The depletion quotas set in this way could be for forest clearing, for planting grasslands, or for harvesting species of animals or fish. As discussed above in connection with the results of CHS, the distribution of these quotas would have implications for efficiency. The key aspect of such a tradeable depletion scheme, from an economic perspective, would be the establishment of a clear economic incentive *not* to deplete: it may seem paradoxical that giving tradeable rights to deplete gives an incentive not to deplete, but the point is that unused depletion rights, resulting from a country depleting less than its allocation, have a market value and can be sold for hard currency on world markets. This is precisely how quotas for gaseous emissions operate: they establish a cost to emission, because if not used they can be sold. There are many practical details that would have to be resolved prior to the introduction of such a scheme: equivalent details for CO_2 emissions are reviewed in Chichilnisky and Heal [9]. One of these details would be the relationship between depletion quotas and CO_2 emission quotas, given that the emission of CO_2 may in the long run be one of the main threats to biodiversity.

3.3 Valuing the Very Long Run: Biodiversity and Sustainability

Biodiversity matters most in the very long run, i.e., over fifty to one hundred years at least. By this, I mean that the costs of a loss of biodiversity would be felt in full only over a period of at least this length. Most economic evaluation procedures are intrinsically biased against investments which payoff only over a long period: this is a consequence of our habit of ranking projects according to their present discounted value. Discounting at any positive discount rate (i.e., weighting benefits in a way which decreases with their futurity) discriminates against future-oriented projects, but is nevertheless absolutely standard practice. Conventional economic criteria make it almost impossible to justify any investment in preventing climate change, preserving biodiversity, preventing leakage of nuclear waste, etc., as all of these have time horizons which stretch over a hundred years or more. The key point here is that even if we could value biodiversity accurately, then to the extent that its value is realized more than a quarter of a century hence,[6] conventional approaches will undervalue it systematically.

Many authors have expressed reservations about the balance that discounting strikes between present and future. Cline [12] and Broome [4] have argued for the use of a zero discount rate in the context of global warming, and Ramsey and Harrod were scathing about the ethical dimensions of discounting in a more general context, commenting respectively that discounting *"is ethically indefensible and arises merely from the weakness of the imagination"* and that it is a *"polite expression for rapacity and the conquest of reason by passion"* (see Ramsey [22], Harrod [18] and Heal[7] [15]). It may be fair to say that discounted utilitarianism dominates our approach more for lack of convincing alternatives than because of the conviction that it inspires. It has proven particularly controversial with non-economists concerned with environmental valuations.

Alternatives are being developed: an interesting approach far more consistent with an appreciation of the value of biodiversity is that of Chichilnisky [5], who formalizes the concept of "sustainable growth" in economically operational terms. I suggest in [17] [16] that the essence of sustainability lies in two axioms:

- a symmetric treatment of the present and of the long-term future, which places a positive value on the very long run, together with
- explicit recognition of the intrinsic value of environmental assets.

The first of these points is captured in a definition of sustainability proposed by Chichilnisky [5]. The second point relates to the way in which we value environmental assets: in their own right, rather than instrumentally, for their capacity to provide services to humanity.

In fact, the proper economic valuation of biodiversity is inseparable from a proper development of the concept of sustainable economic development. To me, a test of the appropriateness of an economic approach to sustainability is the extent to which it enables one to argue satisfactorily about the value of biodiversity. Chichilnisky's ideas are developed further in Heal [16] and Beltratti Chichilnisky and Heal [2] and [3]. The key point is that it is possible to make operational a concept of valuation that systematically places more importance on the very long-run than does discounting: Chichilnisky's approach does this by valuing an income stream as the present discounted value of that stream, *plus* an amount that depends on the very long run

[6] This is surely a great extent.

[7] Heal [15] has argued that a zero consumption discount rate can be consistent with a positive utility discount rate in the context of environmental projects.

characteristics of the stream. These very long run characteristics, almost by definition, contribute nothing to the present discounted value of the stream of benefits. In effect an pattern of payoffs wins additional points for continuing *ad infinitum*: if one compares two investments which have the same present value of payoffs according to the conventional approach, with one having a finite life and the other having a payoff that continues indefinitely, then according to Chichilnisky's criterion the latter would be more valuable. Clearly such an approach reorients the economic playing field in field in a way more favorable to biodiversity. So developing a "sustainable" approach to cost benefit analysis is a necessary prerequisite to realizing the value of biodiversity. A corollary of success in this area would be a revised, "green", approach to the construction of national income accounts.[8]

3.4 Value Uncertainty and Option Values

There is great uncertainty about the exact value of certain types of biodiversity. This means that the concept of *option value* is relevant (for a more detailed development, see Chichilnisky and Heal [7] and Beltratti Chichilnisky and Heal [1]). The issue here is as follows: if you preserve a resource whose value is uncertain, then you may be able in the future to get better information about its value and so make a better-informed decision about its long-run disposition. If the information you get then suggests that its value is low, at that point you of course still have the option of destroying it. But if the information obtained in the future indicates that the resource is of great value, permanent preservation is still a policy option then. Preservation now gives you the right, but not the obligation, to keep the resource should this seems appropriate when better information is available in the future. If however you destroy the resource now, and then in the future find it to be valuable, you no longer have the option of preserving it, however worthwhile that may then seem. Hartwick [14] gives an interesting application of related ideas to biodiversity.

This fundamental asymmetry between destroying and preserving gives rise to what is called an option value, a value which is related to the value of a financial option: a financial option gives you the right, but not the obligation, to buy or sell a security. There is a large literature in finance on how to value options, and a literature in accounting on how to account for them. A key point is that failing to recognize the option value in valuing irreplaceable assets, of which biodiversity is surely the prime example, will systematically lead to their being undervalued and hence under-preserved. It is not at all clear that markets do in fact recognize this option value in the case of biodiversity. The reason is one that we have touched on before: no one firm or individual owns or can appropriate the benefits from this option. It is society's option, a public good. The social value of this option must in principle be added as a benefit in any analysis of the costs and benefits of biodiversity preservation, although this value is hard to compute unless all of the previous problems are resolved.

[8] These issues are discussed at length in Heal [16].

4 Conclusion

Can we rely on the market to preserve biodiversity? The overall answer is clearly no: there are too many aspects of biodiversity that strike precisely at the weak points of the market. These relate to the public good aspects of biodiversity, to the time horizon one needs to appreciate the value of biodiversity, and to the uncertainties associated with its importance. Understanding how it is that biodiversity defeats the market's efforts to attain efficiency is a necessary first step in deciding how to alter the usual market approaches to deal better with biodiversity. Possible directions of such modifications have been indicated. But if we ask a more limited question—can we use to market to provide some incentives for the preservation of biodiversity—the answer is certainly positive. There are aspects of biodiversity that are marketable and are being marketed (see Chichilnisky and Heal [10]). We should encourage these. But they leave a lot out. For the time being at least we have to recognize biodiversity as a socially valuable resource whose value cannot even approximately be quantified, and which therefore cannot be managed entirely by the market. Note that although we cannot quantify the value of biodiversity, we can probably calculate a lower bound on its value, and this may be high enough to have a major impact on policy choices. We will have to invoke non-market measures such as the endangered species act or the CITES agreement on trade in endangered species. However, markets may come to play a more substantial role than they can at present via the development of more understanding of the socio-economic role of biodiversity, the economics of privately produced public goods, and of a framework for sustainable cost benefit analysis (again see [10]). But we will never rely fully on the market to manage biodiversity: intrinsic, aesthetic and cultural values in other areas of society have always been protected by legislation, and that will continue to be true of the area of biodiversity. Only the balance between market and legal solutions may change, not the need for the two.

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