BUNDLING BIODIVERSITY

Geoffrey Heal
Columbia Business School

Abstract
Biodiversity provides essential services to human societies. Many of these services are provided as public goods, so that they will typically be underprovided both by market mechanisms (because of the impossibility of excluding non-payers from using the services) and by government-run systems (because of the free rider problem). I suggest here that in some cases the public goods provided by biodiversity conservation can be bundled with private goods and their value to consumers captured in the price realized by the private goods. This may lead to an efficient level of provision. (JEL: H41, Q2, R41)

1. Introduction

Biodiversity provides many services to human societies. It raises the productivity and resilience of ecosystems, both natural and human-managed, and enhances their capacity to provide services to us. It provides us with insurance against pathogen attacks on the crops that provide essential foodstuffs. And it provides us with knowledge of novel and potentially valuable molecular and genetic structures. The importance of these services is such that biologists doubt that humans could survive the loss of a really major fraction of the world's biodiversity. Myers (1997), Naylor and Ehrlich (1997), and Heal et al. (forthcoming) provide information about the role of biodiversity in preventing pathogen attacks on agriculture. Heal (2000) provides an overview of these issues from an economic perspective, and the volume edited by Daily (1997) gives a good impression of humanity's dependence on a multitude of species. The distinguished biologist E. O. Wilson summarized this by his memorable statement about small invertebrates—bugs in common parlance—"We need them and they don't need us."

From an economic perspective conserving biodiversity provides one very

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E-mail address: gmh1@columbia.edu

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sharp challenge: many of the services provided by biodiversity are public goods. Knowledge, one of the most important goods that come from biodiversity, is the quintessential public good. By raising the productivity and resilience of ecosystems, biodiversity provides a form of infrastructure, a metaphor that is pursued further in Heal (2000). Infrastructure services are usually public goods. As we are well aware, market economies do not normally work well for public goods. The inability of producers to exclude those who do not pay implies that the return to providing public goods is small, and the free rider problem also suggests that even in a nonmarket context governments will have difficulty in providing public goods at an efficient level. So the importance of biodiversity provides a challenge to economists: we need to invent mechanisms for conserving this at an economically efficient level in spite of the fact that it is providing a number of services that are public goods.

In fact the market has already done some of this job for us. There are a number of cases of entrepreneurs bundling private goods with public goods and in the process earning a reward to the provision of the public good, the presence of which increases the willingness of their clients to pay for the private goods that they sell. Ecotourism is an example that is relevant to biodiversity conservation. As I note in more detail later, in southern Africa it has often proven most profitable for ranchers to stop cattle ranching and restore their land to its natural state, with native vegetation and animals, so as to charge tourists for viewing the animals. In restoring the native flora and fauna they are providing a public good, biodiversity conservation, and this good is enhancing the willingness of tourists to pay to visit their land. So they capture some at least of the value of the public good in enhanced willingness to pay for the private good. In general there appear to be many aspects of tourism that are based on the use of public goods to enhance willingness to pay for private goods—beautiful scenery, cultural heritages, unique biodiversity and other generators of tourism all are public goods whose existence generates demand for private goods such as transportation, accommodation, and food. In Heal (2001) I cite some striking examples of housing development that also appear to be relying on the provision of public goods associated with the housing to enhance its value and the willingness of buyers to pay for it. Indeed the whole phenomenon of smart growth can be viewed in this light. All of these are examples of the bundling of public and private goods, and ecotourism is the one that corresponds most closely to the bundling of biodiversity with private goods.

In the balance of this paper, I summarize a formal model of this phenomenon. A profit-maximizing firm provides a private good and also a public good that affects people's willingness to pay for the private good, as in the case of ecotourism cited above. If this firm can price discriminate perfectly, and in some cases even if it cannot, then it will provide the public and private goods at levels that are Pareto efficient. So we identify a case in which the market can solve the problem of allocating public goods efficiently. The next section presents a simple version of the model, and subsequent sections develop this further. The final section considers briefly applications in the area of biodiversity conservation.

2. Monopoly, Price Discrimination, and Bundling Public and Private Goods

Consider a firm that produces a private good for sale to a group of buyers $i \in N$ and also produces a public good that affects the welfare levels of these buyers. h_i is the amount of the private good sold to the i-th buyer and e is the provision of the public good, the same for all buyers. Buyer i has an income level of y_i and a utility function $u_i(y_i, h_i, e)$. The utility function u_i is assumed to be differentiable and strictly concave. Prior to any production occurring, buyers have initial endowments of the various arguments of their utility functions given by (y_{i0}, h_{i0}, e_0).

Suppose that as a result of production the amounts of the private and public goods consumed by i change to $(h_{i0} + \Delta h_i, e_0 + \Delta e)$. Then we define agent *i's willingness to pay* for this change as the value w_i that solves the equation

$$u_i(y_{i0}, h_{i0}, e_0) = u_i(y_{i0} - w_i, h_{i0} + \Delta h_i, e_0 + \Delta e) \tag{1}$$

It is the reduction in income that leaves the agent just as well off after the change as before, a standard definition (Varian 1989).

The producer faces a cost function $c(\Delta h_1, \ldots, \Delta h_N, \Delta e)$ which is denominated in units of income y. The function c is differentiable and strictly convex, showing increasing marginal costs of providing both goods. I assume that the producer is profit-maximizing and is able to price discriminate fully, extracting from each buyer his or her willingness to pay for any combination of public and private goods. The problem facing the developer is therefore to choose Δh_i and Δe so as to maximize profits, given by

$$\max \sum_i w_i - c(\Delta h_1, \ldots, \Delta h_N, \Delta e)$$

subject the constraints given by the definition of willingness to pay in (1). Profits here are the difference between total willingness to pay and total costs. If we simplify and assume that $\partial c/\partial h_i = \partial c/\partial h \; \forall i$, so that the cost of the private good does not depend on the identity of the buyer, then the first-order conditions are

$$\frac{\partial c/\partial e}{\partial c/\partial h} = \sum_i \frac{\partial u_i/\partial e}{\partial u_i/\partial h_i} \tag{2}$$

which are identical to the familiar characterization of the efficient provision of a public good, namely that the marginal rate of transformation should equal the sum of the marginal rates of substitution [for more details see Heal (2001)]. We thus have the following proposition:

PROPOSITION 1: *If utility functions are strictly concave and the cost function strictly convex, then a profit-maximizing producer who provides a private and a public good and can practice first-order price discrimination will provide an economically efficient combination of the public and private goods.*

Even though there is no market for the public good, the fact that its extent affects the willingness to pay for private goods will ensure that it is provided efficiently, as long as this willingness to pay can be captured by those selling the private goods. In a competitive market for the private good this willingness to pay could not be captured by sellers, but would be dissipated by competition and would accrue to the buyers as consumer surplus. Some buyers might therefore be better off under competition but the allocation of resources to the public good would no longer be efficient. And of course a separate market for the public good would not reach an efficient level of provision because of the classical free rider problem.

2.1 A Generalization

The explanation above makes it clear that the phenomenon formalized in Proposition 1 is in fact more general that the context in which it is presented. It depends only on the fact that there is a good for which there is no market. In the absence of this market the producer has the power to improve the consumer's welfare via adjustments to the output mix as well as via the total amount of the private good placed on the market, and can charge for this. Similar results will therefore hold whenever there are unmarketed goods provided by a supplier of private goods who can price discriminate. We can formulate a more general result as follows.

Let the utility function be $u_i(y_i, g_i^m, x, x_i)$ where as before y_i is a measure of income or wealth, g_i^m is a vector of goods provided by a discriminating monopolist, x is a vector of public goods for which there are no markets and x_i is a vector of private goods consumed by agent i for which there are also no markets. As an illustration, components of x_i might be person-specific externalities or endowments of goods for which there is no market. As before we define an initial position $u_i(y_{i0}, g_{i0}^c, g_{i0}^m, x_0, x_{i0})$ and a change from this

$$u_i(y_{i0} - w_i, g_{i0}^m + \Delta g_i^m, x_0 + \Delta x, x_{i0} + \Delta x_i)$$

and define willingness to pay as the value of w_i that satisfies

$$u_i(y_{i0}, g_{i0}^c, g_{i0}^m, x_0, x_{i0}) = u_i(y_{i0} - w_i, g_{i0}^m + \Delta g_i^m, x_0 + \Delta x, x_{i0} + \Delta x_i)$$

Here we are allowing possible changes in all arguments of the utility function: the change in income is of course a proxy for changes in the consumption of other goods. A monopolistic supplier of the goods g_i, x and x_i chooses the variations in these from the initial endowments so as to maximize his profits subject to his revenues being the total of willingness to pay and costs being given by a cost function:

$$\max \sum w_i - c(\Delta x, \Delta x_1 \cdots \Delta x_N, \Delta g_1^m, \ldots, \Delta g_N^m)$$

subject to

$$u_i(y_{i0}, g_{i0}^c, g_{i0}^m, x_0, x_{i0}) = u_i(y_{i0} - w_i, g_{i0}^m + \Delta g_i^m, x_0 + \Delta x, x_{i0} + \Delta x_i)$$

Here we can prove the following:

PROPOSITION 2: *Assume that utility functions are strictly concave and the cost function strictly convex. A profit-maximizing firm has a monopoly over the supply of a set of private goods and also determines the supplies of public goods and non-traded private goods, all of which enter agents' utility functions. If this firm price discriminates, then the resulting allocation of resources will be Pareto efficient.*

3. Discrete Choices

So far we have assumed the scale of the scale of the public good to be a continuous variable. In many cases, including environmental cases, this is not so: a site is either preserved or developed, a species preserved or not, etc. Both conservation and development may have to occur at a minimum viable scale if they are to occur at all, forcing a choice of one or the other. In an example to be discussed below, farmers in southern Africa can either use their land for cattle ranching or for game ranching (populating it with native flora and fauna) but cannot do both. The cattle eat the local vegetation and the local carnivores eat the cattle, so farmers have to choose one or the other. In this discrete choice case all of the above results carry over, and there is an interesting extension to second best cases in which not all willingness to pay can be extracted by the seller.

Assume now that the public good is either provided, P, or not, N, and that there are no other options. Everything else is as in the model of section 2. If the developer chooses P and private goods Δh_i then agent i's willingness to pay is given by

$$u_i(y_{i0}, h_{i0}, e_0) = u_i(y_{i0} - w_i, h_{i0} + \Delta h_i, P),$$

which we denote $w_i(h_i, \Delta h_i, P)$. Otherwise it is $w_i(h_i, \Delta h_i, N)$. The developer maximizes profits by finding the most profitable strategy conditional on choosing P, then doing the same conditional on choosing N, and then choosing the overall maximum. Formally the first stage of the problem is

$$\max_{h_i} \sum_i w_i(h_i, \Delta h_i, P) - c(\Delta h_1, \ldots, \Delta h_N, P) \tag{3}$$

where $c(\Delta h_1, \ldots, \Delta h_N, P)$ is the cost of the vector $\Delta h_1, \ldots, \Delta h_N$ given the decision to provide the public good. Let $\Pi(P)$ be the profit that results from solving this problem and $\Delta h^*(P)$ be a vector giving the maximizing choice of production of the private good. Using the obvious extension of this notation, finding the best strategy conditional on choosing N involves solving

$$\max_{h_i} \sum_i w_i(h_i, \Delta h_i, N) - c(\Delta h_1, \ldots, \Delta h_N, N) \tag{4}$$

and we denote the resulting profits and strategies by $\Pi(N)$ and $\Delta h^*(N)$. Clearly the producer will choose P rather than N if and only if $\Pi(P) \geq \Pi(N)$ and in this case will implement $\Delta h^*(P)$.

We can readily show once again that the socially optimal choice satisfies the same inequalities as the most profitable choice, so that we have an extension of the earlier results: the profit-maximizing private producer who price discriminates fully will choose a level of public good provision that is socially optimal. The discreteness of the choice makes no difference.

4. Global Public Goods

In fact in some ways having discrete choices strengthens the results. We can use the results on provision of public goods involving discrete choices to extend the analysis of earlier sections to a more general class of situations, situations in which the provider of the public good cannot hope to capture all of the population's willingness to pay for this. This could happen for several reasons, the most obvious of which is that the good is valued by people who are not in a position to buy the private good. These are the classic cases of existence value, value attributed to a good by those who will never use it. Biodiversity conservation, to be discussed more below, provides a good illustration: landowners may gain from conserving rare species and charging ecotourists for viewing them, but there will generally be many who value the existence of these species yet are not in a position to view them. Landowners will be unable to tap their willingness to pay. Another possibility is that it is the producer's inability to price discriminate fully that prevents him from appropriating all of the value created by providing the public good. He may have no mechanism for obtaining information on willingness to pay.

Suppose that for either of these reasons, or for others, the producer can appropriate only a fraction $\alpha \in (0, 1)$ of the population's willingness to pay for the bundle of public and private goods. Then using the model and notation above the profits from provision and nonprovision, given previously by (3) and (4), now become respectively max $\alpha \sum_i w_i(h_i, P) - c(\Delta h_1, \ldots, \Delta h_N, P)$ and

$\max \alpha \sum_i w_i(h_i, N) - c(\Delta h_1, \ldots, \Delta h_N, N)$. So the decision to provide turns on the inequality

$$\max \alpha \sum_i w_i(h_i, P) - c(\Delta h_1, \ldots, \Delta h_N, P) \lesseqgtr \max \alpha \sum_i w_i(h_i, N) - c(\Delta h_1, \ldots, \Delta h_N, N)$$

Clearly if

$$\max \sum_i w_i(h_i, P) - \max \sum_i w_i(h_i, N) > c(\Delta h_1, \ldots, \Delta h_N, P) - c(\Delta h_1, \ldots, \Delta h_N, N)$$

so that provision is most profitable when all willingness to pay is captured, and so is socially optimal, then for some $1 > \alpha^*$ it is still true that for $\alpha > \alpha^*$

$$\alpha\left(\max \sum_i w_i(h_i, P) - \max \sum_i w_i(h_i, N)\right) > c(\Delta h_1, \ldots, \Delta h_N, P) - c(\Delta h_1, \ldots, \Delta h_N, N)$$

So in spite of the inability to appropriate the full willingness to pay, the developer's optimal strategy still coincides with the socially optimal choice, provided that a sufficiently large fraction of willingness to pay is captured.

5. Illustrations

Ecotourism provides an important environmental context for this phenomenon. In southern Africa it has often proven most profitable for farmers to stop farming and restore their land to its natural state, with native biodiversity, so as to charge tour managers for bringing tourists to view the animals. The extent to which this has happened has taken many conservationists by surprise, to the extent that about 18 percent of the land area of the southern third of Africa (South Africa, Namibia, Botswana, Zimbabwe, Tanzania, Mozambique, and Angola) is now given over to "game ranching," as this is called. In Zimbabwe the land devoted to conservation has increased ninefold in the last quarter of a century [Heal (2000), Bond (1993), Cumming (1990a, 1990b), Cumming and Bond (1991)]. The impact of this profit-oriented development on conservation has been far-reaching and positive, with the populations of many species rebounding from threatened levels. The game ranchers are providing public goods, the conservation of species, and are "bundling" these with private goods, accommodation, and tour guiding. In many cases they are local monopolists and can probably price discriminate. These cases may be an important illustration of the last version of our results, in that they involve discrete choices between conservation and development and are clearly situations where the continuation of species via habitat conservation is of value to many people who will never visit the sites as paying tourists. Only a fraction of the world's willingness to pay can be appropriated, but this appears to be sufficient to ensure conservation.

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