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COMMENTARY

Is bioprospecting a viable strategy for conserving tropical ecosystems?

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1. Introduction

Many prominent scientists avidly advocate bioprospecting, the systematic search for new commercial applications for biota, especially hitherto unstudied species, as a mechanism for inducing tropical biodiversity conservation by making it commercially attractive (Wilson, 1992; Reid et al., 1993; PAHO, 1996; Weiss and Eisner, 1998). Bioprospecting's premise is that nature contains hidden assets of potentially huge, yet unknown magnitude to humankind that can motivate and even finance biodiversity conservation in the tropics. This undiscovered genetic or biochemical information is commonly framed in the context of potential improvements in medicine or food, thus defining a massive global population of potential beneficiaries. It is further argued that bioprospecting can affect social and economic development in developing countries by rewarding biota-rich but income-poor tropical communities that preserve and wisely manage their genetic resources. The premise of bioprospecting, coupled with the claim that practically all of humankind stands to benefit, and perhaps most especially the poorest of the poor, naturally leads to an urgent desire to conserve tropical biodiversity in order to enable discovery, extraction, and value-adding transformation of tropical biota.

Specifically, it is claimed that bioprospecting stimulates conservation through two mechanisms. First, bioprospecting firms should be willing to pay to preserve biodiversity for its innovation option value since they stand to reap direct financial benefits from any marketable discoveries. Second, conditional on an increase in life sciences firms' willingness to pay for conservation, local inhabitants' and landholders' valuation of biodiversity will change to the extent that they, as stewards over biodiverse habitats, are compensated for their contribution to bioprospecting activities. To date, most attention with respect to

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bioprospecting has focused on the first of these mechanisms and on resolving issues of property rights allocation prerequisite to internalizing the spillover benefits of discovering valuable information in nature. The International Convention on Biological Diversity (CBD) is essentially a progressive Coasian solution to this problem in that it grants to low-income host nations sovereign rights over the genetic resources contained within their borders. The widespread misimpression is that all we need do is obtain the property rights to biota and their derivatives, both in situ and ex situ, effectively creating a market for biodiversity, and the rest will fall into place. The attractive intuition of such arguments is deceptive, however, and we believe the ability of bioprospecting to translate into conservation is less than its advocates claim.

This essay focuses on the likely microeconomic effects of increased demand for tropical biota, and asks the key bottom line question: is bioprospecting a viable strategy for inducing endogenous conservation of tropical ecosystems, especially if conservation must be performed by local residents? In most of the low-income world, asset poverty is a primary, intractable causal factor behind biodiversity loss (Reardon and Vosti, 1995). When the poor depend inordinately on the consumptive use of bioassets (e.g. soils, forests, water, wildlife) to produce the entitlements necessary to ensure their survival from day to day, biodiverse habitats fall under constant pressure. This pressure can have devastating and widespread impacts on tropical ecosystems hosting smallholder agricultural systems. Such areas are of particular relevance to an analysis of bioprospecting as a strategy to improve locals' conservation incentives since they seem to be among the most promising and popular bioprospecting sites.

Biodiversity conservation has fundamental economic drivers. Marginal forest, wet, and desert lands are converted to agricultural, industrial, and residential uses rather than left in their undeveloped state because the cost of conservation is higher than the benefits of conservation for those who control the land. The cost of conservation includes primarily the foregone discounted stream of net benefits associated with development, plus any direct costs of conservation, e.g. patrolling and maintenance. The benefits of conservation may include: (i) environmentally-conditional aid, such as the bioprospecting fees or royalties firms might pay for valuable biota or transfers from governments or NGOs tied to conservation efforts; (ii) net revenues from ecotourism, sustainable harvest or other nonconsumptive activities; (iii) the value of ecosystem services provided in the land's present state; (iv) psychic or spiritual dividends; as well as (v) foregone direct conversion costs (principally time spent clearing land). The value to the land user of a given parcel is often greater when developed. This is especially true when the costs of conservation (equivalently, the benefits of development) are borne directly by the land users while the benefits of conservation (equivalently, the costs of development), accrue more broadly, creating significant externalities. And if the conversion of some habitat shifts the cost/benefit ratio for others — for example, increasing the spatial concentration of fauna that can damage crops or threaten livestock or humans or increasing (decreasing) the agglomeration economies accruing to either development (conservation) — then a domino effect of sequential conversion can too easily result.

The key issue is therefore whether bioprospecting can reasonably be expected to change rural land users' incentives sufficiently to induce conservation of tropical ecosystems of any meaningful magnitude. This can be usefully reduced to two subsidiary questions. First, are firms likely to put a high enough value on bioprospecting so that new rents exist which could, in principle, be used to induce resource conservation? Second, if the necessary rents are indeed created from bioprospecting, are they likely to be distributed in such a way that local inhabitants would themselves voluntarily undertake biological resource conservation? It is posited by bioprospecting advocates that biotechnology and the prospect of discovery of macro- or micro-biota of immense worth offer an avenue to increase the valuation of nature, thereby significantly tipping the benefit-cost scales against habitat conversion and inducing local conservation efforts. Under what conditions might this claim be valid?

2. Firms' ambiguous incentives

Most of the economic literature on bioprospecting has focused on firms' incentives to undertake costly bioprospecting in the face of uncertain benefits. The first such inquiries estimated firms' willingness-to-pay for conservation by multiplying the probability of discovering a commercially valuable lead by the value of the discovery. These estimates range from $44 (Aylward et al., 1993) to $23.7 million per untested species in situ (Principe, 1989). Recognizing flaws in this methodology, Simpson (1999) illustrated that, although the aggregate benefits to biodiversity conservation for the as-yet-unknown genetic information contained in nature may be huge, the bioprospecting firm will consider the value of the marginal species. In the SSR analysis, the firm accounts for the possibility of species with some genetic similarities and adjusts its valuation of biodiversity accordingly by asking the question, 'How will this particular untested species incrementally contribute to our probability of making a profitable discovery?' With this adjustment for redundancy, the expected marginal returns to commercial bioprospecting seem too modest to reasonably expect much activity by profit-minded firms.

In a pair of recent papers Rausser and Small, (1998, 1999) challenge the SSR model by allowing concentration of research effort towards leads showing the highest expected productivity based on prior information on the 'quality' of a given site and positing 'patent races' between bioprospectors. Under such circumstances, firms may be willing to pay a bit more than only the marginal value of an untested species in order to reduce the risk that a competing firm will preempt its innovation efforts by making a prior discovery. Nonetheless, the demand curve for genetic resources still slopes downward; the firms' marginal willingness to pay remains less than its average willingness to pay. So, taken over the range of endangered habitats, the marginal conservation incentives induced by bioprospecting are likely small.

Most estimates of the annual rents associated with exploring the pharmaceutical potential of biological resources in tropical ecosystems range from pennies to up to about US$20 per hectare (SSR; Ruitenbeek 1992; Pearce 1993). Whether rents of this rather small magnitude tip the benefit-cost scales in favor of conservation is a context-specific, empirical question. These research results are corroborated by the facts that (a) the most celebrated bioprospecting contract in the developing world, between Merck Pharmaceutical and Costa Rica's INBio, amounted to only $1.1 million, and (b) such contracts are uncommon as most firms have shown only limited interest in directly paying for conservation.

The above, ex ante analyses focus on firms' *willingness-to-pay* to preserve bioprospecting options. As such, these estimates likely generate upper bounds on any *actual payments* from firms to tropical communities for biodiversity conservation. Furthermore, direct payment for conservation is likely only in those sites containing particularly promising biota that a prospecting firm believes will be lost without some intervention on its part, and which the firm might explore and use with some degree of exclusivity. Recognizing these caveats and the continuing debate on the bioprospecting value of biodiversity, it is unclear how much additional value added can reasonably be expected as a result of firms' desire to preserve bioprospecting options. With the possible exception of a few extraordinary sites, there is no hard empirical or theoretical evidence that bioprospecting adds significant value to tropical ecosystems.

3. The effect on local conservation incentives

The existence of nontrivial added value from bioprospecting is merely a necessary condition to tropical biodiversity conservation. If the rents do not accrue to local land users who ultimately make conservation or conversion decisions, the debate surrounding the size of bioprospecting rents is irrelevant since the key questions ultimately surround the calculus of land and labor use in fragile ecosystems. The distributional effects depend heavily on national policies and institutional arrangements, especially with respect to land tenure. In what follows, we concentrate primarily on local land owners and users. States' legal and police powers almost surely yield greater bargaining power with commercial bioprospectors than local users have. But even if the state is better disposed to extract marginal bioprospecting rents, it still must be able either to transfer these benefits to local users to induce voluntary conservation or to exclude locals successfully from valuable habitats. The spotty-at-best record of the 'fences-and-fines' approach to conservation in the low-income world suggests that low-income states have a hard time achieving effective habitat exclusion. Meanwhile, the history of integrated conservation and development projects (ICDPs) over the past 15 years raises significant questions about states' ability to transfer environmental rents to locals effectively so as to achieve conservation (Brandon and Wells, 1992; Barrett and Arcese, 1995, 1998).

It is important at this juncture to distinguish between two different sorts of resource use: single-shot extraction for subsequent ex situ laboratory production and ongoing in situ extraction. Single-shot extraction is conceptually simpler: valuable biochemical material is discovered, extracted, and then reproduced ex situ. Whether the host receives compensation and the extent of that compensation may depend largely on the national policy framework and institutional arrangements (Reid, 1996). While the CBD explicitly requires the equitable benefit sharing *between* nations (although no enforcement mechanisms exist), and facilitates claims for compensation, it only encourages equitable benefit sharing *within* nations. While a few local benefit sharing mechanisms exist in the case of single-shot extraction (e.g. establishment of funds for local projects, etc.), practical implementation remains challenging and we are unaware of any study that examines the actual distribution of bioprospecting benefits and costs among the inhabitants and landholders who live within or near targeted biodiverse habitats.[1] Yet if these subpopulations are important agents of ecological degradation, the incentives facing them play a crucial role in tropical biodiversity conservation.

Two considerations deserve mention here: prospective (perhaps delayed) income effects of bioprospecting receipts and the time consistency of firms' demand for bioprospecting-induced conservation. In single-shot extraction, once a discovery is made, the option exercised, and the genetic material extracted, the firm's willingness-to-pay almost surely falls. Past payment for conservation will have income effects that may lead to renewed, even increased local consumptive pressure on the resource if the demand for bioprospecting-motivated conservation falls off. Whether the income effects of the transfer favor conservation or increased consumptive use (e.g. by stimulating greater fuelwood or wildlife consumption) is an open, empirical question. Would environmental conservation in Madagascar be appreciably different today had the rosy periwinkle extracts used to design leukemia drugs been appropriately compensated? We suspect not.

The key problem in single-shot extraction is the time inconsistency of bioprospecting as a basis for conservation. The idea of bioprospecting rests on quasi-option value, the informational value associated with maintaining flexibility in the face of temporal uncertainty. Uncertainty surrounding the future commercial value of the genetic material of a natural resource creates an incentive to conserve it (Arrow and Fisher, 1974; Henry, 1974). The permanence of these altered incentives ultimately depends on the expected profitability of continuing to prospect. As uncertainty regarding the habitat is resolved (i.e. as the genetic material of a habitat is screened), the quasi-option value of resource conservation diminishes. Bioprospecting can therefore do little more than buy time to find a more durable solution.

The case of Shaman Pharmaceuticals is instructive. The firm established the Healing Forest Conservancy as a non-profit trust fund to receive and administer royalty payments arising from profitable discoveries. This fund rewarded indigenous peoples, typically in-kind, for their participa-

[1] None of the studies commissioned by the secretariat of the Convention on Biological Diversity (http://www.biodiv.org/chm/techno/gen-res.html # cases) addresses local, intra-community benefit-sharing. The benefit sharing questions have thus far remained issues of distribution between the community in aggregate and outsiders.

tion in drug discovery from tropical ecosystems in an attempt to tip local incentives in favor of conservation. By February 1999, however, Shaman realized it had overestimated the expected returns to 'indigenous knowledge directed' bioprospecting and announced the cessation of its unprofitable pharmaceuticals business. It is unlikely that whatever conservation incentives Shaman may have engendered in its host communities will persist. Bioprospecting for single-shot extraction, the aim of most life sciences multinational firms today, thus can only encourage conservation until discoveries are made, at which point the quasi-option value of biodiversity falls unless the discovery increases the probability firms assign to finding further valuable biochemical material in the habitat.

In the case of ongoing extraction, in situ production yields a stream of revenues in cash or in kind (e.g. as schools, health clinics, technology transfer) and stimulates demand for local labor, both of which are tied to ongoing production and therefore to the maintenance of the biodiverse habitat. But who gets these revenues and who benefits from the additional employment? The distribution of transfer payments at this local level depends on the local governance structures. If the existing literature on the distribution of nonfarm income and transfer payments is any indication, such payments commonly disproportionately benefit local elites, not the poor.[2]

Labor demand likewise tends to be for relatively skilled labor educated folk who can communicate with western businessmen, scientists, and lawyers, either to organize local extraction and/or processing or simply to provide services when outsiders visit. In this way, the process is akin to ecotourism, an overhyped path to biodiversity conservation with sometimes disturbing local distributional consequences (Brandon and Wells, 1992; Barrett and Arcese, 1995). We know of no published, empirical evidence of the benefits of biochemical discoveries filtering down to the poorer segments of host communities. If that conjecture is true, then to a first-order approximation, the opportunity cost of habitat conversion does not change among the poor. Then the pressure to convert habitat remains among the poorer subpopulations in communities in or surrounding biodiverse areas. If the poor are among the principal agents (as well as victims) of tropical ecological degradation (Barrett, 1996), bioprospecting then fails to alter the incentives of those whose behaviors most need to be changed.

Of course, instead of tinkering with the incentives to local inhabitants, marginal populations can simply be forced off protected lands in order to preserve the innovation option value of biodiversity. This route is commonly taken, if often only implicitly. Property rights originate in creation, discovery, improvement, purchase, or conquest.[3] The redefinition of indigenous property rights to suit western models of private, transferable rights too commonly involves, de facto, the creation of property rights by conquest. The gazetting of state-owned protected areas for conservation or of concessions for sale or lease to companies for biological or geological mining, and even the clear definition of previously fuzzy rights commonly extinguishes rights (in particular, state-contingent options) held by the relatively powerless. Moreover, since tenurial regimes typically respond endogenously to changing incentives, bioprospecting windfalls may well induce redistribution of resource rights, which rarely occur in a distributionally progressive manner (Platteau, 1996). When trees become more valuable, the powerful tend to find ways to crowd the poor out of the forest. So induced tenurial evolution to seize prospective bioprospecting rents is likely to entail some direct cost to the poor, forcing tangible tradeoffs between poverty and environmental goals in the short-to-medium run.

Even when not forced off the land, however, the poor can suffer from a bioprospecting-based

[2] Moreover, transfer volumes are an issue. The first case we can identify of commercial payment to an indigenous community for a commercial product based on bioprospecting results occurred in March 1999, for only $21 000 (Bagla, 1999). Without a substantial increase in the sums involved, it is hard to imagine individuals in poor rural communities receiving transfers sufficient to induce them to desist from consumptive use of proximate habitats.

[3] We are indebted to Norman Uphoff for this useful taxonomy.

boom in the extraction of genetic or biochemical resources. There are three basic mechanisms by which this occurs. First, there is a booming sector (Dutch disease) phenomenon familiar from open economy macroeconomics. By bidding up the price of some factors of production (e.g. transport, skilled labor), the biotech industry gains at the cost of other producers who purchase those same inputs (e.g. traditional healers, local light manufacturing). These subjective valuation differentials and price effects may subsequently result in a significant reallocation of productive resources, causing changes in returns to factor owners. These changes in factor returns and the induced changes in local prices largely determine the distribution of gains and losses from a resource boom (Cassing and Warr, 1985). Second, increased aggregate local income stimulates demand for and thereby the relative price of non-tradable goods and services (e.g. local roots, tubers, coarse grains), which tend to be consumed disproportionately by the poor.

Third, if markets are heterogeneous in information, producer capacity or infrastructure, then price signals are also likely to be heterogeneous and those with access to favored activities often gain at the expense of the asset poor (Carter and Barham, 1996). In this case, even if ongoing extraction creates significant local opportunities, only those with access to technology, credit or land may be able to respond, leading to highly inequitable growth (Barrett and Carter, 1998). For example, in so far as any processing of the extracted biochemical product is done locally, there may be induced technical change in processing that displaces some. As a case in point, the oil extracted from the fruit of Morocco's argan tree has valuable chemical properties that have made it a popular additive to cosmetic moisturizers in Europe. Demand pressure has increased the price of argan oil in Morocco's argan forest and attracted entry by (usually male) outsiders whose access to working capital permits investment in mechanical presses yielding higher volumes of purer oil. Product differentiation has resulted in the argan oil market, with the new entrants reaping substantial profits even as the real price received by traditional producers remains unchanged or falls. Locals are understandably frustrated by this trend.

The basic point is that growth due to bioprospecting windfalls may be exclusionary or even regressive, not fundamentally changing the calculus of habitat conversion for the poor without forcible exclusion of poor consumptive users of biodiverse habitats from their traditional lands. Unless one is prepared to defend regressive intragenerational redistribution in the name of intergenerational equity, such effects should be troubling.

4. Some alternatives

The need to conserve precious biodiversity is clear, especially as we begin to appreciate the magnitude of the spiritual, social and economic services it provides. But bioprospecting is an unpromising base on which to rest the economic rationale for conservation. Rather, in so far as increasing the economic value of biodiverse habitat is central to stemming conversion of marginal lands, then we should emphasize three alternatives.

First, help host communities better understand and value their fundamental dependence on ecosystem services. While recent efforts at valuing ecosystem services are understandably contentious, the indisputable point is that the sums involved are huge (Costanza et al., 1997). Basic science and education are necessary long-term propositions if people are not to take nature for granted. At present, virtually all humans underestimate the opportunity cost of conversion because we undervalue the services ecosystems provide.

Second, we need to emphasize the necessity for wealthy western communities that recognize and value biodiversity in distant lands to pay for its conservation, playing up the aesthetic, cultural, and ethical reasons to value biodiversity conservation. It costs Kenya, for example, approximately 3% of its meager GDP annually to protect habitat for the benefit of humanity (Norton-Griffiths and Southey, 1995). It is unrealistic to expect continued highly regressive financing of global conservation efforts on anything approaching the scale ecologists recommend.

Third, we need to raise the opportunity costs of conversion by increasing the productivity of the poor's labor applied elsewhere. This requires basic public investments in child health, nutrition, and education and in rural institutional and physical infrastructure necessary to induce private agricultural intensification and investment in value-added manufacturing, processing, and distribution in rural towns. The best way to keep the poor from clearing fragile lands is to provide productive opportunities elsewhere (Reardon and Barrett, forthcoming). As labor productivity and wages rise and become more stable, the incentives to draw down bioassets diminish because the opportunity cost of conversion becomes too great. Not only is this good development policy, it's good conservation policy too.

All three of these challenging tasks face considerable political obstacles. But slow progress is being made on all three fronts. We must not relent in tackling these challenges, especially not be drawn off by seductive but economically naive approaches to changing the calculus of ecosystem conversion so as to maintain necessary biodiversity.

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