The Cost-Effectiveness of Conservation Payments

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ABSTRACT. *International donors invest billions of dollars to conserve ecosystems in low-income nations. The most common investments aim to encourage commercial activities, such as ecotourism, that indirectly generate ecosystem protection as a joint product. We demonstrate that paying for ecosystem protection directly can be far more cost-effective. Although direct-payment initiatives have imposing institutional requirements, we argue that all conservation initiatives face similar challenges. Thus conservation practitioners would be well advised to implement the first-best direct-payment approach, rather than a second-best policy option. An empirical example illustrates the spectacular cost savings that can be realized by direct-payment initiatives.* (JEL H21, Q28)

I. INTRODUCTION

Intact ecosystems provide important global services, including the regulation of climate and the protection of biodiversity. Many valuable and biologically diverse ecosystems, including the majority of tropical rainforests, are located in low-income countries. The citizens of low-income countries receive few of the global benefits derived from their ecosystems. With limited resources and myriad pressing social needs, they are not in a position to provide global ecosystem services *gratis*.

To help low-income nations conserve their endangered ecosystems, international conservation and development donors have made substantial investments over the last two decades. Between 1988 and mid-1995, the World Bank committed $1.25 billion in loans, credits, and grants for projects with explicit objectives of conserving biodiversity. This money leveraged an additional half billion dollars (Jana and Cooke 1996, 107). The United States Agency for International Development spent $650 million each year on its environmental portfolio during the early 1990s (USAID 1994). Private foundations have spent millions of dollars per year on international biodiversity conservation (MacArthur 2000). In our analysis below, we examine the cost-effectiveness of different approaches to encouraging ecosystem protection in low-income nations.

Among the more common approaches is assistance to ventures that yield commercial outputs and ecosystem protection as joint products. Examples include ecotourism, biodiversity prospecting, non-timber forest product extraction, and selective logging. These activities typically employ relatively undisturbed ecosystems as inputs. The ecosystems are combined with purchased inputs such as capital and labor to produce a valuable output, such as tourist excursions, novel chemical compounds, fruits, or timber. Interventions to support these activities have been initiated by the World Bank, United Nations Environment Program, the Inter-American Development Bank, the Asian Development Bank, the European Union, the bilateral aid organizations of Canada, Germany, the Netherlands, Norway, Sweden, Switzerland, and the United States, and non-governmental organizations such as the World Wildlife Fund, Conservation International, Cultural Survival, and the International Union for the Conservation of Nature (Wells et al. 1992;

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Brown and Wyckoff-Baird 1994; Conservation International 1994; Cultural Survival 1994; Simpson and Sedjo 1996; Southgate 1998; Honey 1999).

To encourage commercial eco-friendly activities, donor funds are often directed toward increasing the eco-output price or facilitating the acquisition of complementary inputs, such as tourism infrastructure, product marketing, and processing facilities. The assumption underlying such interventions is simple: local agents, faced with cheaper inputs or higher output prices for an eco-friendly activity, will demand a greater area of intact ecosystem, thereby *indirectly* protecting ecosystems and their constituent services. Indirect approaches that motivate conservation by subsidizing related activities have, in the words of one survey of the subject, ''become the predominant approach to most large-scale internationally financed conservation efforts in developing countries'' (CIFOR 1999).

The introduction of new technologies and employment opportunities in rural environments, however, can be a challenge (World Bank 1988). It is thus not surprising that many reviews of conservation interventions report that they have had limited success in achieving their objectives (Wells and Brandon 1992; Ferraro et al. 1997; World Bank 1997; Oates 1999). Approaches based on eco-friendly commercial activities[1] are plagued by their ambiguous impact on conservation incentives, by their complex implementation needs, and by their lack of conformity with the temporal and spatial dimensions of ecosystem conservation objectives (Ferraro et al. 1997; Southgate 1998; Chomitz and Kumari 1998; Simpson 1999; Ferraro 2001).

An alternative approach to encouraging the conservation of endangered natural ecosystems is to pay for conservation performance *directly*. In this approach, domestic and international actors make payments to individuals or groups that protect ecosystems and thereby supply public services of ecological value. The idea of directly contracting with individuals to maintain resources that have global value is not new (e.g., Barbier and Rauscher 1995; Barrett 1995; Simpson and Sedjo 1996; Ferraro 2001). We are not aware, however, of any formal analysis comparing the effectiveness of direct payment interventions to the indirect interventions that have, to date, been more widely adopted in low-income countries. Our intention is to begin to fill this analytical gap.[2]

We use a simple model in which an entrepreneur operates an ecologically benign production process. We focus on two among perhaps many inputs. The first input, which we call ''forest,'' could represent any ecological attribute useful in the generation of an eco-friendly output and identified by conservation agents as requiring greater protection. The second input, ''capital,'' could represent any input or aggregation of other inputs.

Another actor, whom we will refer to as the ''donor,'' wishes to induce greater conservation of forest than the entrepreneur would find profit-maximizing under prevailing market conditions. The donor has two options. First, it can motivate greater conservation *indirectly* by subsidizing either the use of capital or the eco-output price. Alternatively, the donor can make a *direct* payment for every unit of forest protected. A direct payment is equivalent to subsidizing the use of forest in eco-friendly activities. We are implicitly assuming, then, that the entrepreneur's activities *are*, in fact ''eco-friendly.'' If they were not, the conclusion that direct incentives are preferable would be made *a fortiori*.

We consider the costs of inducing conservation in excess of the forest area that would be chosen by a profit-maximizing entrepreneur responding to market prices. The overall cost of conservation can be defined as the

[1] Such projects occur as elements of ''integrated conservation and development projects (ICDPs),'' ''gestion de terroirs'' and ''community-based natural resource management.'' Our sense is that, while different titles are coined over time, the same types of field interventions are instituted under each.

[2] There are a number of contributions to the public finance and environmental economics literatures that consider choices between taxes and/or subsidies and interactions between them; see, e. g., Fullerton and Wolverton 1997; Goulder et al. 1997; Eskeland and Devarajan 1996. We are not aware, however, of any previous work focusing on the cost-effectiveness of alternative subsidies.

payments made by the donor for conservation (whether direct or indirect), less whatever profits arise from the eco-friendly activity. We reach three conclusions. First, the overall cost of conservation is least when direct payments are employed. Second, the donor will find direct payments more cost-effective under what we will argue are "normal" conditions. Third, the preferences of donors and eco-entrepreneurs are opposed: when the donor prefers direct payments, the eco-entrepreneur prefers indirect subsidies. However, the donor could make a transfer to the entrepreneur that would leave the entrepreneur indifferent between approaches. Although some may assert that consideration of transaction costs would reverse our first conclusion, we argue that the first-best policy of direct payments would likely remain optimal in the presence of transaction costs.

A number of economists (Pearce and Moran 1994; Anderson and Leal 1998; Heal 1999) have argued that eco-friendly activities can be profitable in some settings and should be encouraged. We do not disagree with the proposition that activities that are good for both entrepreneurs and the environment are desirable. Nor do we dispute that interventions should be initiated when local people do not preserve as much as outsiders are willing to pay for. When donors perceive the need for more conservation than markets provide, however, they should offer the most cost-effective incentives. This issue has not been adequately addressed. Our intention in writing this article is to engage other economists in an overdue discussion of what policy advice those of our profession ought to be providing to conservation practitioners.

Since one argument against direct incentives might be that they are impractical, we present, in the next section, examples of direct-payment conservation approaches in both high- and low-income countries. In Sections 2 and 3, we introduce the model and we demonstrate that a direct payment approach is the least-overall-cost conservation strategy. In Section 4, we derive the conditions under which the donor prefers the direct approach. In Section 5, we demonstrate that the incentives of the outside donor and the local agent are opposed. In Section 6, we provide an empirical example demonstrating the relative cost-effectiveness of direct as opposed to indirect interventions. In the final two sections, we discuss our results and conclude.

II. DIRECT PAYMENT INITIATIVES

Paying individuals or groups for supplying goods and services of ecological value is not merely a speculative proposal. There are a variety of such programs already in existence (Ferraro 2001). The best-known conservation payment initiatives are the agricultural land diversion programs of high-income nations. In Europe, fourteen nations spent an estimated $11 billion between 1993 and 1997 to divert over 20 million hectares into long-term set-aside and forestry contracts (OECD 1997). In the United States, the Conservation Reserve Program (CRP) spends about $1.5 billion annually to contract for 12–15 million hectares.

Local and state governments and non-governmental organizations (NGOs) are also actively involved in direct approaches to ecosystem conservation. For example, local and state governments in the U.S., Costa Rica, and Brazil give property tax breaks to landowners who manage their land for conservation. In North America, the Delta Waterfowl Foundation's "adopt-a-pothole" program pays prairie farmers who protect nesting areas for ducks (Delta Waterfowl Foundation 2000). Another NGO, Defenders of Wildlife, has a program that rewards U.S. landowners for occupied wolf dens on their property (Cecil 1997). The Nature Conservancy pays landowners an annual annuity in return for the rights to log the forest in ways that are compatible with the protection of terrestrial and aquatic biodiversity (Gilges 1999).

Although rare outside of high-income countries, direct payment systems can also be found in the tropics. In Guatemala, the Forestry Incentives Program (PINFOR) delivers direct payments to forest stewards who manage forests for conservation goals (World Bank 2000). In the last four years, Costa Ricans have created institutional mechanisms through which local, national, and international beneficiaries of ecosystem services compensate those who protect ecosystems

(Castro et al. 1998; Calvo and Navarrete 1999). Similar programs are underway in El Salvador, Colombia, Honduras, and Panama (Stefano Pagiola, World Bank, per. comm. 2000). In the remainder of the paper we look at the reasons for which direct-payment conservation programs may be superior to the indirect-payment conservation interventions more commonly encountered in the low-income nations.

III. THE MODEL

We compare direct- and indirect-conservation interventions in a simple, yet general, model. An ''eco-entrepreneur'' produces a quantity Q of an ''eco-friendly'' product using a production technology, $f(K, F)$. The production technology represents an economic activity (e.g., tourism) that allows ecosystem services (e.g., biodiversity) to flow relatively unimpeded from the ecosystem used in eco-production. We will refer to F as forest, but it can be any ecosystem that the entrepreneur uses in her eco-production activities. We will refer to K as capital, but it might be more broadly interpreted as any input or aggregate of other inputs. The model is easily generalized to consider multiple inputs and quality-adjusted quantities of output.

Examples of eco-friendly activities include eco-tourism and bioprospecting (the search among diverse natural organisms for commercial products of industrial, agricultural, or pharmaceutical value).[3] The prices of output, capital, and forest, are p_Q, p_K, and p_F, respectively. The price of forest, p_F, can be viewed as the opportunity cost of using forest in eco-production instead of, for example, agriculture.

We assume that the eco-entrepreneur behaves as a profit maximizer with competitive conjectures in both input and output markets. Our results also obtain under the weaker, but empirically plausible, assumption that the eco-entrepreneur is able to price discriminate in the purchase of forest. We assume that output would be positive in the absence of outside interventions. If offering capital or output subsidies to an existing eco-enterprise is a questionable conservation policy, offering these subsidies when there is little evidence of the enterprise's viability seems more questionable yet.

It is more convenient to work with a profit function as opposed to a production function approach.[4] We will define the eco-entrepreneur's profit function in the usual fashion,

$$\pi(p_Q, p_K, p_F) = \max_{K,F} \{p_Q f(K, F) - p_K K - p_F F\} \quad [1]$$

It will be useful to exploit the derivative properties of the profit function as summarized in Hotelling's Lemma. We will express derivatives of the form $\partial\pi/\partial p_J = \pi_J$. Thus,

$$Q = \pi_Q, \quad [2a]$$

$$K = -\pi_K, \quad [2b]$$

and

$$F = -\pi_F, \quad [2c]$$

where [2a] represents output supply and [2b] and [2c] are input demands.

In the interest of giving the benefit of the doubt to the indirect strategies, we will make two additional assumptions. First, we will suppose

$$\frac{\partial F}{\partial p_K} < 0. \quad [3]$$

In other words, we will assume that what we call ''complementary capital'' is, in fact, a technical complement to forest in eco-friendly production. It is worth noting that this assumption, which motivates many initiatives observed in practice, is not always valid. If it were not, subsidizing non-forest inputs would be counterproductive as a con-

[3] The model could be extended to the harvest of non-timber forest products or timber, but doing so would require the incorporation of additional variables representing ''natural capital'' comprised of stocks of timber or nontimber forest products. This would complicate what is intended to be a relatively simple and straightforward exposition without changing its general results.

[4] Results derived working from the production function (primal problem) are, of course, identical, but the derivations require more equations.

servation strategy, and our results would hold *a fortiori*.

Second, and contrary to some examples (Peters 1994; Honey 1999), we will suppose that what is purported to be ''eco-production'' is, in fact, eco-friendly.[5] We suppose, then, that a unit of forest in eco-production provides the same quantity and quality of environmental services as a unit of strictly protected forest.

In the absence of outside intervention, the eco-entrepreneur uses, and thus protects, forest for eco-production. However, an outside agent, the ''donor,'' also receives benefits from intact forest and wishes to induce a greater area of locally protected forest than the entrepreneur would achieve under prevailing private incentives. We use a static analytical approach because we believe that the results from a dynamic analysis are more complicated without being more informative. The context for our analysis is best viewed as a situation in which an eco-entrepreneur stands on the edge of a forest frontier with a fixed stock of forest in front of her. The eco-entrepreneur must decide how much forest to allocate to eco-production, given that the cost of using forest in eco-production is p_F. Ecosystem conversion typically happens in such frontier environments, and thus the way in which we frame the analysis captures the important features of the habitat conservation problem. Using standard methods of comparative statics, we then compare equilibrium levels of forest allocated to eco-production under different donor interventions.

In our analysis, the donor has two options: an *indirect* intervention or a *direct* intervention. An indirect intervention renders eco-production more profitable by subsidizing the eco-output price or the acquisition of complementary capital. Indirect subsidies induce the eco-entrepreneur to use more forest in eco-production, thereby protecting a greater area of forest.

A direct intervention refers to performance payments made by the donor for forest protection. A direct payment for intact forest is equivalent to subsidizing the use of forest in eco-friendly activities (i.e., by making a payment for forest protection, the donor makes it less expensive for the local agent to allocate forest to eco-production). The payments may be periodic or one-off. We have chosen the term ''direct'' inasmuch as the essence of our argument is that ''You get what you pay for.'' Our results below suggest that if the donor wants to achieve forest preservation, the most effective way to do so is to pay for the preservation of forest *per se*, rather than for something else that is only indirectly related.

IV. THE COST OF CONSERVATION

Let us first consider the overall costs of conservation. In order to compare the costs of direct and indirect interventions, we proceed in the following manner. We compare the costs of forest and capital subsidies that generate the *same* increase in forest protected (and hence, under our assumptions, used in eco-production). We demonstrate that for a given increase in forest area protected, the indirect intervention induces higher capital use than does the direct. The eco-entrepreneur employs subsidized capital beyond the level at which the value of its marginal product equals its market price (recall that the amount of forest protected under both interventions is the same by construction).[6] Thus, the overall cost of the indirect intervention is greater. As we demonstrate in the empirical example of Section 6, the cost differences between direct and indirect approaches can be dramatic.

We assume that the capital subsidy, $dp_K < 0$, and the forest subsidy, $dp_F < 0$, are small and we evaluate the local impacts of subsid-

[5] A debate rages in the conservation literature as to what, precisely, is entitled to be designated as ''ecotourism,'' or more generally, ''sustainable use.'' We infer from this that many of the activities in which entrepreneurs might choose to engage in natural ecosystems would not, in fact, be consistent with the unspoiled preservation of such systems. We are then, for the sake of argument, taking a rosier view of the assertion that indirect incentives can be effective in promoting conservation than the facts may support.

[6] The lower capital use of the direct payment approach is also desirable if one considers that even ''eco-friendly'' activities may result in some degradation of ecosystem quality, and such degradation is often positively correlated with the employment of capital and other inputs (e.g., more hotel rooms shelter more tourists who increase the impact on a park).

ies on the production decisions of the eco-entrepreneur. Let dK^I be the change in capital use under the indirect intervention, and dK^D be the change in capital use under the direct intervention. From expression [2b], we know

$$K = \pi_K.$$

Taking derivatives,

$$dK^I = -\pi_{KK}\, dp_K \quad [4]$$

and

$$dK^D = -\pi_{KF} dp_F. \quad [5]$$

We choose dp_F and dp_K such that they both induce a one-unit increase in forest protected:

$$1 = \frac{\partial F}{\partial p_F} dp_F = -\pi_{FF} dp_F = -\pi_{FK} dp_K = \frac{\partial F}{\partial p_K} dp_K, \quad [6]$$

or

$$\frac{-1}{\pi_{FF}} = dp_F, \quad [6a]$$

and

$$\frac{-1}{\pi_{FK}} = dp_K. \quad [6b]$$

Combining the results of expressions [4] and [6b], we obtain

$$dK^I = \frac{\pi_{KK}}{\pi_{FK}}. \quad [7]$$

Combining the results of expressions [5] and [6a], we obtain

$$dK^D = \frac{\pi_{KF}}{\pi_{FF}}. \quad [8]$$

Thus,

$$dK^I - dK^D = \frac{\pi_{KK}}{\pi_{KF}} - \frac{\pi_{KF}}{\pi_{FF}} = \frac{\pi_{KK}\pi_{FF} - (\pi_{KF})^2}{\pi_{KF}\pi_{FF}}. \quad [9]$$

Convexity of the profit function in prices and the assumed complementarity between capital and forest imply that both the numerator and denominator are positive. The intuition for the higher overall costs of the indirect approach is straightforward. The direct subsidy on forest purchase achieves a one unit increase in forest protection with the least overall distortion. When some positive incremental change in forest protected is desired, it can be most efficiently accomplished by applying a subsidy to the good from which the externality arises, as opposed to another good which is only indirectly related. We demonstrate in the appendix that the incremental cost of using the indirect approach rather than the direct approach is approximately

$$-\frac{dp_K}{2}(dK^I - dK^D).$$

The analysis of an indirect *output* subsidy (i.e., $dp_Q > 0$) is analogous. The overall costs of the output subsidy are higher than the costs of the direct forest subsidy. It can also be shown using the same analytical methods that using a mix of indirect and direct subsidies is never more cost-effective than using the direct subsidy alone.

One aspect of our results calls for further comment. We have assumed that the profit function is *strictly* convex in prices, which implies that the production function underlying it exhibits decreasing returns to scale. Constant returns to scale are often assumed on the argument that production processes are replicable. Eco-friendly production processes are unlikely to be replicable. First, many eco-friendly production processes are centered on unusual and unique features; consider, for example, an ecotourism destination such as Canaima National Park in Venezuela, whose principal attraction is Angel Falls, the world's highest waterfall (Terborgh 1999). Second, surviving areas of natural habitat are, almost by definition, found in landscapes that are not served by dense road networks. The replication of production processes would involve the replication of transportation opportunities. Improved rural transportation networks, however, have consistently been identified as playing an important role in ecosystem degradation and loss (Kaimowitz and Angelsen 1998).

V. SUBSIDIES AND THE DONOR'S INCENTIVES

Given that conservation donors with limited budgets dictate the choice of intervention, the "cost to donor" might be a more important criterion for comparing direct and indirect approaches than "overall cost."[7] Our derivations, however, suggest that the donor will typically prefer the direct approach.

As in the previous section, the donor can motivate conservation by providing either (1) a subsidy of dp_F per unit of forest protected (employed in eco-production), or (2) a subsidy of dp_K per unit of complementary capital employed in eco-production. The donor prefers the approach that minimizes his total costs of providing the subsidy. If the donor prefers the direct payment approach, it will be because

$$-dp_F F < -dp_K K \qquad [10]$$

(recall that per-unit subsidies are presumed negative in both instances).

We show in the appendix that the donor will prefer to subsidize the use of forest directly if the demand for capital is less elastic with respect to the price of forest than is the demand for forest itself (i.e., , $\eta_{KF}/\eta_{FF} < 1$, where η_{ij} is the elasticity of demand for the ith input with respect to the jth). This condition implies that "own" price effects must be stronger than "cross" price effects, and ought generally to be true. A sufficient condition for the donor to prefer the forest subsidy is that the ratio of input demand elasticities with respect to the output price is greater than the ratio of input demand elasticities with respect to the price of forest (i.e., $\eta_{KQ}/\eta_{FQ} > \eta_{KF}/\eta_{FF}$). This condition holds for all homothetic eco-production technologies.

Our results therefore suggest that the donor will find the direct-payment approach cost-effective under a broad class of production technologies. We have performed numerical exercises using a variety of nonhomothetic functions and have found no counter-examples. Conservation practitioners should be wary of adopting indirect approaches.

VI. SUBSIDIES AND THE ECO-ENTREPRENEUR'S INCENTIVES

We have demonstrated that the overall costs of conservation are lower when forest protection is achieved through direct subsidies. Moreover, under plausible assumptions, the conservation donor will also prefer the direct approach. The incentives of donors and entrepreneurs are opposed, however.

Let $d\pi^I$ be the change in eco-entrepreneur profit under the indirect approach and let $d\pi^D$ be the change in profit under the direct approach. For small subsidies,

$$d\pi^D \approx \frac{\partial \pi}{\pi p_F} dp_F = -F dp_F, \qquad [11]$$

where the second equality follows from Hotelling's Lemma and dp_F is given in [6a], and

$$d\pi^I \approx \frac{\partial \pi}{\pi p_K} dp_K = -K dp_K, \qquad [12]$$

where, again, we have used Hotelling's Lemma and dp_K is given in [6b].

Combining [11] and [12], the eco-entrepreneur will prefer the direct subsidy to the indirect if $d\pi_F > d\pi_K$, or

$$-dp_F F > -dp_K K. \qquad [13]$$

Expression [13] is exactly the reverse of expression [10]. The intuition underlying this result is straightforward: the donor wants to minimize the value of the subsidy he offers, whereas the eco-entrepreneur wants to maximize value of the subsidy she receives.

This opposition of interests can be resolved, however. Given that the direct ap-

[7] If the donor purchases or leases an area of ecosystem *and* performs the eco-friendly activity (or sells a concession), "overall costs of conservation" and "donor costs" are the same (see, for example, The Nature Conservancy forestry initiative described in Section 2).

proach is always cost-effective, the donor (as he is likely to be the party preferring the direct approach) could institute both a direct payment for conservation and a transfer to the entrepreneur so as to make both parties better off than under an indirect subsidy on capital.

VII. AN EMPIRICAL EXAMPLE

From 1991–1995, one of the authors participated in a conservation field initiative in the eastern rain forests of Madagascar.[8] The goal of the project was to increase the value of intact ecosystems by providing support for three commercial eco-production activities: forest management, bee-keeping, and aquatic species management (Ferraro and Razafimamonjy 1993). In the following empirical example, we compare the cost-effectiveness of the bee-keeping initiative to that of a direct forest subsidy scheme.

The underlying assumption of the bee-keeping initiative is simple. The production of honey and beeswax requires nectar and pollen inputs from melliferous plants, which are found in the rain forest. Bee-keeping as a means to promote conservation is quite popular and descriptions of such initiatives can be found in many conservation project documents (e.g., Ambougou 1993; PPNR 1995).

The Madagascar bee-keeping initiative targeted the semi-modern regional apiculture technology that uses top-bar hives housed in wooden boxes. The bee-boxes are placed near villages at the edge of forests. As in our previous analytical exercise, we view the production of honey as a function of forest, F, and capital, K. An apiculturalist allocates a fixed number of labor units per bee-box and thus we are justified in combining labor and bee-boxes into the variable K (labor and capital are perfect complements). We assume that all bee-boxes are placed at the edge of the forest. The foraging pattern of bees, the finite supply of food per unit area of forest and the prohibitive labor cost of safeguarding hives placed inside the forest lead to a decreasing returns to scale production technology.[9]

In order to estimate a production function for honey, we use farm-level biological and economic data on honey production in Madagascar (Ferraro and Razafimamonjy 1993; Ralimanana 1994) and published behavioral data on honeybees (Jaycox 1982; Hooper 1991).[10] The data were fit to a Cobb-Douglas production function, which provides a reasonably good fit for the nearby foraging area used most frequently by a colony of bees.

TABLE 1
APICULTURE PRICES AND CONSERVATION SUBSIDIES

Variable	Price	Subsidy
Honey (per liter)	\$1.00	\$0.14
Forest (per hectare)	\$50.00	\$9.34
Capital (per 2 bee-boxes)	\$2.57	\$0.79

The estimated apiculture production function is

$$q = f(K, F) = 48\ K^{.36}\ F^{.15},$$

where q is liters of honey, K is a unit of capital (two bee-boxes and associated labor), and F is hectares of forest. We converted prices in Malagasy francs to U.S. dollars using an early 1990s exchange rate of 2000 Fmg/\$. Prices are listed in Table 1. All input prices are annual rental prices.

Under current prices, the representative household would employ thirty bee-boxes and about one-third of a hectare of forest to apiculture. Now consider a conservation donor that wishes to induce bee-keepers to protect one more hectare of forest. We will assume that the donor accomplishes his objective by inducing ten households to conserve 0.10 more

[8] The project was funded by the Sophie Danforth Conservation Biology Fund of the Rhode Island Zoological Society, by the Rainforest Alliance's Kleinhan's Fellowship, and by the Biodiversity Support Program (Grant #7529) of the World Wildlife Fund, World Resources Institute and the Nature Conservancy.

[9] Bees tend to forage close to the hive, particularly in rain forest environments. Few bees forage beyond 2.5 kilometers and most forage within .5 kilometers. Bees traveling farther from the hive contribute less to honey production than those foraging close.

[10] The most common honey bee in Madagascar is *A. mellifera unicolor*, a subspecies of the European honey bee.

TABLE 2
DIRECT AND INDIRECT SUBSIDIES INDUCING A ONE-HECTARE INCREASE IN FOREST PROTECTED

Subsidy	Donor Cost	Additional Profit (for 10 households)	Overall Cost	Cost Savings of Forest Subsidy
Forest	$39.45	$34.41	$5.04	—
Capital	$225.29	$163.35	$61.94	$56.90
Output	$174.54	$163.30	$11.24	$6.20

hectares of forest each. As in our analysis above, the donor can choose a direct approach and subsidize the forest input, or he can choose an indirect approach and subsidize the price of capital or output. The direct and indirect subsidies that generate a one-hectare increase in forest protected by ten representative households are listed in Table 1.

Table 2 shows, for each approach, the costs to the donor, the *additional* profits to the ten eco-entrepreneurs (original profit/entrepreneur = $52.67), and the overall costs. Table 2 also includes the overall incremental cost of choosing the indirect approaches over the direct approach.

The cost-savings achieved by the direct approach is substantial. For the same increase in forest protected, the indirect approach has an overall cost more than twelve times that of the direct approach. From the perspective of the donor, the indirect approach can be five times more expensive than the direct approach. Note that the donor's cost per additional hectare of forest protected under the direct approach is about 79% of the full opportunity costs of using forest for apiculture rather than for crop agriculture. In contrast, the cost of the indirect approach is over 350% of the opportunity costs of using forest for apiculture—it would be far cheaper simply to buy the land outright. These dramatic relative differences are maintained when sensitivity analyses are conducted by varying the parameters of the production function.

As predicted in the previous sections, the entrepreneur's preferences are opposite those of the donor. Under the indirect approach, profits increase by over 30%, while they increase by less than 10% under the direct approach. Note, however, that the donor could make a transfer to the eco-entrepreneur such that they would both prefer the direct approach to the indirect approach.

We should also note that we implicitly made several assumptions which, if they were not satisfied, would make the argument for the direct approach still stronger. First, we assumed that every unit of forest contributes equally to honey production, when in reality there is a small set of melliferous plants with heterogeneous distributions. A pollen analysis by Ralimanana (1994) indicates that four species make up 45% of the total pollen found in the regional honey. Of these four species, one is not native. Depending on the village, Ralimanana also found that anywhere from 0–97% of the pollen came from secondary forests or exotic plantations. Thus, conservation practitioners cannot be sure that the forest ecosystems desired for conservation are the same ecosystems desired for apiculture.

We also assumed that there are no incentives to manipulate the quality of forest to enhance production. However, of the 46 melliferous plants identified, local residents identified 25% as being highly desirable for their contribution to taste and color. Another 25% were identified as undesirable. Thus enhanced indirect apiculture incentives may increase the incentives to manipulate habitat to enhance production, which could have undesirable conservation impacts (similar incentives have been identified under other indirect interventions; see Southgate 1998; Chomitz and Kumari 1998).[11]

[11] Pawlick (1989) suggests that the ''secret'' to enhancing food supply in apiculture is to plant ''trees which are actually somewhat ill-suited to their environment.'' Such manipulations will lead to staggered and often abundant flowering periods across species.

Finally, we assumed that an increase in output price or a decrease in capital price induces local agents to protect more forest. Bee pollen and nectar, however, provide nonexcludable benefits. If a local agent protects forest, she cannot prevent her neighbors' bees from foraging on her plants. The benefits from cutting down forest and planting crops, however, are excludable. Thus, unless payments are tied specifically to forest protection, there may be very little impact on forest protection via decreased capital prices or increased output prices. Each resident might calculate that the best course of action is to use her forest for agriculture and allow her bees to forage on neighboring forest parcels. Similar outcomes are possible in areas in which forest product collection activities are managed by common property regimes, rather than private property regimes.

VIII. DISCUSSION

Although we have highlighted recent experimentation with direct payment conservation initiatives in Section 2, there are clearly barriers to implementing the approach in low-income nations. In particular, markets for intact ecosystems are often absent, or are imperfect in that the costs of enforcing property rights are prohibitive. We have ignored a variety of issues that will be important in any contracting initiative for habitat conservation in low-income nations. These issues include minimizing transaction costs, designing and targeting effective contracts, and enforcing property rights once they are claimed. In this respect, however, a system of conservation performance payments has much in common with less direct interventions. Both require institutions that can monitor ecosystem health, resolve conflict, coordinate individual behavior, and allocate and enforce rights and responsibilities.

Unlike less-direct development interventions, however, a system of conservation contracting allows practitioners to focus their energies on designing these institutions. In contrast, conservation practitioners adopting indirect approaches must allocate their resources across many more tasks in order to augment the capabilities of residents in remote rural areas to cater to national and world markets. Even when practitioners are successful, there is no guarantee that market conditions will not change overnight, rendering the commercial activity unprofitable and often stranding an expensive sunk investment.

In short, the direct-incentive approach we advocate presumes the establishment of an institutional context in which it can be implemented. Indirect approaches, however, presume the same ability to demarcate and enforce rights and responsibilities. Moreover, they also require greater sophistication on the part of donors in, for example, anticipating market trends and predicting the conservation effects of specific investments. For these reasons, we conclude that the direct-payment approach remains the first-best ecosystem conservation policy option.

As we have stated earlier, we do not dispute the wisdom of making *profit-maximizing* investments in eco-friendly commercial activities. Our point is only that if such investments are not financially wise, as we suspect is the case in many instances, they will not be cost-effective in promoting conservation either.

If indirect approaches to conservation are not cost-effective, then why, one might ask, are they the predominant form of intervention in low-income nations? Proponents often assert that indirect interventions encourage local economic development. We have shown that eco-entrepreneurs will likely favor subsidization of output prices or the acquisition of complementary capital. We have also shown, however, that the donor can offer a grant to local agents such that both donor and eco-entrepreneurs are better off under the direct approach. Furthermore, encouraging the growth of eco-friendly activities is a form of industrial policy that we doubt anyone could implement, especially donors whose main concern is conservation.

Proponents of indirect approaches also assert that large short-term capital investments can achieve long-term results through "demonstration effects" or "spillovers." For example, one landowner might devote her holdings to tourism rather than farming after observing that another has done so successfully, or one landowner's property may become a more attractive tourist destination if her neighbor chooses to keep her land in its natural state as well. The ability of indirect approaches to achieve these demonstration and spillover effects, however, has been limited. As a recent World Bank analysis (Wells et al. 1999, 26) noted, conservation initiatives ''based on simplistic ideas of making limited short-term investments in local development and then hoping this will somehow translate into sustainable resource use and less pressure on parks need to be abandoned.''

Finally, we acknowledge that donors' incentives are not always as simple as one might suppose. Many funders want to see clear short-term results (Wells and Brandon 1992). A large capital investment may have greater visibility than would periodic conservation payments. Large capital investments also result in large budgets that support the staff and infrastructure of organizations that implement indirect approaches to conservation. Political constraints can also affect donor incentives. Bilateral donors, for example, often face strong pressures to engage their own nationals in foreign assistance projects. The more complex the project, the more easily this objective is accomplished. A larger cadre of expatriate consultants is likely to be sustained by a program calling for indirect interventions than by one whose objective is simply the acquisition and management of conservation habitat. Such consultants may comprise an effective lobby for indirect interventions. Although political realities affect the feasibility of any policy, donors whose primary intent is ecosystem conservation may be well advised to closely examine their policy choices.

We have shown that direct incentives are more cost effective than indirect ones despite making assumptions favorable to the latter throughout the analysis. In the same vein, we assumed that the donor could identify *ex ante* the capital subsidy required to motivate the conservation of the desired area of forest just as easily as he could identify the forest subsidy. In reality, the donor may be able to ascertain the appropriate forest subsidy more easily (e.g., via a procurement auction like that used by the U.S. Conservation Reserve Program). We also assumed that the capital acquired at subsidized prices would be employed in eco-production. Some forms of capital, however, may be easily diverted to less benign uses without the donor's knowledge. In contrast, the donor may find it easier to monitor the amount of intact forest protected by an individual or community.

We assumed that the units of forest in which a donor is interested are the same units protected by the entrepreneur when faced with cheaper capital or higher output prices. As we observed in the empirical example above, however, the forest protected under the two approaches may in fact not be the same. A direct payment approach has the advantage of permitting more precise targeting of conservation funds, thus facilitating the maximization of environmental benefits per dollar expended.

Finally, we note that our simple model may also be applied to some ''conservation by distraction'' (CBD) interventions.[12] CBD interventions, such as providing off-farm employment opportunities or promoting labor-absorbing technical change in agriculture, are attempts to direct capital and labor away from ecosystems. Such interventions aim to encourage alternative production patterns that require less land to achieve a given production/income level. For example, some authors have argued that commercial fertilizer is a technical substitute for the biomass fertilizer accessed through cutting and burning forest parcels (e.g., Sanchez et al. 1982).[13] Thus, fertilizer subsidies have been proposed as a conservation strategy. Our model could easily be adapted to evaluate such a strategy. Consider an entrepreneur who engages in eco-*un*-friendly production. A direct payment for non-use is the same as an increase in the price of using forest for agriculture and thus our results translate: subsidizing fertilizer is likely to be more ex-

[12] The CBD term was suggested by Franz Tattenbach, Director of FUNDECOR in Costa Rica.

[13] The assumption that commercial fertilizers are technical substitutes for land in low-income nations, however, may not be correct (e.g., Lewandroski et al. 1997).

pensive than making a direct payment for land conserved.

IX. CONCLUSION

In order to achieve ecosystem conservation objectives in low-income nations, conservation practitioners have invested in promoting commercial enterprises intended to generate local incentives for conservation. By virtue of their complicated and indirect linkages to conservation objectives, however, development interventions are often ill-suited for achieving ecosystem conservation.

In contrast to the emphasis on indirect approaches to ecosystem conservation in low-income nations, high-income nations, and a few low-income nations, have been experimenting with approaches based on conservation performance payments. Despite the increasing use of direct-payment approaches, the role that they can play in low-income countries has been largely overlooked.

Our results suggest that conservation performance payments can be much more cost-effective than indirect approaches. Our model is simple and may not capture all of the relevant aspects of the choice between using indirect or direct approaches to achieve ecosystem conservation. However, we know of no other systematic effort to elucidate the nature of this choice. One of our main motivations in writing this piece is to invite other economists with an interest in these issues to formalize more sophisticated models with contrary implications if they believe them to be appropriate. Our feeling, however, is that the more parsimonious approach should be adopted until a compelling case is made for abandoning it. Hence, we believe that continued experimentation with direct-conservation incentives in the developing world is warranted and will prove successful.

APPENDICES

Appendix 1: Derivation of Overall Cost of Choosing an Indirect Rather Than the Direct Approach

Consider a second-order approximation to the eco-entrepreneur's profits when additional forest is provided directly:

$$\pi(p_Q, p_K, p_F + dp_F) \approx \pi(p_Q, p_K, p_F) + \pi_F dp_F + \frac{1}{2}\pi_{FF}(dp_F)^2. \quad [A1]$$

Alternatively, if sufficient additional capital is provided to induce the eco-entrepreneur to acquire one more hectare of forest, her profits will be approximately

$$\pi(p_Q, p_K + dp_K, p_F) \approx \pi(p_Q, p_K, p_F) + \pi_K dp_K + \frac{1}{2}\pi_{KK}(dp_K)^2. \quad [A2]$$

Using [2b] and [2c] (Hotelling's Lemma) and rearranging, we have

$$\pi(p_Q, p_K, p_F + dp_F) - \pi(p_Q, p_K, p_F) + dp_F\left(F_0 + \frac{\partial F}{\partial p_F}dp_F\right) \approx -\frac{1}{2}\frac{\partial F}{\partial p_F}(dp_F)^2 \quad [A3]$$

and

$$\pi(p_Q, p_K + dp_K, p_F) - \pi(p_Q, p_K, p_F) + dp_K\left(K_0 + \frac{\partial K}{\partial p_K}dp_K\right) \approx -\frac{1}{2}\frac{\partial K}{\partial p_K}(dp_K)^2, \quad [A4]$$

where F_0 and K_0 are the quantities of forest and capital demanded absent any subsidies. The interpretation of [A3] and [A4] is straightforward. The first two terms on the left-hand side of each is the difference in profits arising from ecoproduction resulting from the subsidy on forest or capital. The last term on the right-hand side is the value of the subsidy; that is, the amount of the subsidy per unit times demand after the subsidy. Note, then, the left-hand side of [A3] and [A4] is the overall cost of the respective subsidy, defined as the difference in profits less (again, recall that dp_F and dp_K are both negative by assumption) the cost of the subsidy. The right-hand side expressions are, then, "cost triangles," the cost to the donor of providing incentives that is not recovered as a transfer to the eco-entrepreneur.

Subtracting the right-hand side of [A4] from [A3], we obtain

$$\frac{1}{2}\left[\frac{\partial K}{\partial p_K}(dp_K)^2 - \frac{\partial F}{\partial p_F}(dp_F)^2\right] = \frac{1}{2}\left[\frac{\pi_{KK}\pi_{FF} - (\pi_{FK})^2}{(\pi_{FK})^2\,\pi_{FF}}\right], \quad [A5]$$

where the right-hand side comes from Hotelling's lemma and the derivations of the subsidies, expressions [6a] and [6b]. Given our convexity assumptions, expression [A5] is positive (i.e., the direct approach is more cost-effective). Using expressions [4], [5], and [6b], we can derive an alternative expression for the additional costs incurred when the indirect approach is chosen over the direct approach:

$$-\frac{dp_K}{2}(dK^I - dK^D). \quad \text{[A6]}$$

Thus, the relative cost advantage of the direct approach is proportional to the difference in capital demanded.

Appendix 2: Derivation of Conditions under which the Donor Prefers Direct Approach

Under the assumption that both subsidies assure equal incremental acquisition of forest for the eco-friendly activity, dp_F and dp_K are as given in [6], [6a], and [6b]. Making these substitutions in [10], we obtain

$$\frac{-F}{\partial F/\partial p_F} < \frac{-K}{\partial F/\partial p_K}, \quad \text{[A7]}$$

Noting that, by symmetry of cross-price derivatives, $\partial F/\partial p_K = \partial K/\partial p_F$, and multiplying both sides by p_F and negative one, we have

$$\frac{1}{\frac{\partial F/F}{\partial p_F/p_F}} > \frac{1}{\frac{\partial K/K}{\partial p_F/p_F}} \quad \text{[A8]}$$

or, defining by η_{ij} the elasticity of demand for the ith input with respect to the price of the jth,

$$\frac{\eta_{KF}}{\eta_{FF}} < 1. \quad \text{[A9]}$$

To interpret [A9] further, recall that the convexity of the profit function in prices implies that the principal minors of its Hessian matrix be positive. Specifically,

$$\pi_{FF}\pi_{KK} - (\pi_{FK})^2 > 0. \quad \text{[A10]}$$

Using Hotelling's Lemma to restate the derivatives, we have

$$\left(\frac{\partial F}{\partial p_F}\right)\left(\frac{\partial K}{\partial p_K}\right) - \left(\frac{\partial F}{\partial p_K}\frac{\partial K}{\partial p_F}\right) > 0, \quad \text{[A11]}$$

or, rearranging one more time to express relationships as elasticities,

$$\frac{FK}{p_F p_K}(\eta_{FF}\eta_{KK} - \eta_{FK}\eta_{KF}) > 0. \quad \text{[A12]}$$

Since factor demands and prices are all positive,

$$\eta_{FF}\eta_{KK} > \eta_{FK}\eta_{KF}, \quad \text{[A13]}$$

or

$$\frac{\eta_{KK}}{\eta_{FK}} > \frac{\eta_{KF}}{\eta_{FF}}. \quad \text{[A14]}$$

Factor demands are homogeneous of degree zero in all prices, so

$$\frac{\partial K}{\partial p_Q}p_Q + \frac{\partial K}{\partial p_F}p_F + \frac{\partial K}{\partial p_K}p_K = 0, \quad \text{[A15]}$$

or, dividing both sides by K,

$$\eta_{KQ} + \eta_{KF} + \eta_{KK} = 0. \quad \text{[A16]}$$

Similarly,

$$\eta_{FQ} + \eta_{FF} + \eta_{FK} = 0. \quad \text{[A17]}$$

Using [A16] and [A17] to eliminate η_{KK} and η_{FK} from [A14], we have

$$\frac{\eta_{KQ}}{\eta_{FQ}} > \frac{\eta_{KF}}{\eta_{FF}}. \quad \text{[A18]}$$

From expression [10], we know that a sufficient condition for the donor to prefer the direct approach is that $\eta_{KF}/\eta_{FF} < 1$. Thus, if the left-hand side of [A18] is no greater than one, [10] holds and the direct approach is preferred. The left-hand side of [A18] is one if the eco-friendly production function is homothetic.

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