Is the value of bioprospecting contracts too low?

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In order to regulate the proliferated bioprospecting and protect the biological diversity in the source countries, the Convention on Biological Diversity (CBD) established a legal framework for the reciprocal transfer of biological materials between the interested parties in bioprospecting activities, subject to the Prior Informed Content (PIC) principles and a set of mutually agreed items on equitable sharing of benefits (CBD 1992, Bhat 1999; Ten Kate and Laird 1999; Dedeurwaerdere 2005).

Although interesting and valuable to the cause of conservation, there is a feeling that the 'price' being paid under these arrangements is too low. Somehow ecologists argue that, surely, these materials have a greater value than the few million dollars being paid to national conservation organizations for the protection of the areas where the material are located. In this paper we seek to understand better how a biodiversity resource' use value in production is determined, and how the real value is obscured by the fact that the resource is largely open access. We attempt to analyse how special arrangements, set op top of a basic framework in which the resource open access is limited in what it can achieve and in the 'price' that will emerge from any transaction between the buyers of the rights and the sellers of the rights.

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I. Introduction

There has been considerable interest recently in using market-based mechanisms to pay for ecosystem services. In the past the traditional tools used to foster biodiversity and ecosystem conservation, especially in developing countries, consisted of indirect support through grants and loans to support domestic resource management agencies charged with 'conservation'. These methods of natural resource management have now been questioned. The criticisms stem from the realisation that a more effective policy would be to make direct payments to landowners, conditional on the maintenance of the land in its natural state. The financial benefits of healthy ecosystems and the environmental services they provide have thus gained increasing attention in the debate on public choice and environmental management (Mayrand and Paquin 2004, Pagiola and Agostini 2004).

There have also now been a number of transactions in which commercial interests, particularly in the pharmaceutical industry have made payments for exclusive access to genetic materials. In order to obtain a better understanding such transactions, it is necessary for us to propose an explicit analysis on the contractual relationships, taking account of all the related parties. Table 1 in the annex summarizes the main existing bioprospecting contracts and thus provides a general overview of the contractual parties involved and their respective costs and benefits.

As we can see, the contractual relations put forward between different economic agents, notably linked to the industry and to resources suppliers, which are predominantly located in geographical areas where there is a high richness of biodiversity (e.g. Brazil and Costa Rica) are complex. Table 1 shows wide variety of private sectors involved in bioprospecting – eight in total. The actual forms represent a range of contractual specifications. For instance, industries of botanical medicines, personal care and commercial agricultural traditionally depend upon plant genetic resources, but pharmaceutical biotechnological companies always acquire material as raw samples, extracts from plant genetic resources or 'value-added' genetic resources. Further details of such contracts are available in: (Ten Kate and Laird 1999; Ding, Nunes and Onofri, 2007)[1].

The emblematic bioprospecting contract was the one signed between the INBio-national biodiversity institute of Costa Rica and the Merck Pharmaceutical Ltd. in 1991. Merck was granted the right to evaluate the commercial prospects of limited number of plant, insect, and microbial samples collected in Costa Rica's 11 conservation areas, from which INBio received US$1 million over two years as well as equipment for processing samples and scientific training from Merck. In addition, a share of potential royalties and technology transfer to develop local sample preparation and screening capabilities was addressed in the agreement. INBio agreed to invest 10 percent of any payments and half of royalties by Merck into the Conservation Areas (Mulholland and Wilman 1998; Merson 2000; Artuso 2002). More recently, Glaxo Wellcome and Brazilian Extracta have jointly signed a bioprospecting contract where Glaxo paid US$3.2 million for the right of screening 30,000 compounds of plant, fungus and bacterial origin from several regions in the forest of Brazil. In addition, Glaxo will be responsible for allocating part of the royalties derived from market products arising from the discovered compounds in Brazilian university based research groups and in the support of community-based conservation projects.

[1] An issue that is discussed but not explained is why contracts are made up of part 'up-front' fee and part royalty sharing. The form implies certain risk preferences on the parts of buyers and sellers of biodiversity that are worth exploring further.

In order to regulate the proliferated bioprospecting and protect the biological diversity in the source countries, the Convention on Biological Diversity (CBD) established a legal framework for the reciprocal transfer of biological materials between the interested parties in bioprospecting activities, subject to the Prior Informed Content (PIC) principles and a set of mutually agreed items on equitable sharing of benefits (CBD 1992, Bhat 1999; Ten Kate and Laird 1999; Dedeurwaerdere 2005).

Although interesting and valuable to the cause of conservation, there is a feeling that the 'price' being paid under these arrangements is too low. Somehow ecologists argue that, surely, these materials have a greater value than the few million dollars being paid to national conservation organizations for the protection of the areas where the material are located. In response to that there have been some papers justifying the relatively small amounts involved in such contracts. Barbier and Aylward, 1996 note the high costs of development of any drugs derived from genetic materials (e.g. it takes 20,000 samples that have to be analyzed at considerable expense to get a 'hit'). Polski, 2005, reports that, in the US on average 10 years are needed to bring a new drug to market at a cost of around US$ 800 million. In a similar vein Frinn, 2003, makes the points that any material found naturally has a low chance of having useful biological activity, and that random synthetic chemicals are much easier to work with and one has an equal chance of finding a chemical that has a specific activity as a natural product.

Notwithstanding these observations, we do find that drugs derived from natural organisms are significant contributors to the output of drug companies. Frinn, 2003 reports that 75 percent of drugs in developing countries and 25 percent in developed countries are based on chemicals made by organisms. So, in spite of the high costs and difficulties in working with natural genetic material, the latter continues to play a major role in drug development.

In this paper we seek to understand better how a biodiversity resource' use value in production is determined, and how the real value is obscured by the fact that the resource is largely open access. Although bioprospecting contracts are becoming popular, they are still very few in number. The annex identified eight such contracts, which can only represent a small part of the work undertaken using genetic material. The CBD has stated the legal principle that each country has "sovereign property rights over the biodiversity within its jurisdiction and is able to obtain truthful information about the use of the genetic resource, control the access procedures and equitably negotiate the benefit-sharing items with the biodiversity prospectors. Yet, as far as we are aware, there are no cases of countries enforcing these rights in international courts. We conclude therefore that, at present the 'default' assumption on biodiversity is one of open access. To be sure some major pharmaceutical companies make bioprospecting contracts. These can be justified on the grounds of corporate social responsibility and good relations[2].

In the light of these observations this paper looks at how special arrangements, set on top of a basic framework in which the resource open access is available, can work and what they can achieve. The appropriate model for such analysis is one of monopolistic competition, which allows us to look at product differentiation, a feature we believe to be important in this market. Given the competitive conditions in which these firms operate and the lack of barriers to entry the assumption of monopolistic competition appears appropriate.

[2] It is rumoured that the budget for the InBio-Mercx contract came from Mercx's publicity budget.

The structure of the paper is as follows. Section II provide the basic model for the analysis of an open access biodiversity resource in the presence of many firms with increasing returns to scale over a part of their production function and a capacity to influence price. The model characterising the open access equilibria is presented, and the scope for special arrangements is discussed. In section III we work through a model with a simple production structure and obtain closed form solutions for the open access equilibria, the shadow price of the biodiversity resource and the likely price to emerge from any special deals. Numerical examples are provided for plausible parameter values. Section IV discusses the limitations of the analysis and the range of policy options available and offers some conclusions.

II. Open Access Biodiversity with Competitive Firms

When a resource such as genetic materials is under open access (OA) there are two implications. The first is that it is exploited to the maximum extent possible – i.e. to the point where all that can profitably be extended is so extracted. The second is that such a process of extraction combined with the OA nature of the resource results in damage to the resource base, or at least no attempt by anyone to protect it and enhancing the future values it could provide.

We envisage a world with a large number of firms operating in a monopolistically competitive market. They have two inputs, one of which is genetic material (b) and the other a composite (called it l). They produce a single output (q)[3].

The firms maximise profits but, given the competition condition, the number of firms (n) is such that each makes a zero profit[4]. The genetic material input is available free and, given a total supply under OA of B, each form has B/n. Of course this quantity is has a non-zero value to the firm and a shadow price of the material can be computed. Call this r_B.

Now suppose one firm decides to make a deal with a supplier of genetic material and under the agreement it will pay a certain amount for each unit of b extracted. The supplier offers to protect the resource and manage it and the deal is that the greater the amount made available, the higher the unit price will be[5].

Under this arrangement the single firm will make a payment per unit of b to the point where the marginal value is equal to the marginal cost to the owner of supplying the last unit. Furthermore it will only do this if its profits under the special deal are higher than under the competitive solution – i.e. greater than zero.

The analysis can be shown as in the figure below. The OA equilibrium is at $[r_b, B/n]$, while the special deal equilibrium is at $[r_d, b_d]$. The second equilibrium will, however, only be chosen is profits there are greater than zero.

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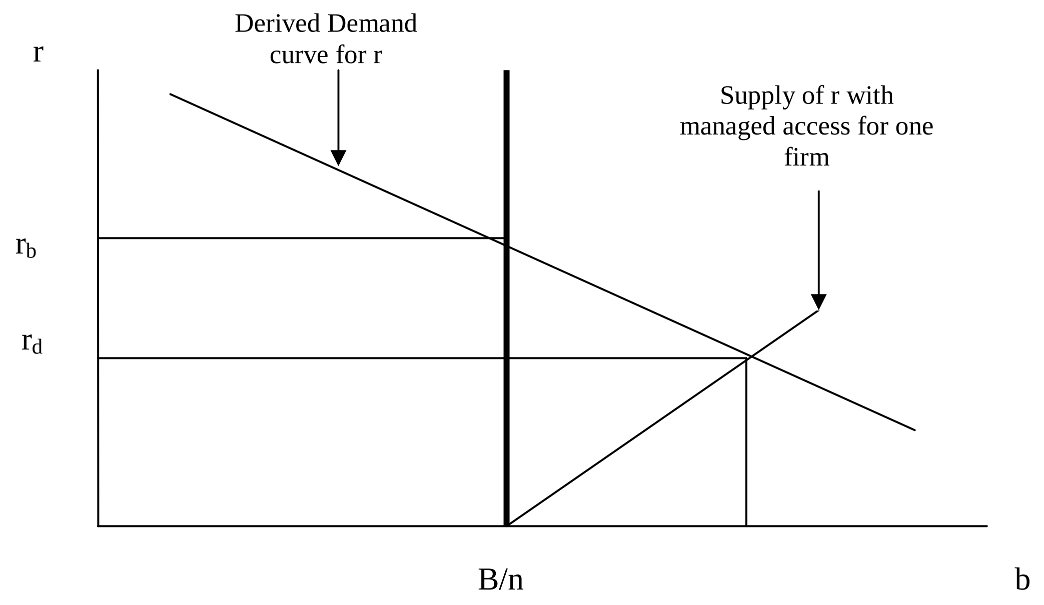
[3] We plan to extend this later to cover differentiated outputs and a stochastic production structure.

[4] The zero profit constraint implies that firms cannot have a production structure that is one of only decreasing or constant returns to scale. With such a structure either one firm dominates the market or the number of firms increases without bound, with each becoming infinitesimally small. Hence we have to assume that the firms have some section of their production structure that is with increasing returns to scale. The easiest way to do that is to assume set up costs for entering the market and undertaking production, which is also realistic for this market.

[5] We do not look here at the stochastic dimension, in which a royalty sharing component could be added to the contract. As noted this requires a stochastic structure which has yet to be developed.



The model can be represented analytically as follows. Profits **Π** are given by:

$$\Pi = p.q^s(l, \frac{B}{n}) - wl \qquad (1)$$

Where q^s is the production function *p* is the price of q and *w* is the price of *l*.

The first order conditions for a maximum when the firm can influence price are:

$$\frac{\partial \Pi}{\partial l} = p.\frac{\partial q^s}{\partial l}(1 + \frac{1}{\varepsilon_D}) - w \qquad (2)$$

Where ε_D is the elasticity of demand for the product and is negative. Note furthermore that equilibrium requires the elasticity of demand to be greater than one in absolute value; otherwise an equilibrium level of output for the firm is not defined.

From (2), *l* is determined as a function of *p* and *w*. Feeding that into (1) gives

$$q^s = \psi(p, w, \frac{B}{n}) \qquad (3)$$

The demand for the output *q* is given by

$$q^d = \phi(p) \qquad (4)$$

With *n* identical firms we have

$$q^d = nq^s \qquad (5)$$

The zero profit condition gives

$$pq^s - wl = 0 \tag{6}$$

Equations (3)-(6) determine $q^d_{OA}, q^s_{OA}, p_{OA}, n_{OA}$ which characterize the OA equilibrium.

Now the special deal equilibrium is characterized as follows. The profits are now:

$$\Pi_{SD} = p.q^s(l,b) - wl - r(b - B/n) \tag{7}$$

Where *b>B/n*. The firm is only paying for the 'extra' amount *b - B/n* under the contract.

The FOC for an increase in *b* require

$$\left.\frac{\partial \Pi}{\partial b}\right|_{b>\frac{B}{n}} = p\frac{\partial q^s}{\partial b}(1+\frac{1}{\varepsilon_D}) - r = 0 \tag{8}$$

$$\left.\frac{\partial \Pi}{\partial l}\right|_{b>\frac{B}{n}} = p\frac{\partial q^s}{\partial l}(1+\frac{1}{\varepsilon_D}) - w = 0 \tag{9}$$

Finally there is a supply curve for r:

$$r = \theta(b), b \geq \tfrac{B}{n} \tag{10}$$

Substituting (10) into (8) gives 2 equations for *l* and *b*. These will be chosen only if the corresponding profit is positive.

It is possible that the special deal equilibrium will allow the company making it to differentiate its product *q* in the market and charge a higher price than $p_{OA.}$ In that case the equilibria will be adjusted accordingly.

In the next section we estimate a possible function and see what the equilibria will look like. We can then compare the shadow price of b with the special deal price.

III. Modelling the Equilibria with Specific Functions

Setting out the analytical model
In this section we take the following simple Cobb-Douglas production function for *q*:

$$q = (l - l_0)^\alpha (\frac{B}{n})^{(1-\alpha)}$$
$$0 < \alpha < 1, l > l_0 \tag{11}$$

Profits **Π** are given by:

$$\Pi = pq - wl - wl_0 \quad (12)$$

The first order conditions for a maximum give:

$$l^s = \frac{B}{n}\left[\frac{p}{w}\right]^{1/(1-\alpha)} (A\alpha)^{1/(1-\alpha)} + l_0$$
$$A \equiv (1 + \frac{1}{\varepsilon_D}) \quad (13)$$

and

$$q^s = \frac{B}{n}\left[\frac{p}{w}\right]^{\alpha/(1-\alpha)} (A\alpha)^{\alpha/(1-\alpha)} \quad (14)$$

Equation (12) for profits now becomes:

$$\Pi = p^{1/(1-\alpha)}.w^{-\alpha/(1-\alpha)}\,\frac{B}{n}((A\alpha)^{\alpha/(1-\alpha)} - (A\alpha)^{1/(1-\alpha)}) - wl_0 \quad (15)$$

Setting demand q^d equal to supply as in equation (5) where demand is represented by an isoelastic demand function with price elasticity equal to β we have:

$$q^d = G.p^{-\beta} = nq^s \quad (16)$$

Substituting for q^s from (14) and solving for p the OA equilibrium price of q we get:

$$p_{OA} = \left[\frac{B}{G}\right]^{-(1-\alpha)/k} w^{\alpha/k} (A\alpha)^{-\alpha/k}$$
$$k \equiv \beta(1-\alpha) + \alpha \quad (17)$$

It follows from (17) that p is a decreasing function of B and an increasing function of w. The solution for n, the number of firms is given by substituting for p from (17) into (15) with Π set at zero. Rearranging terms and solving for n we get:

$$n = \left[\frac{p_{OA}}{w}\right]^{1/(1-\alpha)} \frac{B}{l_0}\left\{((A\alpha)^{\alpha/(1-\alpha)} - (A\alpha)^{1/(1-\alpha)})\right\} \quad (18)$$

Where p_{OA} *is* as given in (17). Substituting for it from (17) gives:

$$n = \left[B^{(1-1/k)}.G^{1/k} w^{-\beta/k} (A\alpha)^{-\alpha/k(1-\alpha)}\left\{(A\alpha)^{\alpha/(1-\alpha)} - (A\alpha)^{1/(1-\alpha)}\right\}\right] \Big/ l_0 \quad (19)$$

Note that the number of firms n declines as the set up costs l_0 increase. The number also increases with B but only if (1-1/k) > 0, i.e. if k > 1. This requires that β, the price elasticity of demand be greater than one in absolute terms – a condition also for an equilibrium to exist.

Finally we want to calculate the shadow price of the biodiversity resource *b*, r_b. This is obtained by differentiating the profit function (15) with respect to B/n:

$$\frac{\partial \Pi}{\partial B/n} = \frac{1}{(1-\alpha)} p^{\frac{1}{(1-\alpha)}-1} w^{-\alpha/(1-\alpha)} \frac{B}{n} \left\{ ((A\alpha)^{\alpha/(1-\alpha)} - (A\alpha)^{1/(1-\alpha)}) \right\} \frac{\partial p}{\partial B/n}$$
$$+ p^{1/(1-\alpha)} w^{-\alpha/(1-\alpha)} \left\{ ((A\alpha)^{\alpha/(1-\alpha)} - (A\alpha)^{1/(1-\alpha)}) \right\} / n \qquad (20)$$
$$where \frac{\partial p}{\partial B/n} = -\frac{(1-\alpha)}{k} \frac{p}{B/n}$$

Substituting for $\frac{\partial p}{\partial B/n}$ into the main expression gives:

$$\frac{\partial \Pi}{\partial B/n} = (1-\frac{1}{k}) p^{\frac{1}{(1-\alpha)}} w^{-\alpha/(1-\alpha)} \left\{ ((A\alpha)^{\alpha/(1-\alpha)} - (A\alpha)^{1/(1-\alpha)}) \right\} \qquad (21)$$

Note that in differentiating the profits function with respect to B we hold n constant. If n is allowed to vary the change in profit is of course zero, as defined by the profit maximisation and zero profit restrictions. As in the case of *n*, the profits will only increase with an increase in *B* if β is greater than one.

In order to compare the value of biodiversity at its shadow price with the value of output from the firms we compute the relative value of biodiversity RB as:

$$RB = \left. \frac{\partial \Pi}{\partial B/n}.(B) \middle/ p.q \right. \qquad (22)$$

Some numerical solutions of the OA solution

Since the model is fully solved in closed form we can calculate the solutions for specific values of the parameters. Table 1 gives the range of values tried with some *a priori* justification for them.

The results are given in Table 2. We make the following observations:

(a) The value of biodiversity at its shadow price is small (around 0.5 to 4 percent) relative to the value of the output. It does not vary notably with β (the price elasticity of demand) but not with with l_0 (the set up costs) and varies not at all with *w* (the wage). It also varies with α (the share of output not attributable to biodiversity), but even in this case the highest value (with α at 0.6 and β at 1.1) is only 2.5 percent. The lowest value (with α at 0.9) is 0.5 percent.

(b) The set up costs have a major impact on the number of firms. A four-fold increase in the set up costs, for example, reduces the number of firms from 173 to 43, thus increasing their market power.

(c) Increases in *w* reduce the number of firms (a doubling w reduces the number of firms by about 50 percent). Increases in *w* also of course increase *p* – a doubling of *w* increases *p* by about 40 percent. However, increasing *w* does not reduce output. With the fall in the number of firms output in fact increases slightly.

Table 1: Range of Parameter Values for the OA Equilibrium

Parameter	Values	Reasoning
‘α’	0.6 to 0.9	Determines the share of value of output attributable to factors other than biodiversity. This could vary by application and above range should cover most cases.
‘β’	1.05 to 1.3	Has to be greater than one. Elasticity range for products such as drugs can be quite elastic but can also be inelastic. Range chosen is plausible but need further investigation
‘l_0’	0.5 to 2	Chosen so that the set up costs are about 25% of the direct non-biodiversity costs.
‘w’	1 to 2	Normalised to be roughly equal to 65 to 75 percent of the price of the output.
B	100000	Chosen so that the number of firms in the OA is in the range 50 to 250 for the different parameter values.
G	100	

Table 2: Results for the OA Equilibrium

		No of Firms	Output	Value of biodiversity as (%) of value of output
α = 0.8 ‘l_0’ = 0.5 ‘w’= 1.0	‘β’=1.05	181	15	1.0
	‘β’=1.10	173	27	1.1
	‘β’=1.20	166	46	1.2
	‘β’=1.30	164	63	1.3
α = 0.8 ‘w’ = 1.0 ‘β’=1.10	‘l_0’ = 0.50	173	27	1.1
	‘l_0’ = 0.75	115	40	1.1
	‘l_0’ = 1.50	58	80	1.1
	‘l_0’ = 2.00	43	107	1.1
α = 0.8 ‘l_0’ = 0.5 ‘β’=1.10	‘w’ = 1.0	173	27	1.1
	‘w’ = 1.2	142	28	1.1
	‘w’ = 1.4	120	29	1.1
	‘w’ = 2.0	82	30	1.1
‘l_0’ = 0.5 ‘β’=1.10 ‘w’ = 1.0	α = 0.6	209	141	2.5
	α = 0.7	190	61	1.8
	α = 0.8	173	27	1.1
	α = 0.9	157	12	0.5

Analysing the Special Deal Equilibrium

In the special deal a firm has access to the open access share of the genetic materials but, in addition, it negotiates an arrangement to have access to *further* material on an exclusive basis. It pays for the additional material and the price depends on the amount that is extracted. Mathematically we can then write profits as:

$$\Pi = pq - wl - r(b).(b - \frac{B}{n}) - wl_0$$
$$b > \frac{B}{n}, l > l_0 \qquad (23)$$

The first order conditions are given by:

$$\frac{\partial \Pi}{\partial l} = A\alpha p l^{\alpha-1} b^{1-\alpha} - w = 0 \qquad (22)$$

$$\frac{\partial \Pi}{\partial b} = A(1-\alpha) p l^{\alpha} b^{-\alpha} - r'(b)(b - \frac{B}{n}) - r(b) = 0 \qquad (23)$$

In the absence of any better information we choose a linear form of the function *r(b)*:

$$r = a + db \qquad (24)$$

Replacing *r* and the derivative of *r* from (24) in (23), and substituting for *l* from (22) into (23) we get:

$$b = \frac{A(1-\alpha) p^{1/(1-\alpha)} w^{-\alpha/(1-\alpha)} (A\alpha)^{\alpha/(1-\alpha)} - a}{2d} + \frac{B}{n} \qquad (25)$$

It follows from (25) that *b* decreases with *a* and also with *d*. Note also that this quantity and the corresponding price of r is independent of *β*, the overall elasticity of demand. This is because the single buyer is not assumed to influence the market price though the special deal.

It is difficult to determine the nature of the *'r'* function (24), but it is an important one and more effort is needed to understand better its structure. In the calculations below we use the linear form and select the parameters *a* and *b* as follows:

i. 'a' is chosen as somewhere between zero and the shadow price of *b* in the OA. A value of around 50 percent of the shadow price is taken.

ii. 'd' is chosen so that the elasticity of the supply price with respect to *b* is around 0.5 at the point where *b* = *B/n*. Recall that the elasticity with respect to price is of course the inverse of the elasticity of quantity with respect to price, which is set at around 2. We test for sensitivity to this price elasticity below.

The main results are as follows:

(a) For the 'base case' numerical values of α = 0.8, 'l_0' = 0.5, '*w*'= 1.0, β = 1.1, we find that a special deal can be struck if the supply function starts at a value of around 15 percent of the shadow price of *b*, when the price elasticity of demand is 1.05. With a price elasticity of 1.1 the supply function can start at a value of around 29 percent of the shadow price of b. As the elasticity of demand for the final product increases so the starting price that can be demanded in the special deal also increases.

(b) In this base case the final price for the special deal purchase of *r* – i.e. *r(b)* is around 55 percent of the shadow price of *b* when the starting value of the supply function is 15 percent of the shadow price of *b*. As the initial price increases to 50 percent of the shadow price of *b*, final price in the special deal rises to 75 percent of the special deal price. Remarkable this final price is insensitive to the slope of the supply function – as the value of 'd' changes so the amount of b bought changes in compensation. So the special deal price appears to be an underestimate of the 'true' value of the biodiversity by a considerable margin.

(c) The amount of *b* bought under the special deal will depend crucially on the elasticity of the *r* function and on the initial price *a*. With an initial price of only 15 percent of the shadow price of biodiversity the amount purchased is nearly three times the freely obtainable amount. With a starting price of 50 percent of the shadow price it falls to about 50 percent of the freely obtainable amount. Similarly the slope of the supply function (i.e the parameter *d*) has a major impact. Increasing this slope by a factor of two reduces the amount bought also by a factor of two while reducing the slope to half the previous level increases the amount bought by a factor of two.

(d) There is no guarantee that a special deal can be struck. That depends on a number of parameters. In general terms a deal is more likely the lower the value of *a* in the *r* function, the lower the slope of the *r* function, the lower is *w*, and the lower is α.

Analysing the effects of an increase in the price of output when there is a special deal
If the special deal has the added advantage of increasing the price that the firm will receive for its output the implications of that are straightforward. The amount of *b* the firm will be willing to buy increases, and the price paid for it both in absolute terms and as a percentage of the shadow price of *b* will increase. As an example, we assume that the price that can be charged goes up by 5 percent or 10 percent. The increases in the amount of *b* bought under the special deal goes up by 6 percent and 12 percent respectively. The price at which the deal is struck as a percentage of the shadow price of biodiversity, however, increases by only two to five percentage points respectively.

Analyzing the Impact of Reducing the Availability of Freely Available Biodiversity
Finally we look at the impact of making the special deals less 'special'. Although this needs a different model we can see some of the effects by reducing the amount of 'B" in the model. Suppose that the amount available freely falls by half. The implications of such a fall are the following:

- The price of the final output increases by about 44 percent.
- The number of firms is not much affected but decline by about 2 percent.
- The shadow price of biodiversity increases by 98 percent.
- Assuming the supply function is unchanged the amount of biodiversity prospecting rights bought under the special deal equilibrium increase by nearly 300 percent.

Of course if all firms then engage in such deals the model set out here will not apply and a different model will have to be constructed. Nevertheless we can see that a reduction in the freely available prospecting rights has a major impact.

IV. Some Concluding Remarks

In this paper we have explored the way in which a firm may negotiate for a special deal to obtain genetic material by bioprospecting, with a background in which such material is available effectively on an open access basis. We believe this characterizes the current situation in this field. The open access equilibrium has been set out with firms facing increasing returns to scale in the initial stages of production because of set up costs. The OA equilibrium has been further explored using specific functional forms for the production and demand functions. It turns out that the shadow price of biodiversity is small (generating a value of around one percent of the value of output) and sensitive to the values of α and β, which measure, respectively, the degree to which factors other than biodiversity are important in determining the final output of the firms interested in bioprospecting and the price elasticity of demand for the final product. Not surprisingly the lower the role of biodiversity, the small its shadow price relative to the price of output. The OA equilibrium is also strongly affected by the set up costs (increases reduce the number of firms) and by the costs of other inputs (the higher these costs the smaller the number of firms although the level of output does not fall and can even increase slightly).

When we look at the special deal we find that such deals can be struck, in the sense that the firm gains an increase in profit relative to the OA equilibrium, in which it makes zero profits. The presence of such a deal, however, is not guaranteed. It depends of the parameters of the 'r' function, which determines how the price of the biodiversity increases as the amount bought increases. The lower is the starting value of this function and the lower the slope of the function the more likely it is that profits under the special deal will be positive. They are also more likely to be positive, the greater is the role of biodiversity in the production process (the lower is α), and the lower is the wage relative to the price of output.

The special deal equilibrium may also serve to promote the product and obtain a higher price. If such an impact can be realized the benefits are present and can increase the amount of prospecting rights that are bought, but only by a small amount.

Finally we comment on the impact of a change in the amount of biodiversity prospecting available freely. This can have a major impact on the nature of the special deals, increasing the amount bought and raising the price paid to sellers.

One can question a number of the assumptions of this analysis. One of the most obvious is that if a special deal works for one firm, why does it not work for all, and thus why do we not move to a private equilibrium. The answer that immediately comes to mind is that the arrangements under which the deals are worked out are not easy or transparent and resources are needed to achieve the deal and to keep it operating. To some extent any returns to the arrangements are then returns to the initiative of negotiating under uncertainty and in a risky environment. As these risks decline, we will see a move away from OA, but that is not the current situation.

We should also explore the possibility that, as the deal is struck, the amount of materials that can be extracted will vary according to the kind of deal. Under carefully managed conservation resources it may be possible to get much more material than under a looser agreement to bioprospecting in a given area. To some extent the r function is intended to capture that but it does so in a rather mechanistic way.

Finally we can look more closely into the production structure of firms interested in bioprospecting and in particular model the role of uncertainty, which is critical to the activities of such firms.

To conclude we return to the question posed in the title of this paper. We judge the value of bioprospecting contracts relative to the shadow price of biodiversity in the OA equilibrium in which they are embedded. We find that, under a range of conditions the price will be fraction of that shadow price. More work is needed to determine the real values.

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ANNEX:

Table 1 A review of existing bioprospecting contracts

Contractors and Legal Nature of the parties	Date of Signature, Duration and Possibility to Renew	Contract Payment of biodiversity	R&D, Patenting and Biodiversity Protection Obligations	Other Obligations
INBio (national biodiversity institute of Costa Rica, non-profit, public interest organization &Merck (private company)	1991 (2 years) Renewable	Lump-sum transfer	- Royalties Sharing -Technology transfer to develop local preparations and screening capabilities - Obligation for the private company to financially contribute to protect biodiversity	No Exclusive contracts - Common use of the resource
ICBG (International Cooperative Biodiversity Group, U.S: governmental venture) & Bristol-Myers Squibb, Monsanto, and Glaxo Wellcome (consortium of private companies)	1993 (5 years) Renewable	Lump-sum transfer	- No Royalties Sharing - No technology transfer to develop local preparations and screening - Obligation for the private company to financially contribute to protect biodiversity	No Exclusive contracts - Common use of the resource
European botanical Gardens (EU public institutions) & U.S. Phytera (private company)	1996 (11 years) Renewable	Payment per plant	-Royalties Sharing - No technology transfer to develop local preparations and screening - No Obligation for the private company to financially contribute to protect biodiversity	Exclusive contracts - Common use of the resource
TBGRI (Tropical Botanical Garden and Research Institute in Kerala, public institutions) & Arya Vaidya Pharmacy Coimbator Ltd (private company)	1996 (11 years) Renewable	Lump-sum transfer	- Royalties Sharing -Technology transfer to develop local preparations and screening capabilities. Investment in the Kani Community for human capital formation - Obligation for the private company to financially contribute to protect biodiversity	Exclusive contracts - Common use of the resource
Yellowstone National Park (U.S. public institution) & Diversa (private company)	1997 (10 years) Renewable	Lump-sum transfer	Royalties Sharing - No Technology transfer to develop local preparation and screening capabilities. - No Obligation for the private company to financially contribute to protect biodiversity	No Exclusive contracts - Common use of the resource

Table 1 A review on the existing bioprospecting contracts (cont.)

CSIR (The Bio/Chemtek division of South Africa's Commission on Scientific and Industrial Research, public institution) & Diversa (private company)	1998 (9 years) Renewable	No monetary transfer	No Royalties Sharing Technology transfer to develop local preparations and screening capabilities for traditional healers No Obligation for the private company to financially contribute to protect biodiversity	Exclusive contracts - Common use of the resource
Brazilian Extracta (public institution) & Glaxo Wellcome (private company)	1999 (3 years) Non Renewable	Lump-sum transfer	Royalties Sharing Technology transfer to develop local preparation and screening capabilities Obligation for the private company to financially contribute to protect biodiversity	No Exclusive contracts - Common use of the resource
Department of Chemistry University of South Pacific (public institution) & Smith Kline Beecham (private company)	1995 (3 years) Renewable	Non Monetary	Royalties Sharing Technology transfer to develop local preparation and screening capabilities. Investment in the Verata Community for human capital formation Obligation for the private company to financially contribute to protect biodiversity	Exclusive contracts - Common use of the resource

Sources: Taken from Ding, Nunes and Onofri, 2007. Original sources include: (Breibart 1997; ICBG 1997; Mulholland and Wilman 1998; Neto and Dickson 1999; Ten Kate and Laird 1999; Merson 2000; Simpson 2001; Nunes and Bergh 2001, Artuso 2002; Greer and Harvey 2004; Dedeurwaerdere et al. 2005)