On the Distribution of Benefits Arising From Bioprospecting Between the North and the South

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Abstract

Bioprospecting is a measure aiming at protecting biodiversity. It is based on the Convention on Biological Diversity (CBD), which states that the benefits arising out of the utilization of genetic resources should be shared on a fair and equitable basis between the contracting countries. The attempt of this paper is to investigate theoretically the issue of distribution of benefits between a developed and a developing country (the North and the South) in bioprospecting for pharmaceutical products by using the genetic resources in the rainforest and the traditional knowledge possessed by the South. It is shown that the profits should be shared between the North and the South according to the level of contribution to R&D.

Key words: Bioprospecting, the CBD, Benefit-sharing, Equity, Traditional knowledge.

JEL Classification: Q56, Q57, Q58.

1 Introduction

Bioprospecting is an attractive measure aimed at protecting biodiversity. It is very often an attempt by pharmaceutical corporations or agribusiness in developed countries to develop new drugs or crops by using the genetic resources that are possessed in natural capital stocks, such as rainforests, in developing countries. In exchange for gaining access to the regions, corporations contract to make substantial payments to the source country of the genetic resources, and also pay royalties if products with commercial value result from the project. Roughly speaking, a bioprospecting project gives a developing country an incentive to conserve its own natural capital stock, in that conservation can lead to greater benefits than its opportunity costs; benefits from deforestation for ranching or agriculture, for example, must be smaller than those under bioprospecting for the country.

Bioprospecting is based on the Convention on Biological Diversity (CBD). The CBD acknowledges that the source country has sovereign property rights over its natural resources. Thus, it might be natural to consider that the source country is eligible to share the benefits from bioprospecting. In fact, Articles 1 and 19 of the CBD refer to benefit-sharing; they require that the benefits arising out of the utilization of genetic resources should be shared on a fair and equitable basis between the contracting countries.

However, how should a "fair and equitable" distribution be defined in specific terms? Economics has a long history investigating this issue, but it is still unsolved, mainly because there is no agreement on what fairness or equity points to. This sharply contrasts with the area of efficiency, where, needless to say, the concept of Pareto efficiency is unanimously accepted.

In the literature on bioprospecting, most studies are devoted to other important issues such as the value of biodiversity, rather than distributional questions. In studies on the value of biodiversity for the development of new products, for example, Simpson, Sedjo and Reid (1996) focus on the value of marginal species and show that this value might not be sufficient to encourage the conservation. Costell and Ward (2006) also derive similar implications. On the contrary, Rausser and Small (2000) claim, by numerical simulation, that the bioprospecting value of certain genetic resources could provide a large enough incentive for conservation. Craft and Simpson (2001), using two theoretical models, suggest that the private value of marginal species is likely to be small, but the social value can be large.

On the other hand, Bhat (1999) investigates the protection of intellectual property rights in bioprospecting and demonstrates that it can promote the conservation of biodiversity under a cooperative agreement among the parties involved. Nunes and van den Bergh (2001) examine the methods to value biodiversity under bioprospecting. Artuso (2002) does deal with the problem of benefit-sharing, but does not study monetary distribution under a theoretical framework.

The attempt of this paper is to investigate the issue of fairness or equity in benefit-sharing in bioprospecting from a theoretical viewpoint. But we do not intend to provide our own definition on what a fair or an equitable distribution in bioprospecting means. Instead of doing this, we attempt to show how Pareto efficiency, or the global optimality, determines the way of monetary transfer between contracting countries in an economy with bioprospecting. By showing this, we can claim what types of distributional contract should be selected or should be excluded in terms of Pareto efficiency, if a fair and equitable distributional contract needs to satisfy conditions of efficiency.

We suppose an economy where a firm in a developed country (the North) develops a pharmaceutical product using the genetic resources in a rainforest that a developing country (the South) conserves. We consider a distributional contract between the two countries such that the North pays to the South according to the scale of rainforest conserved for bioprospecting. Moreover, if the new pharmaceutical product is commercially successful, then some part of the profits from the sale of the product goes to the South.

We consider the case that the South can contribute to R&D; for example, it collects and screens the genetic resources. In this case, therefore, the South expends some part of the R&D costs. For the contribution, the South can use "traditional knowledge" that is inherited in indigenous communities in the country. ten Kate and Laird (1999) survey the studies of the importance of traditional knowledge in drug discovery. According to the survey, "[t]he ethnobotanical approach to drug discovery—the use of people's knowledge and experiences of the medicinal properties of plants and other genetic resources to guide drug discovery—has yielded most of the plant-based pharmaceuticals in use today". [1] That is, the South contributes to R&D, providing traditional knowledge that must be useful in bioprospecting, in addition to conserving rainforest.

In this case, we examine what kind of the distributional contract will be compatible with efficiency, and in particular what proportion of the profits from the sale of pharmaceutical product should go to the South. Under conditions of efficiency, we show that the profits should be shared between the North and the South according to the level of contribution to R&D of the pharmaceutical product. Although "fair" or "equitable" benefit-sharing may require the

[1] See p.61 in ten Kate and Laird (1999).

distribution of the profits to reflect that the South provides the genetic resources and traditional knowledge, efficiency never allows this.

This paper is constructed as follows: the section 2 introduces the model for this paper. Section 3 studies the monetary transfer system to attain the efficiency. Section 4 summarizes and presents some conclusions.

2 The Model

We consider an economy where there are two countries, S (the South), and N (the North). Country S is a developing country with a rainforest that is rich in biodiversity. On the other hand, country N is a well developed country with advanced scientific technology.

In what follows, the original and the conserved scales of the rainforest are denoted by $\bar{L}$ and L, respectively. Country S can transform its rainforest into ranching or agricultural land, which is represented by $A(=\bar{L}-L)$. The net benefit from this transformation is expressed by

$$\mu = \mu(A), \mu' > 0, \mu'' < 0 \tag{1}$$

On the other hand, the rainforest has direct and indirect economic values for the South, derived from its various functions. This value, V, is expressed by

$$V = V(L), V'(L) > 0, V''(L) < 0 \tag{2}$$

The rainforest also may have global environmental value that is not reflected in V. This is represented as $G(L)$, with $G'(L) > 0$ and $G''(L) \leq 0$.

Now suppose that both the North and the South jointly try to develop a pharmaceutical product, using the biodiversity of country S. Let R expresse the total R&D expenditure for the new pharmaceutical product, which is determined by the North. R involves the cost of all stages of R&D; from the collection of samples to clinical test.

The South can contribute to R&D in the first few stages. For example, it can collect samples from the rainforest and do some activities such as primary screens. We express the contribution of the South to R&D as a fraction β of R; the contribution amounts to βR. Since the South can contribute only in the first few stages of R&D, the rate of contribution β must have a maximum, which is less than one. We denote the maximum by $\bar{\beta}(< 1)$. That is,

$$\beta \in [0, \bar{\beta}] \tag{3}$$

For a while, we assume that β is a constant.

On the other hand, the size of the rainforest conserved, L, is determined by the South herself.

Let $P(r, l)$ represent the probability that the development will result in commercial success. Here

$$r = \lambda R, l = \gamma L, \lambda, \gamma \geq 1 \tag{4}$$

Here λ and γ are multipliers that increase the effect of $R\&D$ and conserving rainforest. Later, we will relate λ and γ to the traditional knowledge owned by the South.

We assume that $P(0, l) = P(r, 0) = 0$, $P_r(\equiv \partial P(r, l)/\partial r) > 0$, $P_l(\equiv \partial P(r, l)/\partial l) > 0$, $P_{rr}(\equiv \partial^2 P(r, l)/\partial r^2) < 0$ and $P_{ll}(\equiv \partial^2 P(r, l)/\partial l^2) < 0$ for $(r, l) > (0, 0)$. Furthermore, we suppose that

$$P_{rr} P_{ll} - (P_{rl})^2 > 0 \tag{5}$$

Therefore, P is strictly concave.

On the other hand, let M stand for the prospective profit from the pharmaceutical product if the joint venture succeeds in developing and commercializing it. In the bioprospecting project, the North transfers to the South $\alpha(>0)$ per hectare of rainforest conserved for the project as an advance payment. Moreover, if the project succeeds, then both countries share the profit M; the North receives $\theta_N M$ and the South $\theta_S M(\equiv(1-\theta_N)M)$, where $0<\theta_N\leq 1$. That is, $\theta_S M$ can be interpreted as royalties for the use of genetic resources by the North.

In the contribution to R&D, the South can utilize "traditional knowledge" that is inherited in the indigenous communities in the conserved rainforest. The utilization might increase the probability of a commercially success in bioprospecting, since, for example, the knowledge can tell the wild species that may own the genetic resources for pharmaceutical products, so that the efficiency of R&D might be raised. We express the effect of inputting traditional knowledge as follows.

$$P = P(\lambda R, \gamma L), \lambda, \gamma \geq 1 \tag{6}$$

Here λ and γ are multipliers that increase the effect of $R\&D$ and conserving rainforest. We suppose that the multipliers depend on the rate of contribution of the South to R&D and the usefulness of knowledge. That is,

$$\begin{aligned} \lambda &= \lambda(\beta, k), \\ \gamma &= \gamma(\beta, k), \end{aligned} \tag{7}$$

where $k(k\geq 0)$ represents the usefulness of traditional knowledge in bioprospecting. We express that the knowledge is useful by k being positive. We assume

$$\lambda(0,k) = \lambda(\beta,0) = \gamma(0,k) = \gamma(\beta,0) = 1, \tag{8}$$

and

$$\frac{\partial \lambda}{\partial k} > 0, \frac{\partial \gamma}{\partial k} > 0, \text{if } \beta > 0. \tag{9}$$

That is, if the South does not contribute to R&D so that traditional knowledge cannot be employed, then the probability is unchanged. Moreover, more useful traditional knowledge raises the probability P, if the South contributes to R&D. In addition, we suppose that the more the South contributes to R&D with traditional knowledge that is useful for R&D, the more the efficiency of R&D increases. That is, $\frac{\partial \lambda}{\partial \beta} > 0$ and $\frac{\partial \gamma}{\partial \beta} > 0$ if $k > 0$. In what follows, we refer to this transfer system as (θ_N, α).

2.1 Global welfare and the net benefits of the North and the South

The global welfare, W_G, is represented by

$$W_G = P(r, l)M - R + \mu(A) + V(L) + G(L) \tag{10}$$

Here PM is the expected profit from the bioprospecting. Thus, the (ex ante) global optimum is attained if the following conditions are met.

$$\begin{aligned} \lambda P_r M &= 1, \\ \gamma P_l M + V'(L) + G'(L) &= \mu'(A) \end{aligned} \tag{11}$$

We denote the global optimum by (R^*, L^*). [2] Also, P_r^* and P_l^* represent $\partial P(\lambda R^*, \gamma L^*)/\partial r$ and $\partial P(\lambda R^*, \gamma L^*)/\partial l$ respectively.

On the other hand, the expected net benefit for country N, W_N, is expressed by

$$W_N = \theta_N P(\lambda R, \gamma L)M - (1 - \beta)R - \alpha L \tag{12}$$

[2] We assume that (R, L) that satisfies (11) exists. From our assumptions on P, μ, V and G, the second order condition $P_{rr}M(P_{ll}M + \mu'' + V'' + G'') - (P_{rl}M)^2 > 0$ is satisfied there.

The North determines R to maximize its own net benefit, which leads to

$$P_r M = \frac{1-\beta}{\lambda\theta_N} \tag{13}$$

Also, that of country S, W_S, is defined as:

$$W_S = \theta_S P(\lambda R, \gamma L)M + \alpha L + V(L) + \mu(A) - \beta R \tag{14}$$

The South determines L to maximize its net benefit, from which we have

$$\alpha = \mu'(A) - \gamma\theta_S P_l M - V'(L) \tag{15}$$

3 Monetary transfer system to attain the global optimum

In this section, we explore a monetary transfer system that can achieve the global optimum. Given (β, k), $(\theta_N, \alpha; \beta, k)$ represents an income transfer system. Can this transfer system attain the global optimum (R^*, L^*)? If so, what values do θ_N and α take?

As we show below, (11) is attained by defining (θ_N, α) as follows:

$$\theta_N = 1 - \beta \tag{16}$$

and

$$\alpha = \gamma\theta_N P_l^* M + G'(L^*) = \gamma(1-\beta)P_l^* M + G'(L^*) \tag{17}$$

Suppose that (11) is satisfied. Then, from (13), we obtain (16), and subsequently (17) is derived.

Next, suppose that (16) and (17) hold. Then, it is obvious (11) holds. Therefore, we have the following proposition.

Proposition 1 *Suppose that the monetary transfer system for bioprospecting is prescribed by $(\theta_N, \alpha; \beta, k)$ where $P = P(\lambda R, \gamma L)$. Then it attains the global optimum if and only if $\theta_N = 1-\beta$, i.e., $\theta_S = \beta$ and $\alpha = \gamma(1-\beta)P_l^* M + G'(L^*)$.*

From the determination of θ_S, the rate of profit sharing increases with β but independent of k. That is, the rate of profit sharing is the same as that of the contribution of the South to R&D, regardless of whether traditional knowledge is useful or not.

From this property, it is straightforward to have the next corollary.

Corollary 1 *If the South does not contribute to R&D, i.e., $\beta = 0$, then the rate of profit sharing for the South, θ_S, is equivalent to zero.*

if $k > 0$, R^* and L^* in general change with β and k. Obviously global welfare at the optimum increases with β and k in terms of the definition of W_G. But regarding the South's net benefit, we cannot judge from proposition 1 whether W_S will increase with them or not; since $\theta_S = \beta$, $\theta_S PM$ increases with β but it is not certain whether $\alpha L(\equiv ((1-\theta_S)\gamma P_l L + G'(L))L)$ also increases. Let us see this aspect below.

Differentiating (11) with β, we obtain

$$\begin{aligned}(\lambda P_{rr}\frac{dR}{d\beta} + \gamma P_{rl}\frac{dL}{d\beta})\lambda M &= -(\lambda_\beta P_r + \lambda_\beta \lambda P_{rr} R + \lambda\gamma_\beta P_{rl} L)M \quad (18)\\ (\gamma\lambda P_{rl}\frac{dR}{d\beta} + \gamma^2 P_{ll}\frac{dL}{d\beta})M + H'' dL &= -(\gamma_\beta P_l + \gamma\lambda_\beta P_{rl} R + \gamma\gamma_\beta P_{ll} L)M\end{aligned}$$

From this, we can derive

$$\begin{aligned}\frac{dR}{d\beta} &= -\frac{(\gamma^2 P_{ll} M + H'')(\lambda_\beta P_r + \lambda\lambda_\beta P_{rr} R) - \lambda\gamma P_{rl} M(\gamma_\beta P_l + \gamma\lambda_\beta P_{rl} R)}{\phi} M \quad (19)\\ &+ \frac{H''\lambda\gamma_\beta P_{rl} L}{\phi} M\\ \frac{dL}{d\beta} &= -\frac{\lambda^2 P_{rr} M(\gamma_\beta P_l + \gamma\gamma_\beta P_{ll} L) - \lambda\gamma P_{rl} M(\lambda_\beta P_r + \lambda\gamma_\beta P_{rl} L)}{\phi} M\end{aligned}$$

where

$$\phi = \lambda^2\gamma^2 M^2 (P_{rr} P_{ll} - (P_{rl})^2) + \lambda^2 P_{rr} H'' > 0 \quad (20)$$

and

$$H'' = V'' + \mu'' + G'' \tag{21}$$

The sign of ϕ is unambiguous to be positive since we assume (5) and that V'', G'' and μ'' are all non-negative. From (19), however, the signs of $\frac{dR}{d\beta}$ and $\frac{dL}{d\beta}$ are not definite. To make the argument clearer, we add the following assumptions on P:

$$P_{rl} \geq 0, P_{rrr} \geq 0, P_{lll} \geq 0, G'' = 0 \tag{22}$$

That is, R and L are not complements, P_r and P_l are convex, and G is linear with respect to L. Under (22), it holds that

$$P_r + \lambda P_{rr} R \geq 0, P_l + \gamma P_{ll} L \geq 0 \tag{23}$$

Using this property, it is easy to see

$$\begin{aligned} \frac{dR^*}{d\beta} &> 0 \\ \frac{dL^*}{d\beta} &< 0 \end{aligned} \tag{24}$$

Lemma 1 *Suppose that traditional knowledge is useful, i.e., $k > 0$. Then, under (22), a higher contribution of the South to R&D increases the optimal R&D, but decreases the optimal scale of conservation of rainforest. That is, $\frac{dR^*}{d\beta} > 0$ and $\frac{dL^*}{d\beta} < 0$ hold.*

Using this lemma, the effect on the South's net benefit can be derived:

$$\frac{dW_S}{d\beta} = (PM - R) + \beta\lambda_\beta P_r RM + \beta\gamma_\beta P_l LM + L\frac{d\alpha}{d\beta} \tag{25}$$

Here,

$$\begin{aligned} L\frac{d\alpha}{d\beta} &= -\gamma P_l LM + (1-\beta)\gamma LM(\lambda P_{rl}\frac{dR}{d\beta} + \gamma P_{ll}\frac{dL}{d\beta} \\ &+ \lambda_\beta P_{rl} R) + (1-\beta)\gamma_\beta LM(P_l + \gamma P_{ll} L) + G'' L\frac{dL}{d\beta} \end{aligned} \tag{26}$$

Since we have lemma 1 so that $L\frac{d\alpha}{d\beta} > 0$ and since $PM - \gamma P_l LM - R > 0$ by strict concavity of P [3] , we obtain

$$\frac{dW_S}{d\beta} > 0 \tag{27}$$

Thus, we have the following proposition.

Proposition 2 *Suppose that traditional knowledge is useful, i.e., $k > 0$. Then, under (22), a higher contribution of the South to R&D increases its net benefit, i.e., $\frac{dW_S}{d\beta} > 0$.*

Note that this also holds even if $k = 0$, which means $\lambda_\beta = \gamma_\beta = 1$ so that $\frac{dR}{d\beta} = \frac{dL}{d\beta} = 0$. Thus, even when the South does not use traditional knowledge, the South's welfare increases with the rate of contribution.

Let us express the level of the South's net benefit under (β, k) by $W_S(\beta, k)$. Since $W_S(0, k) = W_S(0, 0)$ $(\forall k \geq 0)$, we obtain from proposition 2

$$W_S(\beta, k) > W_S(0, 0), \forall\ (\beta, k) >> (0, 0) \tag{28}$$

$W_S(0, 0)$ is the South's net benefit when the South does not contribute to R&D. That is, the net benefit of the South will increase by taking part in R&D with traditional knowledge. In summary, we can claim:

Corollary 2 *Suppose (22). Then, the South will be better off by contributing to R&D with traditional knowledge.*

Hence, the South should contribute to R&D as much as possible, which will raise the South's net benefit. Thus, the maximum rate of contribution $\bar{\beta}$ maximizes the net benefit as well as the global welfare, where the rate of profit sharing should be equal to $\bar{\beta}$.

[3] Note that $\lambda P_r MR = R$ by (11), so that $PM - \gamma P_l LM - R = (P - P_l(\gamma L) - P_r(\lambda R))M > 0$.

4 Concluding Remarks

This paper investigates how efficient bioprospecting contracts should be designed with respect to monetary transfers from the North to the South. In particular, the paper focuses on the sharing of profits from the sale of pharmaceutical products.

If fair or equitable sharing is interpreted as "equal division" of profits, our results seem to imply that such a division is not compatible with efficiency. Far from equal division, the rate for the South should be low if the contribution of the South to R&D is also low. In fact, the rate of division of profits must be equivalent to the rate of the contribution to R&D, regardless of the amount of genetic resources and regardless of usefulness of traditional knowledge provided by the South.

In our analysis, the maximum rate of the contribution to R&D is expressed by $\bar{\beta}$. The exact value of $\bar{\beta}$ is not available. However, ten Kate and Laird (1999) say, "[a]bout 37% of R&D budgets in the USA are allocated to discovery-related research, the remaining 63% to the development stage". [4] Since the South can contribute to only a part of discovery-related research, $\bar{\beta}$ might be low enough. Thus, it is possible that the requirement of the CBD concerning the benefit-sharing is not compatible with efficiency, if fairness or equity is interpreted as the equal division of the profits, or as requiring that the rate of profits sharing should reflect the provision of the genetic resources by the South.

However, our analysis is carried out under a simple model that does not involve other aspects of non-monetary transfer, such as biotechnology. Also if we consider that the South is comprised of several actors such as the private and public sectors, intermediaries (e.g. universities, botanic

[4] See ten Kate and Laird (1999), p. 47.

gardens or research institute) and the local communities, [5] and if they behave in different ways, then the analysis will become much more complicated so that the results may not be identical to those derived in this paper. These are left for interesting future studies.

[5] See ten Kate and Laird (1999) for more details on bioprospecting.

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