Monetary and Non-monetary Benefits in Bioprospecting and the Behavior of the Intermediary with Traditional Knowledge

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Abstract

This paper deals with non-monetary benefits arising from bioprospecting for a developing country (the South) as well as monetary benefit. In bioprospecting, collecting and indentifying samples for R&D are sometimes carried out by intermediaries such as non-profit organizations, which do not aim to maximize profits. The aim of this paper is to introduce a theoretical framework to incorporate non-monetary benefits as well as monetary benefits. Moreover, we examine how non-profit behavior (NPB) of the intermediary affects bioprospecting, especially how monetary and non-monetary benefits will be different from those when the intermediary takes for-profit behavior (FPB). In the paper, monetary benefit point to the sample fee and non-monetary benefits indicate technology transfer, employment, and the number of collected and identified samples. Moreover, we examine the effects of traditional knowledge on all these benefits.

Under the NPB, the sample fee and technology transfer are shown to be lower than under the PMB. However, employment of local people and collected samples are demonstrated to be higher under the NPB than under the PMB. On the other hand, the profit of the pharmaceutical company (the North) is higher when the South takes the NPB. Our analysis also demonstrates that traditional knowledge does not benefit the South except increasing the collected samples. On the contrary, the North always benefits from traditional knowledge. This suggests that it might not be unreasonable to require some measures to redistribute a part of profits to the South, when traditional knowledge is used in bioprospecting.

Key Words: bioprospecting; intermediary; monetary benefit; non-monetary benefit; traditional knowledge.

1 Introduction

Bioprospecting is drawing a growing attention as a measure to conserve ecosystems rich in biodiversity. A typical form of bioprospecting is a joint venture between a pharmaceutical company in developed countries (the North) and a developing country (the South) to develop a new pharmaceutical product using the genetic resources that the developed country owns in its natural resources.

From bioprospecting, the South receives a number of benefits. ten Kate and Laird (1999, pp.63-77) classify these benefits into two groups, that is, monetary and non-monetary benefits. According to ten Kate and Laird, monetary benefits include various forms of payments, such as advance payment, milestone payment, and royalties. Moreover, since the South is usually involved in the primary stages of bioprospecting, collecting fee of samples for the R&D is also involved in this category of benefits.

On the other hand, non-monetary benefits arise in bioprospecting. ten Kate and Laird (1999, p.68) describe the non-monetary benefits as training, capacity building, technology transfer of equipment and know-how, and information of the biodiversity in the source country. Moreover, Visser et al. (2004) include local development such as social recognition and creation of employment. That is, by cooperating with the firm in the North, the South is provided with a foundation of research and with the opportunity to employ and train the scientists and local people for collecting and identifying samples, which will deepen the knowledge of the South's own biodiversity.

For example, Mercy (2000) reports that bioprospecting between Merck and INBio in Costa Rica, which took place in 1991, was of the great value for INBio, not only in monetary aspect, but also in non-monetary aspect such as the transfer of assaying technology from Merck to INBio and the training of staff in its use. Moreover, local villagers were trained as "parataxonomists" and employed in the scientific identification and collection of species based on the traditional knowledge about the biodiversity. Furthermore, Costa Rica could begin to document its diverse range of plants and animals.

As the case of INBio shows, collecting and indentifying samples for R&D are sometimes carried out by intermediaries such as non-profit organizations. A few multinational pharmaceutical companies conduct the field collections, but the majority of companies outsource the acquisition of samples to non-profit organizations such as universities, research institutes, and botanic gardens (ten Kate and Laird, 1999, p.58). From the definition of non-profit organizations, they do not generally intend to maximize their profits as private firms do, but they must be strongly interested in non-monetary benefits by their nature.

The aim of this paper is to introduce a theoretical framework to incorporate non-monetary benefits as well as monetary benefits, and to examine how such a behavior of intermediary affects bioprospecting, especially how monetary and non-monetary benefits will be different from those when the intermediary is a standard profit maximizing firm. [1] In the paper, monetary benefit point to the sample fee and non-monetary benefits indicate technology transfer, creation of employment as local development, and the number of collected and identified samples as information of biodiversity. Moreover, we examine the effects of traditional knowledge on all these benefits, since traditional knowledge is very important in drug discovery and in fact yielded most of the plant-based pharmaceuticals in use today as the ethnobotanical approach (ten Kate and Laird 1999, p.61).

We suppose a bioprospecting between a pharmaceutical company in the North and an intermediary in the South with traditional knowledge. The latter is transferred technology from the North, by the use of which, the intermediary provides the company with the samples collected and identified,

[1] In health economics, there are many studies on behaviors of non-profit and for-profit hospitals since Newhouse (1970). The review of the literature is included in James (2002).

employing and training the local people. The intermediary is either a research institute or a standard firm. In the former case, the research institute does not to maximize its profit but aims to maximize non-monetary benefits. Therefore, the research institute employs and trains the local people and also increases the number of collected and identified samples as long as the profit is non-negative. In the case of standar firm, the profit is maximized.

On the other hand, we suppose that the pharmaceutical company, the North, determines the sample fee as well as the level of technology transfer to maximize the profit. We derive the equilibrium sample fee, technology transfer, the employment and the number of samples that are collected and identified under the behavior of intermediary as research institute, which we call "non-profit behavior" (NPB). Then they are compared with those under the behavior as the standard firm, which is referred to as "for-profit behavior" (FPB).

In the literature of bioprospecting, some studies focus on the monetary benefit related to the price of sample fee. Simpson, Sedjo and Reid (1996) investigate this aspect in terms of the value of marginal species and show that this value is not high enough to encourage the conservation. Markandya and Nunes (2007) also point out that the sample fee is too low because of the occurrence of "special dealh in the contract of bioprospecting. On the other hand, Rausser and Small (2000) claim that the bioprospecting value of certain genetic resources could provide a large enough incentive for conservation by reducing the search cost.

However, although some works refer to the existence and the importance of non-monetary benefits (ten Kate and Laird 1999; Visser et al. 2004; Ding, Nunes and Muso 2006), there is still unsolved how non-monetary benefits are determined as well as monetary benefit, in particular under the situation that the intermediary is a non-profit organization, which is usually the case in bioprospecting. This paper contributes to the elucidation of this aspect.

Our analysis shows that monetary benefit, the equilibrium sample fee, is always lower under the NPB than that under the FPB. On the aspect of non-monetary benefits, technology transfer is also smaller under the NPB than that under the FPB. However, employment of local people and the number of samples collected are greater under the NPB than under the PBM. Moreover, we also prove that all of monetary and non-monetary benefits except the number of samples are negatively affected by traditional knowledge, no matter how the intermediary behaves. Finally, apart from the above benefits for the South, we demonstrate that the profit of the North under the NPB of the intermediary is always greater than that under the FPB. Traditional knowledge is also shown to benefit the North but to reduce the profit of the South under the FPB.

Therefore, we can conclude that the NPB of the intermediary is shown to be beneficial to the information of biodiversity in the South and to the local development by creating employment. However, the behavior is disadvantageous to technology transfer from the North and also to the sample fee. Moreover, traditional knowledge enhances only the information of biodiversity but decreases other benefits, while it benefits the North. This suggests that it might not be unreasonable to require some measures to redistribute a part of profits to the South, when traditional knowledge is used in bioprospecting. This redistribution may encourage the South to preserve traditional knowledge.

In addition to the above analysis, we also examine how the probability of success in the development of pharmaceutical product and the global welfare will be under the NPB and the FPB. The former is important from the viewpoint of consumers who look forward to the development of the drug, and the latter from the viewpoint of standard criterion in economics, though non-monetary benefits must be taken into consideration in this case. We show that the NPB is always better in the aspect of the probability. On the other hand, the level of global welfare with non-monetary benefits depends on parameters we define, so it is not certain whether the NPB contributes more to the global welfare or not, except the case that the parameters take some values.

The construction of the paper is as follows. In section 2, we introduce our model. In section 3, monetary benefit is analyzed. In section 4, non-monetary benefits are examined. In section 5, we provide with the numerical comparisons of monetary and non-monetary benefits under the NPB and the FPB. In section 6, some other benefits except monetary and non-monetary benefits for the South are examined. That is, the profit of the North and that of the intermediary under the FPB are explored and we will have a brief study on the probability and the global welfare. In section 7, some concluding remarks are stated.

2 The Model

We consider an economy where there are two countries, the South and the North. The South is a developing country with rainforest that is rich in biodiversity. On the other hand, the North is a pharmaceutical company of well developed country with advanced scientific technology. Now suppose that both the North and the South jointly try to develop a pharmaceutical product, using the biodiversity of the South.

In the bioprospecting, the South conserves the natural resources from which samples are collected to provide the genetic resources for the development of pharmaceutical products. There is an intermediary in the South to collect samples and identify them by employing the local people who have traditional knowledge of how to use the biodiversity of the rainforest. The intermediary also trains local people so that they can collect samples that may have the genetic resources for drugs and identify them efficiently. That is, the trained local people will play a role as "parataxonomists".

For the work of the intermediary, the North transfers technology to the South. The technology is used for the intermediary to identify samples and primarily screen them as well as to train the local people.

The number of samples identified, Y, is assumed to depend on the number of local people and scientists to participate in the project, L, and the level of technology T that the North transfers, and the traditional knowledge that the local people already have. The usefulness of the traditional knowledge is expressed by s. So we suppose Y is the function of T and L, given s as:

$$Y = F(T, L; s), F_T' > 0, F_L' > 0. \tag{1}$$

Let us specify the function as

$$Y = sT^b L^c, b + c = 1 \tag{2}$$

The samples collected and indentified are supplied to the North, by exchange of which q per sample is paid to the intermediary. That is, q is a sample fee. Thus, the profit of the intermediary π_S is expressed as:

$$\pi_S = qsT^b L^c - wL, \tag{3}$$

where w stands for the wage rate prevailing in the South.

In this paper, we suppose two type of intermediary. One is a research institute, which is mainly interested in some of non-monetary benefits such as technology transfer, education of local people and deepening the knowledge of biodiversity in the country. We suppose that the institute tries to employ and train as much as the local people in order to collect and identify samples as long as the profit is not negative, using the technology transferred by the North. Thus, the institute does not aim to maximize the profit but behaves to equalize the profit to zero. That is, the profit of the institute is a sort of budget constraint in employing the local people to participate in the project. We call such behavior “non-profit behavior” (NPB).

Another type of intermediary we suppose is a standard firm to maximize the profit. The firm tries to employ the local people as long as the profit is increased. We refer to this type of behavior as “for-profit behavior”(FPB).

On the other hand, the North operates R&D by using the samples provided by the South. The expenditure for R&D is represented by R. The expected profit of the North, π_N, is defined as:

$$\pi_N = P(Y, R)M - qY - T - R \tag{4}$$

where P expresses the probability that the bioprospecting results in a commercially success and M stands for the profit arising from the successfully developed product. We assume that $P(0, R) = P(Y, 0) = 0, P'_Y > 0, P'_R > 0$, $P''_Y < 0$ and $P''_R < 0$. We also suppose that q is determined by the North. Thus, the North determines T, R and q to maximize its profit. Throughout the paper, we assume that interior solution of (q, T, R) holds both under the NPB and under the FPB that the intermediary of the South takes.

3 Equilibrium sample fee

In this section, we investigate the equilibrium price of q, the sample fee, depending on the behaviors of the intermediary and the level of traditional knowledge.

3.1 Sample fee under the NPB

First of all, we examine how q differs between under the NPB taken by the research institute. Under our supposition, the institute behaves to equalize its profit to zero. Thus, for a given T, the institute decides to employ the local people to satisfy $\pi_S = 0$, so we obtain the number of the local people employed L^* as

$$L^* = (\frac{qs}{w})^{\frac{1}{b}} T. \tag{5}$$

L^* increases with T in a proportional way.

On the other hand, the North determines R&D expenditure, technology transfer and the price per sample to maximize its own profit. Since L is determined as (5) so that

$$Y = ATq^{\frac{1-b}{b}}, A = s^{\frac{1}{b}} w^{-\frac{1-b}{b}} \tag{6}$$

Using this, the profit of the North is rewritten as:

$$\pi_N = P(ATq^{\frac{1-b}{b}}, R)M - ATq^{\frac{1}{b}} - T - R \tag{7}$$

The North determines R, q and T to maximize the profit. The first order condition with respect to q leads to:

$$(\frac{1-b}{b}) P'_Y ATMq^{\frac{1-2b}{b}} - (\frac{1}{b}) ATq^{\frac{1-b}{b}} = 0 \tag{8}$$

so that we have

$$P'_Y M = \frac{q}{1-b}. \tag{9}$$

The first order condition with respect to T, on the other hand, is:

$$(P'_Y M - q)Aq^{\frac{1-b}{b}} = 1. \tag{10}$$

From these, we obtain the equilibrium sample fee q^* as:

$$q^* = (\frac{1-b}{bA})^b \tag{11}$$

3.2 Sample fee under the FPB

Let us compare q^* with the sample fee when the intermediary is a firm to maximize its profit. The first order condition of the intermediary under the FPB leads to

$$(1-b)qsT^b L^{-b} = w \tag{12}$$

so that we obtain the number of the local people employed L^m as

$$L^m = (\frac{(1-b)qs}{w})^{\frac{1}{b}} T \tag{13}$$

Similarly in the previous subsection, the number of samples collected and indentified is:

$$Y = (1-b)^{\frac{1-b}{b}} ATq^{\frac{1-b}{b}}, \tag{14}$$

Thus, the equilibrium price of the sample q^m is determined as:

$$q^m = (\frac{1-b}{bA})^b (\frac{1}{1-b})^{1-b} \tag{15}$$

Now let us look at q^* and q^m given in (11) and (15). Both of them are increasing with w and decreasing with s. Moreover, q^* is always $(1-b)^{1-b}(< 1)$ times as high as q^m. Note also that they are independent of M and the probability function P. The results are summarized in what follows:

Proposition 1 *Suppose (2). The sample fee q^* under the NPB is determined at $q^* = (\frac{1-b}{bA})^b$ where $A = s^{1/b} w^{-(1-b)/b}$. On the other hand, under the FPB, the fee $q^m = (\frac{1-b}{bA})^b (\frac{1}{1-b})^{1-b}$. Both of them are determined independently of the profit when the project results in a success, M, and the probability function of the success.*

3.3 Effect of traditional knowledge

It is easy to see from proposition 1 that q^* and q^m are *decreasing* with s. That is, useful traditional knowledge lowers the sample fee no matter how the intermediary behaves. This is stated in the proposition below.

Proposition 2 *Suppose (2). The equilibrium sample price under the NPB and the FPB declines as traditional knowledge is more useful.*

We can attribute the reason of the result to the labor market in the South. We do not suppose here that traditional knowledge is reflected in the prevailing wage rate in the South and that the the intermediary can employ the local people at that rate as much as possible. That is, w is independent of s and the supply curve of labor that the intermediary faces is horizontal at w. Then even if the traditional knowledge is more useful, that is, s rises, the labor supply curve does not move, but the marginal cost of the intermediary to supply any given amount of samples will drop because the local people are more efficient. That is, the supply curve of sample shifts downward for a given technology transfer as s increases, by which the equilibrium price of sample fall down.

We have shown that both the NPB and a useful traditional knowledge lower the sample fee. That the fee is too low is pointed out by Markandya and Nunes (2007), where they attribute the cause to the occurrence of "special deal", which means that a single firm contracts with a supplier to use more biodiversity. They derive that the price of biodiversity is lower than the shadow value under open access. Also, Simpson, Sedjo and Reid (1996) justify that the fee is low in terms of expected value of marginal species. Our result shows that there are some other factors in bioprospecting that will also contribute to lowering the sample fee; in particular the behavior of intermediary such as research institute and traditional knowledge are shown to be the important factors.

4 Non-monetary benefits

In this section, we focus on another benefit arising from bioprospecting, non-monetary benefits. We assume in this paper that there are three kinds of non-monetary benefits. First of all, technology transfer T is one of them, as technology transfer improves the South's research environment.

The second one is the number of local people to be employed, which is represented by L. This is also important for the South as the employment not only means the opportunity for the local people to work, but also means the education and training of them, which leads to local development (Visser et al. 2004). The final one of the benefits is the number of samples identified, as the number shows how many animals and plants are accurately documented and how much the knowledge of the South of its own biodiversity is deepened through the project. That is, the number expresses the information of the biodiversity in the South. This is expressed by Y, the supply of samples for R&D.

In order to derive T explicitly, we specify the probability function as:

$$P(Y,R) = 1 - e^{-aYR}, a > 0 \tag{16}$$

This shows $P'_Y > 0, P'_R > 0, P''_Y < 0$ and $P''_R < 0$. Under this specification, the maximization of (4) with R leads to

$$aYe^{-aYR}M = 1 \tag{17}$$

Thus, we have

$$R = \frac{\log aMY}{aY} \tag{18}$$

Since we suppose the interior solution, the optimum R is positive which is equivalent to assume $aMY > 1$ in the equilibrium. Therefore, assuming $aMY > 1$, we obtain

$$P(Y,R) = 1 - e^{-\log aMY} = 1 - \frac{1}{aMY} \tag{19}$$

Thus, the following lemma holds.

Lemma 1 *Suppose (2) and (16). Then under the profit maximization of the North,* $P(Y,R) = 1 - \frac{1}{aMY}$.

4.1 Effects of the behavior of the intermediary

Now we explicitly compare T and L under the NPB with those under the FPB. Note that (L^*, Y^*, q^*) and (L^m, Y^m, q^m) are expressed as

$$L^i = (\frac{kq^i s}{w})^{\frac{1}{b}} T, \tag{20}$$

$$
\begin{aligned}
Y^i &= AT(kq^i)^{\frac{1-b}{b}} \\
q^i &= (\frac{1-b}{bA})^b (k)^{-(1-b)}
\end{aligned}
$$

where $k = 1$ for $i = *$ and $k = 1 - b$ for $i = m$. Using this,

$$
Y^i = k^{1-b} A^b (\frac{1-b}{b})^{1-b} T \tag{21}
$$

Thus, (10) leads to:

$$
P'_Y = \frac{1}{k^{1-b} b^b M A^b (1-b)^{1-b}} \tag{22}
$$

Under the specification of (16) and lemma 1, this equation is rewritten as:

$$
T = \frac{1}{\sqrt{ab^{2-b} k^{1-b} A^b (1-b)^{1-b}}} \tag{23}
$$

Note that T does not depend on M, as q is independent of it. Let us see the level of T when $k = 1$, T^*, and that $k = 1 - b$, T^m, and then compare T^* with T^m. But it is easy to see from (23) that T is decreasing with k. So, we have the proposition.

Proposition 3 *Suppose (2) and (16). Technology transfer under the NPB, T^*, is always smaller than the transfer under the FPB, T^m. Their levels are determined by*

$$
T^* = \frac{1}{\sqrt{ab^{2-b} A^b (1-b)^{1-b}}}, \ T^m = \frac{1}{\sqrt{ab^{2-b} A^b (1-b)^{2(1-b)}}}
$$

From the results, we can derive how many local people participate in bio-prospecting the under the NPB and under the FPB. From (20) and (23), it holds:

$$L^i = (kq^i s/w)^{1/b} T^i = \frac{k^{\frac{1+b}{2}}(1-b)^{\frac{1+b}{2}}}{w\sqrt{ab^{4-b}A^b}} \tag{24}$$

where $k = 1$ for $i = *$ and $k = 1 - b$ for $i = m$. This is obviously increasing with k, so we obtain $L^* > L^m$, which is stated below.

Proposition 4 *Suppose (2) and (16). The number of local people participating in bioprospecting under the NPB, L^*, is always greater than that under the FPB, L^m. Their levels are determined by*

$$L^* = \frac{(1-b)^{\frac{1+b}{2}}}{w\sqrt{ab^{4-b}A^b}}, \ L^m = \frac{(1-b)^{1+b}}{w\sqrt{ab^{4-b}A^b}}.$$

How many local people are educated and participate in bioprospecting can be a focus of the institute playing as a role of intermediary. The above result says that the number of local people under the NPB is always higher than that under the FPB even if technology transfer is lower. This might be an advantage that research institutes or universities are very often in charge of intermediaries in bioprospecting.

Finally, we will see the number of samples collected and identified under the NPB and the FPB. Since (21) and (23) lead to

$$Y^i = k^{(1-b)/2} A^{b/2} (1-b)^{(1-b)/2} b^{-(2-(3/2)b)} a^{-1/2}, \tag{25}$$

we can see $Y^* > Y^m$. The next proposition claims this.

Proposition 5 *Suppose (2) and (16). The number of collected and indentified samples under the NPB, Y^*, is always greater than that under the FPB, Y^m. Their levels are determined by*

$$Y^* = \frac{A^{b/2}(1-b)^{(1-b)/2}}{b^{2-(3/2)b} a^{1/2}}, \ Y^m = \frac{A^{b/2}(1-b)^{1-b}}{b^{2-(3/2)b} a^{1/2}}.$$

4.2 Effects of traditional knowledge on non-monetary benefits and the profit

How will the technology transfer, employment and the number of collected samples vary with traditional knowledge? By (23), (24) and (25), it is easy to see that under both the NPB and the FPB, T^*, T^m, L^*, L^m decrease with s, but Y^* and Y^m increase with s. This property is stated in the proposition below.

Proposition 6 *Suppose (2) and (16). As traditional knowledge is more useful, technology transfer and the employment of local people decrease but the number of samples collected and identified increases under both the NPB and the FPB.*

Traditional knowledge also affects the profit of the intermediary under the FPB. It is obvious that π_S^* declines with s, which is stated below.

Proposition 7 *Suppose (2) and (16). The the profit of the intermediary under the FPB declines as traditional knowledge is more useful.*

5 Numerical comparisons of monetary and non-monetary benefits under the NPB and the FPB

In this section, we show how different monetary and non-monetary benefits under the NPB and the FPB. That is, we derive the rates of $q^*/q^m, T^*/T^m, L^*/L^m$ and Y^*/Y^m.

From propositions 1, 3, 4 and 5, it is easy to see that the following proposition holds.

Proposition 8 *Under (2) and (16), it holds that*

$$\frac{q^*}{q^m} = (1-b)^{1-b} < 1$$

$$\frac{T^*}{T^m} = \sqrt{(1-b)^{1-b}1} < 1$$

$$\frac{L^*}{L^m} = 1/\sqrt{(1-b)^{1+b}} > 1$$

$$\frac{Y^*}{Y^m} = 1/\sqrt{(1-b)^{\sqrt{1-b}}} > 1$$

As this proposition shows, the all the rates depend only b. Let us show how the rates vary as b changes, which is expressed by the table below.

Table 1. q^*/q^m, T^*/T^m, L^*/L^m **and** Y^*/Y^m **when** b **varies from** 0.1 **to** 0.9**.**

b	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
q^*/q^m	0.91	0.84	0.78	0.74	0.71	0.69	0.70	0.72	0.79
T^*/T^m	0.95	0.91	0.88	0.86	0.84	0.83	0.83	0.85	0.89
L^*/L^m	1.06	1.14	1.26	1.43	1.68	2.08	2.78	4.26	8.91
Y^*/Y^m	1.024	1.046	1.064	1.08	1.09	1.096	1.095	1.084	1.059

Table 1 shows the rates as b varies from 0.1 to 0.9. From the table, q^* is lower than q^m by about $9-31\%$ for b within the range. Moreover, T^* is smaller than T^m by about $5-17\%$. On the other hand, L^* is greater than L^m by about $6-791\%$. However, If we assume that $b \leq 0.5$, which shows that supply of samples is not capital intensive, then L^* is changed to be greater than L^m by about $6-68\%$. Furthermore, Y^* is larger than Y^m by $2.3-9.6\%$.

Whether the NPB is better than the FPB or not depends on how high the South values the employment and the number of samples identified, compared with technology transfer. As long as the South has a strong interest in the education and training of the local people and the accumulation of knowledge about its biodiversity, we might say that the NPB has an advantage over the FPB, though sample fee and technology transfer are determined at lower levels.

6 Effects on other benefits

Apart from monetary and non-monetary benefits of the South, we will investigate other benefits of that are affected by the behavior of the intermediary and traditional knowledge, which may also be helpful to evaluate bioprospecting under the NPB.

6.1 Profits of the North and the South

To begin with, we examine how profit of the North varies depending on the behavior of the intermediary. Moreover, we will also see the effects of traditional knowledge on the profits of the North and the South. To see these, we need to look at how R&D expenditure, R, and the total payment for the samples, qY, will be determined under the NPB and the FPB.

The North decides the level of R^i $(i = *, m)$ to satisfy $P_R'(Y^i, R^i)M = 1$ or under (16)

$$R^i = \frac{\log M + \log aY^i}{aY^i}, \; i = *, m. \tag{26}$$

It is easy to see that $\frac{\log M + \log aY^i}{aY^i}$ is decreasing with Y^i. Since $Y^* > Y^m$ by proposition 5, the level of R&D is greater under the FPB of the intermediary than under the NPB.

On the other hand, q^iY^i is calculated as

$$q^iY^i = \frac{(1-b)^{(1+b)/2}}{k^{(1-b)/2}b^{2-(1/2)b}A^{b/2}a^{1/2}} \tag{27}$$

From this, it holds that

$$q^mY^m > q^*Y^* \tag{28}$$

That is, the revenue under the FPB is always larger than that under the NPB. These results are summarized in the following lemma.

Lemma 2 *Under (2) and (16), it holds that* $R^m > R^*$ *and* $q^mY^m > q^*Y^*$.

In what follows, we compare the North's profit under the NPB π_N^* with that under the FPB π_N^m. Using (23), (26) and (27), the profit of the North under (16) is:

$$\pi_N^i = M - \frac{1}{aY^i} - q^iY^i - T^i - R^i, \; i = *, m. \tag{29}$$

From propositions 3, 5 and the lemma 2, we know $T^* < T^m$, $R^* < R^m$, $Y^* > Y^m$ and $q^*Y^* < q^mY^m$, we obtain

$$\pi_N^* > \pi_N^m \tag{30}$$

This is stated in the following proposition.

Proposition 9 *Under (2) and (16), the North's profit under the NPB of the South,* π_N^**, is always greater than that under the FPB,* π_N^m.

That is, the North benefits more if the intermediary takes the NPB. Next, we will see how traditional knowledge affects the profit of the North and also that of the South under the FPB.

From (23) and (27), T^i and $q^i Y^i$ decrease with s, while Y^i increases. Thus, the profit expressed by (29) increases with s. On the other hand, together with (24) and $k = 1 - b$, we obtain

$$\pi_S^m = A^{-b/2} a^{-1/2} b^{-(2-(b/2))} (1-b)^b b, \tag{31}$$

Therefore, π_S^m decreases with s. These results are claimed below.

Proposition 10 *Suppose (2) and (16). The profits of the North under both NPB and FPB increase but that of the South under the FPB decreases as traditional knowledge is more useful.*

Table 2 summaries the effects of traditional knowledge on monetary and non-monetary benefits under the NPB of the intermediary. For the South, only the information of biodiversity, one of non-monetary benefits, will be enhanced when traditional knowledge is more useful. On the other hand, the North always benefits from traditional knowledge. Since the profit of intermediary is always zero under the NPB by definition, $\pi_N^* + \pi_S^*$ also increases by a higher traditional knowledge, so some measures to redistribute a part of profit of the North to the South to compensate for the reduction of q, T and L may be a worthwhile consideration. Unless the South values the information of biodiversity highly enough compared with other non-monetary benefits, the use of traditional knowledge will not pay the South, which may discourage the South to preserve its own traditional knowledge.

Table 2. The effects of traditional knowledge on q^*, T^*, L^{*i}, Y^{*i} and π_N^* .

	q^*	T^*	L^*	Y^*	π_N^*
Effect of s	$(-)$	$(-)$	$(-)$	$(+)$	$(+)$

6.2 Probability and the global welfare

Finally, we will have a brief study on other benefits except profits to evaluate the NPB. The first one is the probability of success in the development of the new drug $P(Y, R)$. If the developed drug is expected to be highly effective for some disease, the patients suffering from the disease must have huge benefit from the development. But the probality is expressed by $1 - (1/aMY)$ by lemma 1 under (16),

$$P(Y^*, R^*) > P(Y^m, R^m) \tag{32}$$

since $Y^* > Y^m$ by proposition 5. Therefore, the ZPB may be said to contribute more in terms of expected consumers of the drug.

The other variable is the global welfare, which represents the sum of the welfare in both the North and the South. The standard definition of it may be $PM - T - R - wL$, the sum of the profits of the both countries, but non-monetary benefits are ignored in this definition, which must be important in the context of bioprospecting. Let us express those benefits arising from (Y, T, L) as $\beta_Y Y, \beta_T T$ and $\beta_L L$, where β_Y, β_T and β_L stand for the benefit per unit of Y, T and L in the South. Thus, the social welfare W^i can be represented by

$$W^i = P(Y^i, R^i)M + \beta_Y Y^i - (1 - \beta_T)T^i - R^i - (w - \beta_L)L^i, \ (i = *, m). \quad (33)$$

The value of W depends on how high β_Y, β_T and β_L are, so it is ambiguous whether W^* is higher than W^m or not. However, If we suppose that $\beta_T \leq 1$ and that $\beta_L \geq w$, it holds

$$W^* > W^m, \quad (34)$$

since we have (32), $Y^* > Y^m, T^* < T^m, R^* < R^m$ and $L^* > L^m$ due to propositions 3, 4, 5 and lemma 2. That is, the NPB contributes more to the social welfare in this case. However, the other cases with different parameters can lead to the opposite result.

7 Concluding Remarks

This paper sheds a light on non-monetary benefits arising from bioprospecting for the developing countries as well as monetary benefit. Non-monetary benefits are highly valued in particular if the supply of samples is collected and identified by non-profit organizations such as universities or research institutes. In this paper, we provide with a framework to incorporate the behavior of such organizations with traditional knowledge, by identifying non-monetary benefits with technology transfer, employment of local people and accumulation of information of the biodiversity in the South, while sample fee is defined as non-monetary benefit.

By comparing the monetary and non-monetary benefits under different behaviors of intermediary in the South, we derive unambiguous results. Under the NPB, which we assume a research institute takes, the equilibrium sample fee is lower than that under the FPB. On the other hand, with respect to non-monetary benefits, the numbers of employment and the collected samples are higher under the NPB that under the FPB, but technology transfer is lower. These show that the NPB contributes more to local development and information, but less to technology transfer. Therefore, it is not the case that the NPB is beneficial to all respects of non-monetary benefits. In particular, if the South has a strong interest in technology transfer, the NPB can be disadvantageous to the country.

On the other hand, the profit of the pharmaceutical company is always higher when the South takes the NPB. So we might say that it is a good incentive for the North to participate in bioprospecting where non-profit organizations play a role of the intermediary.

Our analysis also demonstrates that traditional knowledge does not benefit the South except increasing the number of samples, which increases the information of biodiversity. On the other hand, the pharmaceutical company always benefits from traditional knowledge. So it might not be unreasonable to require some measures to redistribute a part of profits to the South, at least to compensate for the reduction of monetary and non-monetary benefits due to useful traditional knowledge. [2] Such measures may encourage the South to preserve traditional knowledge. The search for such measures will be left for further interesting future studies.

[2] Onuma (2008) shows that the contribution of traditional knowledge should be reflected in advance payment in terms of efficient sharing of monetary benefit.

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