Does Indigenous Knowledge Contribute towards the Benefits of Bioprospecting?[ã]

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Abstract

This paper attempts to examine the contribution of indigenous and traditional knowledge in the process of bioprospecting, and propose a model to analyze how such knowledge influences the benefits of bioprospecting. Empirical evidence suggests that (i) out of the two widely debated but dissenting hypotheses on the benefits of bioprospecting, one estimating higher values is supported and (ii) if the bioprospecting search is based on ethno botanical information available from local people, then the value of bioprospecting benefits will be higher than those predicted by the two hypotheses. It is crucial for bioprospecting firms to design a scheme where the information as well as access to the resources can be effectively shared between the firms and the local people in the bioprospecting site.

Key words: bioprospecting, value of marginal species, value of medicinal plants, indigenous knowledge, convention of biological diversity.

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1 Introduction

Bioprospecting refers to the extraction and screening of chemical compounds from plants to develop useful leads for potentially new drugs. In its early stage, prospecting largely centered around plants from the forest ecosystem. Recently, insects, algae and microorganisms of different ecosystems (e.g. grassland and marine) have also been explored with considerable expectations and success. While scientists are trying to derive useful extracts from the biodiversity of different ecosystems, economists, ecologists and policy planners are debating over the benefits and its value in the bioprospecting processes. The economic value of plants or living organisms for pharmaceutical purposes is crucial not only to pharmaceutical firms but also for the host country or local people, who command exclusive ownership of the biological resources and expect adequate compensation for resource uses especially after the Convention on Biological Diversity (CBD) in 1992 (Secretariat of the Convention on Biological Diversity, 1996). The Convention clearly establishes the control and sovereignty of local agency over the biological resources and its diversity.

The phenomenon of bioprospecting faces a typical situation where crucial raw materials (genetic resources) are primarily owned by the poor tropical countries while the necessary biotechnology and R & D capacity are owned by the pharmaceutical firms of the developed world (US and Europe in particular). Whatever benefits arise from bioprospecting have to be shared in a way acceptable to both parties. This issue becomes the bone of contention when prospecting firms claim the following: the process of bioprospecting involves elements of high risk and cost, and hence they deserve a greater

share of benefits. Host countries and locals on the other hand, suspect foul play in this. In this context, this paper tries to examine the following:

(i) Are there any benefits of bioprospecting (or value of medicinal plants)?

(ii) If yes, how much?

(iii) What are the major findings of some of the recent studies in this direction?

(iv) Do the empirical experiences of bioprospecting confirm that the contribution of indigenous knowledge and information enhance the value of biodiversity in the process of bioprospecting?

An attempt has been made to answer these questions by citing facts from real world events. We have selected two widely debated studies on valuation of biodiversity for pharmaceutical prospecting; one by Simpson et al. (1996) and the other by Rausser and Small (2000). These studies can be looked into as representative of diverse views on this issue. After reviewing recent medical discovery from wild plants in the rest of this section, in section 2 we review these two studies that measured the bioprospecting values of ecological species in several resource-rich regions in the world. We will conclude that the different estimates by these studies are driven by different assumptions on the role of available ethno botanical information in each region. In section 3 we have put forth the arguments that the bioprospecting values of species will be higher than those predicted by the two studies if one takes into account local-specific information on the species –the information available from local people- in addition to the widely available ethno botanical information considered by Rausser and Small (2000). We also propose a model to examine the contribution of indigenous knowledge to the bioprospecting value of diverse species. Section 4 concludes our discussion with the explication of the future

agenda by providing recommendations for further research, which follows from the directions, we have developed in this paper.

Medicinal plants found in nature have been in use for pharmaceutical purposes in different parts of the world for centuries. Also, active ingredients from flora and fauna are found to be dominant in a large number of drugs. In the past many of the known useful drugs have been derived from leads provided by these medicinal plants. In US alone, 57 percent of the prescriptions filled from January through September in 1993 contained at least one major active compound 'now or once derived or patented after compounds derived from biological diversity' (Grifo, 1996). Examples of deriving drugs from plants are numerous and a common knowledge. Table 1 provides representative samples of medical products derived from wild plants.

[Table 1 here]

Comprehensive list of all medicinal products coming directly or indirectly from wild biota could be an unending one. The perceptible contribution of biodiversity to human welfare is thus likely to be enormous.

2 Values of the Benefits from Bioprospecting: Review of Literature

2.1 Alternative views on the value of bioprospecting

One of the enduring questions in the economic research on bioprospecting has been whether it provides private firms (such as pharmaceuticals) with an incentive for preservation of ecological habitats in resource-rich regions. If the value of biodiversity in

an undisturbed habitat for pharmaceutical research exceeds the opportunity cost of conservation, it may result in market-based preservation of the habitat without external intervention on the land use. If this is the case, then the policy needed for ecosystem preservation will have to be considered differently. . With this motivation as governing factors, a number of estimations of benefits of medicinal plants have been conducted. In one of the earlier estimates, Farnsworth and Soejarto (1985) in their pioneering effort calculated the value of medicinal plants that were expected to disappear by 2000 in the US. Based on several assumptions, they estimate the value of the whole plant in the US as $203 billion (1980 USD). Principe (1996) calculates the value of medicinal plants as a total figure of $6.2 billion for the US in 1985. Mendelsohn and Balick (1995) aggregated the potential social value for undiscovered tropical forest. They estimated the pharmaceutical value of the medicinal plants as $147 billion (1980 USD) yielding $48 per hectare of tropical forest. This estimate is of the social value of forest for medicinal plants, but the market value may be lower than this, which has been admitted and estimated to be $3 to $4 billion (1980 USD).

Recently, Simpson et al. (1996) estimated the value of biodiversity for bioprospecting. They advocate that the incentive for biodiversity conservation on the basis of benefits of bioprospecting is not tenable because the value of the benefits is very small. In another significant study, Rausser and Small (2000) present a contrasting finding and explain that if the search for a useful lead is based on scientific inputs and information, rather than being a process of brute testing, then the value of biodiversity can be significant. In the next subsection we examine these two seminal works to identify why they offer different recommendations on the value of the bioprospecting benefits

from the same biological resources.[1] The study by Simpson et al. has generated a great deal of attention, and hence it becomes imperative to examine their findings in some detail.

2.2 Simpson et al. vs. Rausser and Small

Both studies begin by introducing a theoretical model as a basis for deriving a demand function for biodiversity by prospecting researchers and determine their willingness to pay for the species as an input into commercial products. The model by Simpson et al. (1996) characterizes bioprospecting as a process of sequential search on species (or leads) for the discovery of a new product. Each species has the potential to provide genetic information useful for the new product, which earns a net revenue $R > 0$ gross of sampling cost $c \in (0, R)$. They assume that the probability of a discovery (p) is common to all the species under consideration. With these assumptions, each new sampling is treated as an independent Bernoulli trial with equal probability of success p. In valuing the contribution by an additional species, Simpson et al. (1996) emphasize that discoveries may be redundant; once a successful product is found, further discoveries of the same product become valueless. They made this point clear by explaining why genetic resources may be redundant in practice: the same species may be formed over a wide range; there are numerous instances in which identical drugs have been isolated from different species; and there may be non-organic substitutes for the leads discovered from biological resources (p.169).

[1] See Kumar (2001) for a detailed review of the valuation studies on medicinal plants.

Given such potential redundancy of discoveries and the same probability of discovery for all species, the value of the entire collection of N samples is given by

$$V(N;p) = \frac{pR - c}{p}[1 - (1-p)^N]$$

and the value of an additional species is

$$MV(N;p) \equiv V(N+1;p) - V(N;p) = (pR - c)(1-p)^N .$$

Here the marginal value MV is concave in p and there is a global maximum $p^*(N) \in (0,1)$ under the assumption $R > c > 0$. Simpson et al. claim that the maximum marginal value $MV(N;p^*(N))$ is modest at the best. One reason is obvious: as N increases, the value goes down. Simpson et al. (1996) also provide another insight: if all species are promising sources of leads (i.e. p is high), then most would be redundant and the marginal species would be valueless. Conversely, if p is low then it is unlikely that any species will prove to have value. On the other hand, a rise in the likelihood of success with any species (p) causes the expected payoff in the event that the species is tested to increase. At the same time, however, another equally valuable species may be discovered first so that the expected payoff of the species declines. This is the cost generated by redundancy.

As a numerical example, Simpson et al. goes on to estimate $MV(N;p^*(N))$ using data on 18 ecologically distinctive ecosystems (the biological 'hot spots,' Myers 1988).[2] They demonstrate that the value of an additional unit of land in these ecosystems is modest even under optimistic assumptions on the profitability of discoveries (see Table

[2] In fact, what they estimated is the value of an additional unit of land in each hot spot with the same species density in the corresponding ecosystem.

2). This result implies that bioprospecting alone does not provide private pharmaceutical companies with sufficient incentives for habitat conservation.

As Simpson et al. (1996) admits, pharmaceutical researchers do not generally conduct random searches (even though they assume random sampling for their model). Rather, a pharmaceutical firm begins testing with the most promising species first. Rausser and Small (2000) explicitly incorporate this aspect of pharmaceutical research into their model by assuming that the hit probability (p) may vary among species. With a model otherwise identical to the one by Simpson et al. (1996), they claim that an optimal search program involves testing a lead with the maximal hit probability among those not yet examined (Proposition 1, p.181). Letting $p_1 > ... > p_N$ be the hitting probabilities of samples $1, N$, the optimal order of samples to be searched is 1, 2, …, N . Given this optimal sequence, the expected payoff to the search at its outset is given by

$$V_1(\{p_i\}_{i=1}^N, N) = \sum_{n=1}^{N} a_n (p_n R - c) \qquad (1)$$

Where $a_n = \prod_{i=1}^{n-1}(1-p_n)$, the probability that the search is carried to the n th stage.

Correspondingly, the ex post expected value of continuing the search after $n-1$ leads have been tested unsuccessfully is recursively given by

$$V_n(\{p_i\}_{i=1}^N, N) = p_n(R-c) + (1-p_n)(V_{n+1} - c),\ n = 1,...,N\ .$$

Then the incremental value of lead n (the maximum a firm will be willing to pay at the start of a search project for a call option on lead n), denoted by v_n, is a function of the hitting probabilities of all leads $p_1,..., p_N$ as well as R and c :

$$v_n(\{p_i\}_{i=1}^N, N) = v_N(\{p_i\}_{i=1}^N, N) + \tilde{v}_n$$

Where $v_N(\{p_i\}_{i=1}^N, N) = \prod_{i=1}^{N-1}(1-p_i)(p_N R - c)$ and

$$\tilde{v}_n = \frac{\prod_{i=1}^{N-1}(1-p_i)}{1-p_n}(p_n - p_N)R + \left[\sum_{i=n+1}^{N-1}\frac{\prod_{j=1}^{i-1}(1-p_j)}{1-p_n}(p_n - p_i)\right]c.$$

In contrast to the marginal value by Simpson et al. (1996), these incremental values are sample-specific and not necessarily the same across the samples 1, …, N. Their point is that leads that are promising contribute more than the others to the chance of an eventually successful outcome for the project. Moreover, the addition of a higher probability lead to the existing leads reduces the expected total search cost by making the less promising leads more redundant. Thus, in addition to the scarcity rents (given by v_N), promising leads command 'information rents' (given by $\tilde{v}_n$) associated with its contribution to the chance of success and the avoidance of search costs. This information rent is zero if and only if all priors are equal (which is the assumption made in Simpson et al. 1996). In fact, we have $v_N(\{p_i\}_{i=1}^N, N) = MV(N-1; p)$ if $p_i = p$ for all $i = 1,..., N$; the marginal value by Simpson et al. and the marginal value (value of sample N) by Rausser and Small (2000) coincide if the researcher cannot differentiate the samples. Treating the hit probability as the same for all the species can be interpreted as a situation where researchers have no prior information as to which species has a higher likelihood of containing valuable genetic information. If prior information is available (i.e. if the success probability varies among the leads), then the value of certain species contains positive information rents and can be high enough to encourage private incentives for conserving that species (and possibly the habitat containing it).

Rausser and Small (2000) conducted a numerical simulation using the same data as Simpson et al. (1996). They argue that, under plausible conditions, the bioprospecting

value of certain genetic resources could be large enough to support a market-based conservation of biodiversity. In their simulation, a lead is given by a unit of land in each of the 18 hot spots. The hit probability of a unit of land is assumed to be proportional to the density of endemic species in the area. They multiply the probability 1.20×10^{-5}, which is the value for p used in Simpson et al. (1996), by these density values to obtain the hit probability of each land area. Their result suggests that the bioprospecting information rents can be large enough to affect land use decisions (Table 2). For example, the bioprospecting value of a land area (1,000 square meters) in Western Ecuador (which is on the top of the list of the hot spots) is calculated to be $20 by Simpson et al. (1996) whereas it is $9,177 by Rausser and Small (2000). [3] As Rausser and Small (2000) emphasize, they agree with Simpson et al. (1996) about the value of marginal species (i.e. species N): it will be too small to promote private firms to preserve them. However, taking into account the prior information on the success probability of the species, the value of the most promising ones may be high enough to enhance market-based preservation of biodiversity. For the same set of area, the value of biodiversity estimated by Rausser and Small for each hot spot is larger than that by Simpson et al.

[Table 2 here]

[3] Although the numerical examples are based on the same original data by Myers (1988) (1990), the way the value of a unit of land is calculated is different in the two studies. In Simpson et al. (1996), the marginal value (value per unit area) is calculated as the value per species, which is constant across species, multiplied by the species-area coefficient assuming a log-linear relationship between species and area size. Rausser and Small (2000), on the other hand, incorporate the density of endemic species into the hit probability. Simpson et al. (1996) calculate the value per species using 250,000 as the number of species N in consideration, where 250,000 is the number of higher plant species that are considered to contain valuable genetic information for pharmaceutical firms. On the other hand, N in Rausser and Small (2000) is given by 74,640, the sum of the number of units of land in 18 hot spots. This difference partly explains the gap in the estimated marginal values in the two studies. However, the difference in numbers cannot be fully explained by this difference alone; even if the number 74,640 is used in Simpson et al. (1996)'s calculation, the value is still $100 per hectare at most (due to calculation by the authors).

3. A Critical Evaluation

As far as the real life situation is concerned, Rausser and Small's model is more convincing than Simpson et al.'s. Search for potentially useful plant and animal biota is in fact not random. It is often based on good taxonomic information and ethno botanical knowledge. In this section we review evidence on bioprospecting supporting aforesaid view. Further, in subsection 3.1, we also (i) identify a factor that is not considered in either of these studies –contribution of indigenous knowledge on biological resources- and (ii) claim that the bioprospecting value will be even higher than the estimate by Rausser and Small (2000) if the contribution of indigenous knowledge is considered. Subsection 3.2 introduces a model that provides a conceptual framework to incorporate the contribution of indigenous knowledge to the bioprospecting value of species in the hot spots. Subsection 3.3 discusses how the bioprospecting firms can obtain indigenous knowledge (i.e. under what conditions the local people are willing to share their knowledge with the firms).

3.1 Contribution of Indigenous Knowledge

The importance of ethno botanical information in drug discovery is well acknowledged (Balick et al.1996; King 1996; Cox 1994). These studies amply prove that search for new drug (or lead for it) is far more successful when it is based on the clue related to their use by local people. Drug-searching pharmaceutical firms such as Pfizer or Shaman Pharmaceuticals, Inc. (now Monsanto) make use of traditional/indigenous knowledge about the medicinal feature of the plants or biota in general. They do it through field

collection, literature or database searches. In order to use the local information in the search process, firms also approach the locals directly. In such cases, locals can claim for a higher royalty linked to the net sales revenue from developed successful drug (Smith and Kumar, 2002). Prevailing practices also confirm this argument. It is reported that crude extracts of plants used by a healer in Belize (Brazil) produces four times as many positive results in lab tests for anti-HIV activity than did specimens collected randomly (Cox and Balick, 1994). If a search for useful drugs is led by the knowledge of indigenous people who know possibly more about the characteristics of these plants, the probability of getting a 'hit' will considerably improve. Shaman Pharmaceuticals, Inc. is an example of a company, which collects plants for assaying and screening after discussions with the indigenous healers and observing them work. Shaman Pharmaceuticals has employed a plant targeting strategy where they choose a plant for testing as and when they find that two or more communities use the same plant for medicinal purposes. The success rate of drug discovery after following this rule of thumb has been more than 50% (ibid.). This finding authenticates the importance of grass root information in bioprospecting. In fact, much disillusionment about bioprospecting experienced by scientists in the recent past has been caused by the fact that their search process has been devoid of any ethno botanical information. The Experiences of National Cancer Institute (NCI), US are worth mentioning here. For NCI, one sample in ten thousand will show promising activity in the area the researcher is interested in. Out of this, one in ten of these promising samples might go to clinical trial, and finally, one in ten out of this might go to the market (Nature, 1998: 535). This low probability is a typical example of a brute search where consultation and interaction with the locals

before and during the search is entirely ignored and missing. During 1956-75, NCI is reported to have screened around 35,000 plants and animals, in searching anticancer drugs. In fact, this process of search ended due to its failure in getting any clue in the right direction. An evaluation study for the US Congress (1993) concludes that the success by NCI could have been doubled, had they taken into account the knowledge of medicinal folk to target testable species (Research Service Report for Congress, 1993). Therefore, successful search processes are based on some ground truth of finding a probability of favorable outcome. Otherwise scientists of Novartis and Merck could not have traveled in the wilderness of the Amazon and Costa Rican forest in search of unique phytochemicals, which cannot be imagined to synthesize in the laboratory of combinatorial chemistry. Therefore, one finds enough evidence that the value of benefits of bioprospecting may be quite significant and that local's information in the search process can significantly enhance the strike rate of a 'hit'.

In case studies on bioprospecting discussed above, we observe two reasons why bioprospecting is not a random process of choosing sites and species. First, bioprospecting firms choose a site of bioprospecting using scientific information that is widely available (e.g. species density in each site, geographical, climatological information and so on). Second, in a chosen site, the firms utilize local-specific knowledge (that only local people know) to select those plants or insects that are most promising for medical discovery. The difference between the values by Simpson et al. and Rausser and Small is explained by the first factor. In calculating the bioprospecting values, neither of these studies considers the second factor, i.e. the use of indigenous knowledge in their bioprospecting models. The reason why Rausser and Small came up

with a different numerical result from Simpson's is because they consider heterogeneity among biological reserves (hot spots) in terms of species density. Knowledge on species density does not come from local people's knowledge; rather, it comes from more general scientific knowledge that is not local-specific. Their model tells us which site (amongst hot spots) we should choose as a place to conduct bioprospecting. However, it does not tell us which species a bioprospecting firm should look at given a biological reserve. For the latter question, local people's knowledge is crucial. In fact, as described in the above paragraphs, the existing bioprospecting contracts between local people and pharmaceuticals are about which species to choose in a given biological reserve. With indigenous knowledge, the value of some species will be higher; hence the firms, if they could, would be able to utilize efficiently such indigenous information. Consequently, the value of bioprospecting will be higher than what Simpson et al. and Rausser and Small have calculated This argument strengthens the point by Rausser and Small (2000) that the market-based conservation of ecosystem may be possible with bioprospecting. The next subsection introduces a framework to analyze this contribution of indigenous knowledge to the benefit of bioprospecting.

3.2 Modeling Indigenous Knowledge

To summarize the above arguments, a bioprospecting process can be decomposed into two stages:

Stage1 (Site selection): Choose a site where bioprospecting is conducted.

Stage2 (Species selection in a given site): Choose species for bioprospecting in the site selected in Stage 1.

Correspondingly, we can modify the framework used by Simpson et al. and Rausser and Small to incorporate into it the role of indigenous knowledge in the following manner.

A potential bioprospecting firm can make its bioprospecting decision by solving the above two-stage problem with backward induction. Suppose there are M sites for bioprospecting where there are N_j species in site j ($j = 1,...,M$). (If we consider the hot spots by Myers 1988, M is given by 18.) At stage 1, the firm chooses a site based on the prior belief on the average hitting probability in each site. As in Rausser and Small (2000), the firm forms this prior belief by using globally available biological information such as species density in each site. Denote the firm's prior belief on the hitting probability of species in site j by $(p_j,..., p_j)$, a N_j dimensional vector of probabilities. Prior over M sites $\{p_j\}_{j=1}^{M}$ corresponds to the hitting probability in different hot spots calculated by Rausser and Small (2000). Suppose site j is chosen at stage 1. Then, at stage 2, given site j, the firm chooses how much to pay to the local people in site j to maximize the expected profit from bioprospecting. We assume that, without indigenous knowledge, a firm cannot distinguish species with higher success probability from the less promising species. By obtaining indigenous knowledge, a firm can update its belief and identify a couple of species with relatively higher probability of success. By making a payment to local people, the firm can obtain such indigenous knowledge, i.e. local-specific ethno botanical information. Assume that, with indigenous knowledge, the prior success rate of a species p_j is updated to $\pi(p_j)$ where $\pi:[0,1]\to[0,1]$ is an increasing function such that $1 > \pi(p) > p$ for all $p \in (0,1)$, $\pi(0) = 0$ and $\pi(1) = 1$.[4] Let m be the

[4] For example, $\pi(p) \geq 4p$ for small p according to Cox and Balick (1994) (see 3.1).

number of species with which the firm can update the prior. The number m depends on how much the firm pays to the local people, w. The more the firm pays to the local people, the larger the number of species with which the firm can update its prior; that is, $m(w) \geq m(w')$ for $w \geq w' \geq 0$. Without payment, the firm cannot update its belief: $m(0) = 0$. If the firm pays w to the local people, then the firm's belief and the expected payoff change in the following way. First, the prior belief $(\{p_j\}_{i=1}^{N_j})$ is updated to $(\{\{\boldsymbol{p}(p_j)\}_{i=1}^{m(w)}, \{p_j\}_{i=m(w)+1}^{N_j}\})$. The updated belief is such that, out of N_j species, $m(w)$ have a hitting probability of $\boldsymbol{p}(p_j)$ and the rest have probability p_j. Second, the firm's expected revenue from bioprospecting in site j, net of unit sampling cost, is given by $V(m(w), w; p_j, N_j)$ where

$$V(m(w), w; p_j, N_j) = V_1(\{\{\boldsymbol{p}(p_j)\}_{i=1}^{m(w)}, \{p_j\}_{i=m(w)+1}^{N_j}\}, N_j)$$

And V_1 is as defined in equation (1). In words, $V(m(w), w; p_j, N_j)$ is the value of the total species in site j when the firm pays w to the locals and obtain an updated belief on the hitting probabilities of the species. With this set-up, the stage-2 problem for the firm is to maximize this profit choosing how much to pay to the locals:

Stage-2 problem: $V^*(p_j, N_j) = \max_{w \geq 0} V(m(w), w; p_j, N_j) - w$ for $j = 1, ..., M$.

Now consider the stage-1 problem. Assume that, from widely available information, the firm knows that the fixed cost of establishing bioprospecting facility at site j is given by $F_j \geq 0$. Given $\{V^*(p_j, N_j)\}_{j=1}^{M}$ and $\{F_j\}_{j=1}^{M}$, the firm's stage-1 problem is simply to take the maximum over the net total values for M sites:

Stage-1 problem: $\max_{1 \leq j \leq M} \{V^*(p_j, N_j) - F_j\}$.

In this model, contribution by the local people on bioprospecting value at site j, denoted by LC_j, is given by the following formula (2):

$$LC_j = V^*(p_j, N_j) - V(m(0),0; p_j, N_j). \quad (2)$$

The indigenous knowledge contributes to an increase the bioprospecting value by offering a pharmaceutical with differentiated probability of success of each species in a site. The values obtained by Rausser and Small correspond to $\{V(m(0),0; p_j, N_j)\}_{j=1}^{M}$; they do not consider information available from local people and hence variation in hitting probabilities of species within a single site. With the above argument, we argue that the bioprospecting value of species in a given site will be higher than the estimate by Rausser and Small. The crucial parameters in this model are functions m and $\boldsymbol{p}$: function m represents the degree to which the local people are willing to offer their knowledge to the firms under various amount of payments, and function $\boldsymbol{p}$ represents the degree to which the indigenous knowledge is effective in identifying promising leads out of species in an ecological site.[5] As implied by the ongoing bioprospecting activities by some pharmaceutical firms, m and $\boldsymbol{p}$ considerably affects the bioprospecting values of species As in 3.1, it is because of the ethno botanical information from local people that these firms collaborating with local people could have been successful in finding promising leads with less cost. Hence, the contribution of indigenous knowledge LC_j given by (2) is likely to be large for the hot spots. The model provided in this subsection can capture such local people's contribution to the bioprospecting benefits.

[5] Functions $\boldsymbol{p}$ and m may be different across ecosystems or local people due to difference in ecological and economic environment in each region. Hence, different payment scheme may be called for in different regions.

3.3 Implications of Indigenous Contributions to Bioprospecting

Taking off from the arguments above, there is a crucial aspect of bioprospecting that is assumed away in both Simpson et al. (1996) and Rausser and Small (2000) and it is of great significance to our concern. It is based on the process through which bioprospecting firms can form their beliefs on the probability of success of each species. Both findings are silent about this process of information gathering. Information on biological resources is available from the local people who are already familiar with the specific use of any biological resources in their communities. In the above model, the payment w to the locals is independent of success in medicinal discovery. However, it may well be the case that the locals prefer a payment scheme where they can share the benefit contingent on 'hit'. The form of p may also depend on the way the firm pays to the locals. Therefore, a bioprospecting firm needs to propose a proper incentive scheme for locals so that they are willing to share their knowledge as well as access to the resource in a given ecological site. In 1991, with the ratification of CBD by 153 countries at Rio, the sharing of benefits has become mandatory in bioprospecting. CBD also entails a bioresources-rich country to obtain a joint patent over discovered drugs. Joint patenting can be an effective way to share the benefits. Alternatively, a contract between the host country and the pharmaceutical firms can also be entered into. In 1991, with the active intermediation of Biochemist Wisner, a leading pharmaceutical firm, Merck Inc. collaborated with the Costa Rican NGO INBio. INBio was given $ 1 million as advance payment besides an undisclosed rate of royalty on the sales of successful drugs, equipment and instrument for sample testing, and other capacity building measures. This agreement opened new vistas in bioprospecting contracts, and it has become a reference

point for other countries to follow. In cases where royalty or joint patenting is involved, payment to locals is contingent on success in bioprospecting (rather than fixed independent of the research outcome). It should be noted that whatever happened in the case of Costa Rica can not be duplicated in other countries because of its unique situation in terms of richness of biodiversity (5% of the world), competent and robust scientific infrastructure, and stable and conducive political climate. However, this arrangement has aroused the expectation and aspiration levels of the biodiversity rich tropical world. Benefits sharing have been prevalent in one form or the other before CBD; however, it now appears in a more explicit and structured form. This fact itself implies that the contribution by indigenous knowledge is crucial in accounting for the benefits of bioprospecting.

4 Conclusions

Phytochemical from wild plants remain the crucial source of lead for drug discovery. In spite of the ongoing debate regarding the fruitfulness of bioprospecting, a large number of firms such as Merck, Novartis, Glaxo, Sankyo, and Smith Kline Beecham are investing considerable amount of resources in the search for drugs and related processes of study and further demonstrating that the bioprospecting potential of biodiversity is substantial. The hypothesis that the value of such marginal species is very small seems to be untenable because its assumption of brute search is unrealistic and far removed from the prevailing practices of the leading pharmaceutical firms of the world. The search process is essentially through a mechanism where prior scientific information from the locals and the ethno botanical knowledge of the indigenous peoples are incorporated.

This information input plays an important role in enhancing the 'strike rate'. Based on the studies by Simpson et al (1996) and Rausser and Small (2000), we proposed a modified framework of bioprospecting evaluation where effective role of ethno botanical information is acknowledged and assessed. There is still much to be done including the following:

(i) analyzing the effect of the market structure and industrial organization on the efficiency of bioprospecting,

(ii) estimating the gap between private and social bioprospecting value of biodiversity, and

(iii) Taking a general equilibrium approach to address the question of how to allocate industrial effort between non-organic based search and bioprospecting.

So far, the emphasis of the studies has been on how one can estimate the value of biodiversity to a pharmaceutical researcher who faces a competitive market in the product to be discovered. Rausser and Small (2000) argue that (p.175), in the presence of differences in hitting probability among research leads, the market for research opportunities shifts from a purely competitive one to a monopolistically competitive one (points i and ii above). As Simpson et al. (1996) argued in discussing the redundancy of research discoveries, non-organic sources are close substitutes for biological resources as inputs to pharmaceutical production (point iii above).

Finally, if this value of indigenous knowledge in bioprospecting has to be reaped by the international community, an equitable and mutually acceptable mechanism of benefits sharing has to be devised.

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Table 1: Medical Products from Wild Plants

Name of the Wild Plants	Location	Derived Drugs	Use
Pacific Yew	Pacific Northwest	Taxol	Ovarian Cancer
Rosay Periwinkle	Madagascar	Vinblastine Vincristin	Bloood and Lymph Cancer
Foxglove	Europe, Africa, Asia	Digitalis	Cardiac Arrhythmias
Meadowsweet	Worldwide	Aspirin	Fever and Pains
Cinchone	Topics	Quinine	Malaria
Snakeroot	India	Rauwolfia	Hypertension and Schizophrenia
Curare	Amazon	Tubercurarine	Muscle Relaxant

(Source: Compiled by the authors)

Table2: Bioprospecting Values in Several Ecosystems (Values as a Function of Density of Endemic Species)

Biodiversity "Hot Spots"	Forest Area (1,000 ha)	Density, Endemic Species/ 1,000 ha	Hit Probability /1,000 ha	Incremental Value ($/ha)	Simpson et al. Scarcity Rent ($/ha)
Western Ecuador	250	8.75	1.05E-04	$9,177	$20.63
Southwestern Sri Lanka	70	7.14	8.57E-05	$7,463	$16.84
New Caledonia	150	5.27	6.32E-05	$5,473	$12.43
Madagscar	1,000	2.91	3.49 E-05	$2,961	$6.86
Western Ghats of India	800	2.03	2.44 E-05	$2,026	$4.77
Philippines	800	1.98	2.38 E-05	$1,973	$4.66
Atlantic Coast Brazil	2,000	1.88	2.26 E-05	$1,867	$4.42
Uplands of Western Amazonia	3,500	1.10	1.32 E-05	$1,043	$2.59
Tanzania	600	.88	1.06 E-05	$811	$2.07
Cape Floristic Province of South Africa	8,900	.71	8.52 E-06	$632	$1.66
Peninsular Malaysia	2,600	.62	7.44 E-06	$539	$1.47
Southwestern Australia	5,470	.52	6.24 E-06	$435	$1.22
Ivory Coast	400	.48	5.76 E-06	$394	$1.14
Northern Borneo	6,400	.42	5.04 E-06	$332	$0.99
Eastern Himalayas	5,300	.42	5.04 E-06	$332	$0.98
Colombian Choco	7,200	.32	3.84 E-06	$231	$0.75
Central Chile	4,600	.32	3.84 E-06	$231	$0.74
California Floristic Province	24,600	.09	1.08 E-06	$0	$0.20

(Source: Small 1998 and Rausser and Small 2000)

Note: Both studies by Simpson et al. and Rausser and Small assume 10 successes per year, revenues of $450,000,000 per success, a cost of $483 per test, a hitting probability of 1.2E-05 per species, and a discount rate of 10 per cent.