

Using Traditional Knowledge for Commercial Innovations: Incentives, Bargaining and Community Profits

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Abstract

The recent interest in traditional knowledge systems within health care and biodiversity sectors is directly related to the profitable innovations that traditional knowledge can generate. This paper seeks to examine the nature of economic incentives required for protecting and sustainably using traditional knowledge. The paper asks two key questions: (a) under what conditions do communities and pharmaceutical companies enter into contracts to develop traditional knowledge-based innovations? And, (b) what factors influence the benefit-shares of the two parties from commercial use of traditional knowledge? Adapting a bargaining model, this paper shows that the actual sharing of the revenues depends on a number of issues, most importantly, the relative bargaining strengths of the two parties. Factors that affect profits and relative bargaining strengths include the contributions of the parties in developing the innovation, the availability of alternative sources and options, differences in expectations over future revenues and costs, and the involvement of a third party in the negotiations. Such factors need to be taken into account in designing incentive schemes that can help communities benefit from the use of their traditional knowledge.

Key words: traditional knowledge, pharmaceutical companies, bargaining models, incentives, and intellectual property rights

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K. Aparna Bhagirathy

1. Introduction

The international debate over the use of indigenous and traditional knowledge has frequently focused on social, cultural, and ethical concerns about the appropriateness of applying intellectual property rights for protecting traditional knowledge.¹ However, equally important are questions related to the economics of using traditional knowledge. This paper seeks to examine the nature of economic incentives required for protecting and sustainably using traditional knowledge associated with biological resources.

The recent growth of interest in traditional knowledge (TK) systems within health care and biodiversity sectors is directly linked to the profitable innovations it could generate in the future. For example, Mathur (2003) estimates that some 40 percent of the pharmaceutical drug patents are due to expire by 2006 and this has increased interest in developing new active ingredients from traditional medicine. With growth in biotechnology research, traditional knowledge no longer represents a relic from the past that needs to be preserved for its intrinsic and aesthetic values. Instead, it is seen as a rich source of raw material for new innovations. The economic value of TK accrues from serving as an information base for these future innovations.

TK also derives its value from its current use in numerous medicinal and non-medical sectors. The World Health Organization, for instance, estimates that close to 80 percent of the population in developing countries depend on traditional medicine for their health needs (WHO 2002). There has always been interest in TK systems and technologies for use in sectors such as agriculture, water management and town planning.² Some common examples include traditional methods of pest control, indigenous tank irrigation systems, traditional techniques of building earthquake resistant housing etc.

Bio-prospectors and pharmaceutical companies involved in plant-based drugs research are interested in TK as an information source for two reasons: (a) it provides valuable leads in the search for *active compounds* required for producing pharmaceutical drugs and can considerably reduce search costs; and (b), it can provide valuable leads for developing entirely *new* plant-based pharmaceutical drugs from medicinal properties of plants that were hitherto unknown. Pharmaceutical research and development involves several years and considerable investments. Any project involving plant-based medicines requires identifying the useful active compounds from the plants. There are costs associated with bio-prospecting, searching for the medicinal plants and identifying

¹ For the purpose of this paper, indigenous and traditional knowledge are used interchangeably because in the context of intellectual property protection, the issues are the same for both.

² For details, see Sengupta (1995), "Proceedings of Workshops on Traditional Knowledge" (2001, 2002).

active ingredients. TK about medicinal plants can provide prior information and increase the hit rate in identifying active compounds. On another level, TK also provides information about medicinal properties of plant species, the uses of which may be unknown outside the community or region. Thus, TK improves the potential for developing new pharmaceutical products.

TK derives economic value from the value of potential future innovations it enables. The problem of incentives for the protection and use of TK is similar to developing incentive mechanisms for protecting intellectual property associated with cumulative innovations.³ In this paper, I build on theories of cumulative innovations to formulate a single-period bargaining problem that attempts to answer three basic questions: (a) under what conditions will the two players, the pharmaceutical company and the traditional community enter into a contract to share the knowledge and the profits arising out of any future innovations developed thereon; (b) how are the respective shares of the community and the company in future profits from the TK-based innovation determined; and (c) what factors influence the relative bargaining strengths of both players and how do these in turn determine the contract outcomes?

This paper is divided into five sections. In section 2, existing institutional mechanisms at the national and international level for the recognition and protection of TK are briefly summarized. Section 3 defines the specific problem for study in the model and discusses some of the characteristics peculiar to the design of incentives for TK. The model is set out in section 4, where different scenarios are examined with respect to the bargaining positions of the two players and the contract outcomes. Section 5 discusses the key results from the model.

2. Existing Institutional Mechanisms

In this section, I briefly discuss institutional mechanisms that exist at the global and local levels for conserving and using traditional knowledge. Based on this section, I proceed to formulate a bargaining model for sharing the benefits from commercial exploitation of traditional knowledge.

In the last two decades several rules and regulations have been formulated to protect traditional knowledge and also help communities to gain from their knowledge. At the international level, there are multilateral agreements and guiding principles, which lay down the framework for sustainable use of biological resources and associated TK and practices. At the national level, countries have incorporated specific provisions into their intellectual property laws and established what has come to be known as *sui generis* systems. These measures define explicit provisions that govern the sharing and using of TK. At a more local level, during the nineties, several pharmaceutical companies and research organizations developed benefit-sharing contracts with traditional communities in the course of ethno-botanical research.

³ Cumulative innovations are innovations that are based on existing innovations or body of knowledge.

2.1 International Agreements

Several international organizations have recognized the importance of TK and have been involved in a variety of programs to promote the preservation of TK. Some of the key agreements and initiatives are listed below.

- In what was one of the earliest initiatives, in 1982, the World Intellectual Property Organization (WIPO) adopted the Model Provisions for *National Laws on the Protection of Folklore against Illicit Exploitation and Other Prejudicial Actions* (now widely known as the Model Provisions), along with the United Nations Educational, Social and Cultural Organization (UNESCO).
- The Food and Agricultural Organization (FAO) introduced in 1989, provisions for the sharing of benefits arising out of the use of genetic resources and the protection of traditional knowledge as part of the *Farmers' Rights in the Revised International Undertaking on Plant Genetic Resources*.
- The Convention on Biological Diversity (CBD), in 1992 established a common international platform for countries by providing a framework to regulate the access to biological resources and the associated TK and to reward communities for their contribution to conservation and sustainable use of the same (Article 8j⁴).

While none of these agreements is binding, each provides a forum for discussion of TK and establishes guidelines for action by member countries.

2.2 National Legislation

Following the guidelines developed by international agreements, several countries incorporated into existing legal mechanisms, specific provisions for the protection of TK. This largely falls into two types: Intellectual Property Rights (IPR) laws and *sui generis* legislation. In this section, I focus on some of the relevant IPR initiatives in the context of TK.

The scope of protection of intellectual property laws has now expanded to include genetic sequences, plant varieties and other life forms. The use and protection of traditional knowledge goes beyond the medical sphere and in the use of IPR mechanisms, beyond patents alone.⁵

⁴Article 8j mandates that member States: "...respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity...and promote their wider application with the approval and involvement of the holders of such knowledge, innovations and practices and encourage the equitable sharing of benefits arising from the utilization of such knowledge, innovations and practices."

⁵ One issue that increased awareness about TK is wrongful granting of patents for innovations based on knowledge and/or practices that are already in use in traditional communities. A well-known case is the controversial patent awarded to two scientists for the use of turmeric in wound healing - US Patent No. 5,401,504 (CIPR 2002). The patent was contested and eventually revoked by an agency of the Government of India, which provided evidence to show that the use of turmeric for medicinal purposes was not novel but has been in use in India for over a thousand years for healing wounds and rashes. The Indian government provided documentary evidence including an ancient Sanskrit text and a paper published in 1953 in the Journal of the Indian Medical Association.

- Canada uses copyrights to protect tradition-based creations including masks, totem poles and sound recordings of Aboriginal artists.
- In Australia, unauthorized reproduction of traditional art and imagery on items such as T-shirts are prevented using a national trademark certification. In one case in Australia, *Bulun Bulun v. Nejlam Investments and Others*, the unauthorized reproduction was contested and the court granted interlocutory injunctions while settling the dispute for a sum of \$150,000 (Bhagirathy and Sengupta, 2003).
- India has evoked Geographical Indications and Appellations of Origin (use of a particular name, associated with the know-how specific to the place of origin of the product) to protect TK. In 1997, a U.S. rice-breeding firm, Rice Tech Inc., applied for registration of the trademark, “Basmati.” This was successfully opposed and a U.K court ruling established that authentic basmati rice is obtained only from the northern regions of India and Pakistan.

2.3 Benefit Sharing Contracts

Just prior to the CBD, widespread ethno-botanical research and high returns from trade in plant-based medicinal drugs led pharmaceutical companies to invest in bio-prospecting. However, very soon, there was a debate on whether pharmaceutical prospecting generated sufficient revenues for financing conservation. Several economic valuation studies depicted the “vanishingly small” values derived from prospecting in medicinal plants.⁶ Current positions indicate that traditional knowledge-led searches for active compounds in medicinal plants (as opposed to random searches) lead to higher ‘hit rates’ and lower search costs in drug discovery.⁷

There are several examples of bio-prospecting agreements, such as the Shaman Pharmaceutical Initiative developed by the Costa Rican NGO INBio and the pharmaceutical giant, Merck & Co. This initiative tried to establish a sustainable means of interaction with indigenous communities in pharmaceutical research but had to eventually close down and declare bankruptcy because it could not sustain the viability of its operations in the long run in the face of industry risk and technological change. The only case in which a pharmaceutical drug was successfully developed was in the case of the Kani Tribes-Tropical Botanical Gardens Research Institute, India partnership. However, there remain problems of access to the plant resource, market establishment, balancing competing claims of representation for benefit sharing, and calculation of shares in distributing the benefits from royalties and license fees. Some of these issues are yet to be resolved.

⁶ See for instance, Pearce and Moran, 1994, Simpson, et al., 1996.

⁷ See recent studies by Rausser and Small, 2000; Pushpakumara, et al., 2002; Kumar, 2002.

3. Defining the Problem: Sharing of Returns from Traditional Knowledge Innovations

Common issues in most benefit-sharing agreements between communities and pharmaceutical companies include soaring costs, risks associated with ‘hits’, uncertainty and mistrust in interactions between stakeholders, and the length of time involved in clinical trials and research and development. There are often high transaction costs associated with obtaining consent and collecting samples from indigenous peoples and in further clinical trials. Most benefit-sharing efforts have been frustrated by problems in identifying stakeholders interests; and consequently, in designing a system of incentives in a contract for commercial exploitation of TK.

The central concern of this paper is with designing incentive systems for stakeholders such that some of the above problems are resolved. Thus, I ask (a) under what conditions do communities and pharmaceutical companies enter into contracts to develop traditional knowledge-based innovations? And, (b) what factors influence the benefit-shares of the two parties from commercial use of traditional knowledge?

Cumulative Innovation theory provides a good starting point to think about commercialization of TK. The problems associated with investments in TK are similar to any set of cumulative innovations based on scientific and technological knowledge. In reality, there are very few pioneering innovations; most innovations build on earlier works. In the case of biotechnological research, for instance, knowledge of the genetic sequences that code for specific genetic traits is required to develop the final genetically modified product, such as Bt Corn. The social value of an innovation is compounded by the value of future innovations it facilitates. Similarly, the social value of TK depends on the value of subsequent innovations facilitated by the existing stock of knowledge. The use of the knowledge for commercial purposes does not decrease the existing stock available or exclude its current use in the traditional context. The knowledge can be held and used by several persons at a time. And, as with any good knowledge, there is no additional value for obtaining the same knowledge a second or a third time.

An important factor that influences cumulative innovations is the bargaining power held by different stakeholders. Scotchmer (1999), for example, argues that when there are positive externalities from innovations, disputes can arise over contracting between the original and subsequent generations of innovators. She emphasizes that the role of intellectual property is not to exclude competitors from the market but to establish bargaining positions from which licenses are negotiated to resolve conflicts in patent rights. By establishing these bargaining positions, intellectual property determines how the flow of profit is divided among sequential innovators.

As we will see in the subsequent section, this is the crux of the problem in the context of TK as well – the division of the flow of profits among the community and the pharmaceutical company is based on their relative bargaining strengths. However, there are some features peculiar to traditional knowledge. TK is normally held collectively by some or all members of a community rather than an individual. The rights over the

knowledge, in most cases, are held as common rights to which non-members do not have access. Sharing the knowledge with companies interested in developing further applications then amounts to disclosing this knowledge held in common to a non-member but this does not result in the depletion of the stock of traditional knowledge.

Another problem is that TK is rarely documented. It resides primarily in the practices and use by the practitioners and is preserved by means of oral transfer by members of one generation to the next. In one sense, it could be understood as being similar to a trade secret among the community that holds the knowledge. In the absence of intergenerational transfer, there is a danger of losing the existing stock of knowledge. There is already declining use of the knowledge today. It is in this context that the social value of TK provides the incentive for maintaining the existing stock of knowledge. Contractual agreements between the holders of TK and potential users can provide an incentive for preserving the knowledge. Thus, commercial exploitation of traditional knowledge may actually prevent rapid depletion by channeling it towards profitable use.

It should also be noted that given the above characteristics, TK would not normally qualify as subject matter for a patent or copyright protection. In the light of long-term objectives of preservation and sustainable use of knowledge, a system of long-term contracts that rewards the community for preserving and sharing of TK and that also provides the companies with sufficient returns will be more relevant. However, these issues are beyond the scope of this paper and form the base for future research. For the purposes of this paper, the model in the following section formulates a one-period bargaining problem between the community with the TK and the company with the R&D capacity using this TK. As we will see, infinite Nash equilibria are possible in this situation. The actual profit shares of the community and the company depend on the relative bargaining strengths of the two parties and their expectations about the future returns from the innovation. This in turn depends on the information they possess about the revenues and costs of future innovation.

4. The Model: Division of Profits from Innovations Based on Traditional Knowledge

In this paper, I build on Cumulative Innovation theory to develop a single-period bargaining model. Commercial innovations based on traditional knowledge are essentially cumulative in nature. The social value of TK depends on the value of future innovations facilitated by the existing stock of TK. However, there must be sufficient incentives for the parties involved to invest in developing these innovations. These incentives are the focus of the model.

As discussed earlier in this paper, there is declining use of existing TK with diminishing intergenerational transfer of knowledge and practices. There exists, however, a market for valuable TK as a resource base for developing new pharmaceutical and biotech products. Contractual agreements can provide incentives for the community to continue to preserve its knowledge and disclose it for commercial exploitation. Similarly,

contracts can be designed to allow companies to invest in R&D to develop further marketable innovations based on traditional knowledge. There will be an incentive to undertake further innovations based on TK if both parties can share in the subsequent profits derived from the same. The issue, then, is one of determining the respective shares of the two parties in the profits. The sharing of profits between the community and the company will be a result of their relative bargaining strengths in negotiating the contract.

Consider a situation where there are two players: Player 1 and Player 2. Player 1 represents the community that holds the traditional knowledge and Player 2 represents a pharmaceutical company with the technology to develop an innovation based on TK. We assume there is only one community that can supply the TK and only one company interested in developing a TK application, a pharmaceutical product, for instance. The profit equations and conditions for the community and the company are as follows.

Let Y = present value of expected revenue from the TK-based innovation.

Let C_1 = costs incurred by the community in sharing the TK. $C_1 > 0$. These may be understood as transactions costs⁸ to the community at the time of negotiating the contract.

Let C_2 = present value of the costs incurred by the company in R&D and production of the TK-based innovation. $C_2 > 0$

Let a = a percentage of the revenue from the innovation paid as royalty by the company to the community $0 \leq a \leq 1$

Let p_1 = present value of the profits of the community

$$p_1 = aY - C_1$$

Let p_2 = present value of the profits of the company

$$p_2 = (1 - a)Y - C_2$$

The two parties will enter into a contract to develop further innovations from TK if both of the following conditions are satisfied.

$$p_1 \geq 0$$

$$p_2 \geq 0$$

⁸ These refer to costs incurred by the community in organizing and meeting with the company to share the knowledge, collect and transfer the plant resource, if required etc.

There will be an incentive to invest in developing innovations based on TK only if there is a positive return associated with the same. The community's TK about the medicinal plants can provide valuable leads to the company in identifying active compounds for developing plant-based pharmaceutical drugs. This contributes to the company's profits by directly reducing the high search costs associated with random searches in pharmaceutical prospecting. In addition, leads from TK can also bring to light medicinal uses of plants that are as yet unknown and thus help in developing entirely new products. The company will be interested in acquiring the TK from the community only if the profits from the TK-based innovation exceed the costs of developing it and the amount paid out to the community as royalty for using the knowledge.

$$p_2 = (1 - a)Y - C_2 \geq 0 \dots\dots\dots(1)$$

Similarly, the community will be willing to share the TK with the company only if it earns a share of the revenue from the TK-based innovation that at the least covers its costs of sharing the knowledge.

$$p_1 = aY - C_1 \geq 0 \dots\dots\dots(2)$$

The final contract will be a result of negotiations between the two parties regarding the sharing of revenue from the TK-based innovation in a way that at least covers the costs for both players. The final shares depend on the bargaining strengths of both players. The two players derive their bargaining strength from the information they possess about the expected revenue and the costs involved in developing the application.

So far, we have made the implicit assumption that both players know the future stream of revenue. However, this assumption rarely holds. While the community possesses information about the attributes of the TK, the company is better informed about the potential costs and benefits associated with developing the pharmaceutical drug based on TK. As a result, the expectations regarding the future stream of revenue from the TK application are likely to be different for the community and for the company.

In the following sub-sections, different scenarios are analyzed. We first assume that both the community and the company are fully informed about the costs and revenues of the future innovation and that there is one stream of future income, known to both players. There is no asymmetry of expectations between the community and the company about the present value of the expected revenue from the TK-based innovation. In this context, separate individual profit maximization strategies are analyzed. Section 4.2 and 4.3 discuss a cooperative strategy of joint profit maximization. In section 4.4, asymmetry of expectations regarding the future stream of revenues from the innovation is introduced and its impacts on the contract structure discussed. The final sub-section analyzes the situation when there is a third party, such as the government or a NGO, involved and how this affects the relative bargaining strengths of the players.

4.1 Scenario One: Individual Profit Maximization and No Asymmetry

I start with the simple case, where there is no asymmetry of expectations between the two players about Y . I also assume at this point that the community only shares the TK with the company and is not involved in any other activity involving research and development of the TK-based innovation thereafter. The community does not cultivate and supply the plant resource required for making the product either. The company internalizes the cost of raw material supply.

For the community:

The value of a that maximizes π_1 is $a = 1$. This means that the entire surplus revenue from the innovation is transferred to the community in royalties. However, this is unrealistic as it provides no incentive at all to the company to develop the TK-based innovation in the first place. Thus,

$$p_1 = aY - C_1 \text{ if } 0 < a < 1, \text{ otherwise } 0.$$

For the company:

The company, on the other hand, will find that π_2 is maximized at $a = 0$. In this case, the community will not even disclose the TK to the company, as there is no incentive for the community to share the knowledge. Thus,

$$p_2 = (1 - a)Y - C_2 \text{ if } 0 < a < 1, \text{ otherwise } 0$$

Result 1: No contracts exist at $a = 0$ and at $a = 1$. However, anything in the range of $0 < a < 1$ is possible.

Even if there is a positive social value to developing TK-based innovations, i.e. $Y > 0$ is possible unless it is profitable to both parties, they would not enter into a contract to develop the application. The final value of a will depend upon the result of negotiations between the two players, given their relative bargaining strengths.

Following the revenue sharing contract structure, the least value of a the community will be willing to accept is one that is exactly equal to its costs.

$$p_1 = aY - C_1 = 0$$

$$a = \frac{C_1}{Y} \dots\dots\dots(3)$$

In this case, the company will thus maximize its profits given the above condition.

$$\begin{aligned} &\max_a (1 - a)Y - C_2 \\ &s.t. aY = C_1 \quad 0 < a < 1 \end{aligned}$$

Thus, it would pay the community an amount exactly equal to the costs incurred by it in sharing the knowledge. Thus, profits to the company would be

$$p_2 = Y - C_1 - C_2 \dots\dots\dots(4)$$

Equations 3 and 4 determine the lower and upper bounds of α . In this situation, the community usually commands little bargaining power.

Result 2: Under conditions of individual profit maximization, the value of α is determined by the condition $\alpha Y = C_1$.

Note on Different Contract Structures:

It is useful to point out here that the contract structure assumed to be adopted is one of revenue sharing. Several different contract structures are possible. In technology licensing contracts, standard contracts involve payment of (a) a royalty—a percentage of revenue for every unit produced using the original patented technology; (b) a fixed license fee paid at the time of signing the contract; or (c) a combination of both. Thus, if the contract structure in the TK case is a licensee fee at the beginning of the contract, then the equations would be:

$$p_1 = L - C_1$$

L = a fixed licensee fee paid at the time of signing the contract

$$p_2 = Y - L - C_2$$

Alternatively, if it is a combination of the license fee and the royalty payment,

$$p_1 = \alpha Y + L - C_1$$

$$p_2 = (1 - \alpha)Y - L - C_2$$

In this case, $\alpha = 0$ is a possibility. As long as the license fee L covers the costs to the community, C_1 , the company can choose $\alpha = 0$, and it still satisfies the condition for the community. Thus, the bounds for α would be $0 \leq \alpha < 1$. Similarly, another contract structure would be (L, α) such that $L = 0$; $0 < \alpha < 1$.

4.2 Scenario Two : Joint Profit Maximization

Both the community and the company seek to maximize profits. An infinite number of Nash equilibria are possible. One possible solution is when both players decide to cooperate and maximize joint profits. First, I consider a contract structure *ex-post*, that is, the company has already sunk costs and subsequently, I examine a contract that is *ex ante*, before the costs are sunk.

(a) Ex-post Contract

$$\max_{\alpha} (\alpha Y - C_1) ((1 - \alpha)Y - C_2)$$

Differentiating w.r.t. a

$$\Rightarrow a = \frac{1}{2} \left(1 + \frac{C_1 - C_2}{Y} \right)$$

This equilibrium solution represents the case where both parties have the same bargaining power. Similarly, other cooperative and non-cooperative strategies can be explored in relation to the bargaining strengths of the two players.

(b) *Ex-ante Contract*

The company and the community may also decide upon another type of contract structure, where they decide to share both the revenues and the costs of developing the TK-based innovation. This would represent an *ex-ante* sharing of profits from the TK application.

$$p_1 = a(Y - C_2) - C_1$$

$$p_2 = (1 - a)(Y - C_2) - C_2$$

$$\max_a [a(Y - C_2) - C_1][(1 - a)(Y - C_2) - C_2]$$

$$a = \frac{1}{2} \left(1 + \frac{C_1 - C_2}{Y - C_2} \right)$$

Again, the final value of a that is determined is a result of the bargaining strengths of the two parties.

Result 3: Under the above assumptions, the equilibrium value of a under the *ex ante* contract is greater than the equilibrium value of a under the *ex post* contract structure.

4.3 Scenario Three : Joint Profit Maximization and Community Supplies the Plant Resources

The factors that determine the community's bargaining position depend on the extent of contribution of TK in developing the innovation and its involvement in the whole process. So far, we have assumed that the community merely provides the knowledge and is not involved in contributing its expertise in adapting the TK to develop the innovation or in clinical research trials of the product. In the following sub-sections, some specific factors that have an impact on the bargaining positions of the parties involved are introduced to analyze the impact on a .

I continue to assume that there is only one community and it is the sole source of the TK. Also, there is only one company that is interested in and has the R&D capacity to develop the TK-based innovations.⁹ A lot depends also on how the community can negotiate its demands with the company.

In this sub-section, I consider the situation, where the community cultivates and supplies the medicinal plant resources required for developing the TK innovation, along with providing the knowledge about the medicinal plant. The company may not be aware of the cost structure of the community if the community employs traditional practices and knowledge in cultivating the plant. This may also be interpreted as one form of an *ex ante* contract structure, where the community and the company share the costs of developing the TK-based innovation.

Let C_1^p = present value of the costs of cultivation and supply of the plant resource

$$p_1 = aY - C_1^p - C_1 \dots\dots\dots(5)$$

$$p_2 = (1 - a)Y - C_2 \dots\dots\dots(6)$$

$$\max_a (aY - C_1^p - C_1) ((1 - a)Y - C_2)$$

$$a = \frac{1}{2} \left(1 + \frac{C_1 + C_1^p - C_2}{Y - C_2} \right)$$

The community is in a better bargaining position here as it also supplies the plant resource. However, it is also assumed that the company is unable to procure the resource from any other source.

Result 4: The equilibrium value of α is higher under conditions, where the community also supplies the plant resource associated with the TK compared to a situation, where it merely shares the knowledge with the company.

However if the company can synthesize the active compounds in the plant in the laboratory, it no longer needs the plant resource. It would then have internalized the cost of the resource and the bargaining game is similar to the initial situation where the community merely provides the TK.

4.4 Scenario Four : Asymmetry of Expectations – Individual Profit Maximization

At this point, I introduce the fact that expectations regarding the future revenue from the innovation differ for the company and for the community. There usually exists an asymmetry of expectations between the community and the company about Y and C_2 because of the differences in the information available to each player about the

⁹ In a situation, where there are alternative sources for the knowledge, the bargaining position of the players will be different. Further, if several companies are competing to obtain TK from one community, the community can evaluate the benefits it receives from each of the alternative contracts and accept the contract which gives the highest a .

development and marketability of future innovation. The community possesses complete knowledge about the attributes of the resource when it comes to its medicinal properties and their effects. However, the company is better informed about the costs involved in developing a marketable product from the basic knowledge and the market potential for the TK-based innovation. This causes both players to have different expectations about the costs of innovation and about the future stream of revenue from the innovation. The asymmetry about costs does not directly affect the bargaining when the sharing of profits is *ex-post*, i.e., costs have already been sunk by the company. It becomes important when the contract structure includes sharing of the costs as well, as in the case of an *ex-ante* contract. The impact of the asymmetry of expectations on the contract structure is analyzed below.

x = quantity of the resource supplied and C_1^p is an increasing function of x .

$$C_1^p = f(x)$$

q = quantity of the TK-based innovation (pharmaceutical product) produced.
 q is a function of x and the future revenue is in turn a function of q .

Y_1 = community's expectation of present value of revenue from the innovation

$$Y_1 = f(q(x))$$

Y_2 = company's expectation of present value of revenue from the innovation

$$Y_2 = f(q(x))$$

$$Y_1 \neq Y_2$$

The conditions are the same; both players still try to maximize profits (under an *ex-post* contract). The objective here is to arrive at an optimal quantity of supply of the plant resource.

$$p_1 = aY_1(q(x)) - C_1^p(x) - C_1 \dots\dots\dots(7)$$

$$p_2 = (1-a)Y_2(q(x)) - C_2(q(x)) \dots\dots\dots(8)$$

The community maximizes p_1 w.r.t x

$$\text{Max } p_1 = aY_1(q(x)) - C_1^p(x) - C_1$$

By the first order condition,

$$aY_1'(x) = C_1^p'(x)$$

This gives an optimal level (\hat{x}_1) for the community at which profits are maximized. This is the amount that the community will be willing to supply.

The company will maximize p_2 w.r.t. x

$$\text{Max } p_2 = (1 - a)Y_2(q(x)) - C_2(q(x))$$

By the first order condition,

$$(1 - a)Y_2'(x) = C_2'(x)$$

This gives the optimal quantity (\hat{x}_2) required by the company to maximize profits.

Since, the two players have different optimal levels of x as a result of different expectations about Y , they negotiate till the optimal \hat{x} is reached.

The subsequent revenue sharing is again a result of the bargaining positions of the two players. Now, the community is involved for a longer period since it supplies the base plant resource to the company for the development of the product. The company will require that the optimal quantity (x^*) is supplied by the community and the community will supply (x^*) if it receives an amount that covers the cost of supplying (x^*) .

Result 5: Under asymmetry of expectations about future stream of revenues and costs,

the community is willing to accept a value of $a = \frac{C_1'(x)}{Y_1'(x)}$ i.e. it equals the ratio of marginal cost of cultivating and supplying the plant resource over marginal revenue earned

from the TK-based innovation. The company is willing to share $a = 1 - \frac{C_2'(x)}{Y_2'(x)}$, i.e. 1 minus the ratio of its marginal cost of the innovation over the marginal revenue.

4.5 Scenario Five : Third-party Involvement and Relative bargaining Strengths

Bargaining positions of the community vis-à-vis the company can change with the involvement of a third party, such as the government or an NGO negotiating on behalf on the community. This alters the relative bargaining strengths because it may change the asymmetries in the expectations of the future stream of revenues.

Following from the previous sub-section, a realistic initial situation would be one where,

$$Y_2 = Y$$

$$Y_1 < Y$$

(where, $Y =$ present value of expected revenue from the TK-based innovation.

$Y_1 =$ community's expectation of present value of revenue from the TK-based

innovation.

Y_2 = company's expectation of present value of revenue from the TK-based innovation.

Here it is assumed that the involvement of the government, for example, can help the community revise its expectation if the government either already has or can obtain more information through its efforts. This can work towards raising the lower bound of α and change the relative bargaining strengths. Alternatively, the government could, through legislation, regulate the contract structures.

Let a_{\min} = the minimum value of α that the community is willing to accept

And a_{\max} = the maximum value of α the company is willing to pay

The final sharing of the revenue is based on a specific a^* , determined as a result of the bargaining between the two players.

Let $b \rightarrow 1$ represent the bargaining strength of the community to the company.

$$a^* = a_{\min} + b(a_{\max} - a_{\min}) \dots\dots\dots(9)$$

The bargaining strength depends on the information available to each party about the expected future return from the innovation.

With the third party acting on behalf of the community, the expectation about Y will be different so that the new expected income from the application for the community is \hat{Y} , where $\hat{Y} > Y_1$. It pushes up the minimum bound to $\hat{a}_{\min} > a_{\min}$. With a change in the asymmetry of distribution of information, there is correspondingly a change in the bargaining strengths.

$$\bar{a} = \hat{a}_{\min} + \hat{b}(a_{\max} - \hat{a}_{\min}) \dots\dots\dots(10)$$

The above equation shows that not only is the range of α reduced, the bargaining strength of the community also improves.

$$\bar{a} > a^* \text{ and } \hat{b} > b .$$

Result 6: With the involvement of a third-party on the part of the community, the bargaining strength of the community can improve relative to that of the company and this results in a higher value of a .

It is useful to undertake such an analysis when the government or an NGO is involved in programs for the promotion of TK and practices. Formulation of different bargaining scenarios and a comparison of different contract structure can therefore help to develop

equilibrium solutions in dealing with problems when it comes to the sharing of profits from TK-based innovations.

5. Discussion and Conclusions

To summarize, the problem of designing incentives for promoting innovations based on TK is similar to problems in designing incentives for cumulative innovations for any scientific or technological knowledge. The characteristics that set TK apart from other cases have to do with the fact that the knowledge is held collectively and it is not new. There is no pre-existing patent or any other form of IPR over the traditional knowledge. The knowledge has been preserved and used only through inter-generational transfer of the knowledge within the members of the community. However, this practice of inter-generation transfer is declining and therefore the use of the knowledge is also diminishing.

The social value of TK, today, accrues from its value as a resource base for developing future innovations in modern biotechnological and pharmaceutical research. Both the community and pharmaceutical companies can benefit if valuable TK is identified and a system of incentives is provided whereby both parties can earn profits by sharing the revenues generated from investments in developing TK innovations. The problem is one of bargaining between the community and the company on determining their respective shares. The final benefit-shares depend primarily on the expectations of the community and the company about the future streams of revenues and costs associated with the TK-based innovation, their respective contributions in developing the innovation and the involvement of a third party, such as the government or a NGO in the negotiations.

There are six key results that emerge from this initial formulation of the bargaining problem.

(1) No contracts exist at $\alpha = 0$ and at $\alpha = 1$, where α is the benefit share accruing to a community when it enters into a commercial contract with a company and shares its traditional knowledge for drug development. However, anything in the range of $0 < \alpha < 1$ is possible. This tells us that at $\alpha = 0$, the community has no incentive to share the knowledge with the company. Similarly at $\alpha = 1$, the company has no incentive to develop the TK-based innovation as the community captures all the return. This leaves us with infinite possible solutions in the range of $0 < \alpha < 1$. The final value of α depends on the negotiations between the community and the company and their relative bargaining strengths.

(2) Under conditions of individual profit maximization, the value of α is determined by the condition $\alpha Y = C_1$. The lower bound of α is determined by the minimum amount the community is willing to accept and it is at least exactly equal to the costs incurred by the community in sharing the knowledge. The company, on the other hand will not be willing to pay any more than what is required to satisfy the lower bound.

(3) Under conditions of cooperation, the equilibrium value of α is determined through joint profit maximization. There are two possible situations: *ex ante* contract and *ex post* contract. Under the *ex ante* contract, $\mathbf{a} = \frac{1}{2} \left(1 + \frac{C_1 - C_2}{Y - C_2} \right)$ is greater than the equilibrium

value of α under the *ex post* contract structure, $\mathbf{a} = \frac{1}{2} \left(1 + \frac{C_1 - C_2}{Y} \right)$. In the *ex-ante* contract, since the community is involved in the process of developing the TK-based innovation and shares in the costs of innovation, it is likely that it has a better bargaining position in the contract.

(4) For instance, under conditions of joint profit maximization, when the community also supplies the plant resource associated with the TK, the equilibrium value of α is

higher, $\mathbf{a} = \frac{1}{2} \left(1 + \frac{C_1 + C_1^p - C_2}{Y - C_2} \right)$ compared to a situation, where it merely shares the

knowledge with the company, $\mathbf{a} = \frac{1}{2} \left(1 + \frac{C_1 - C_2}{Y - C_2} \right)$. However, if the company is able to synthesize the compound in the laboratory or finds an alternative source or is able to internalize the cost of the plant resource, then the community loses some of its bargaining strength relatively.

(5) Under conditions of asymmetry of expectations (and assuming the community supplies the plant resource), the community and the company have different expectations about future stream of revenues and costs. Both parties maximize individual profits based on their expectations about the future revenue and costs of the TK-based application. The value of α is determined based on negotiations between the two players on the optimal quantity of plant resource required for the innovation. The community

is willing to accept a value of $\mathbf{a} = \frac{C_1^p'(x)}{Y_1'(x)}$ (the ratio of marginal cost of cultivating and supplying the plant resource over marginal revenue). The company is willing to share

$\mathbf{a} = 1 - \frac{C_2'(x)}{Y_2'(x)}$, i.e. 1 minus the ratio of its marginal cost of the innovation relative to marginal revenue.

(6) With the involvement of a third-party (such as the government or an NGO) that supports the community, the bargaining strength of the community can improve relative to that of the company and this results in a higher value of α . With the third party, we

find, $\bar{a} > a^*$ and $\hat{b} > b$ (where b represents relative bargaining strength of the community).

In conclusion, the results suggest that the community and the company will be interested in entering into a contract to develop TK-based innovations if both the parties earn profits that are at least equal to the costs they have to undertake. The actual sharing of the profits depends upon a number of factors, most importantly, the relative bargaining strengths of the two players. The factors that affect the relative bargaining strengths include the contribution of the parties in developing the TK-based innovation, the availability of alternative sources and options, differences in the expectation of future revenue and costs of the innovation, and the involvement of a third party in the negotiations. Each of these has a different impact on the final sharing of the profits.

This paper contains an initial formulation of the problem of sharing of profits from TK-based innovations. It uses an approach of bargaining between the community with the TK and the pharmaceutical company with R&D technology. Future research needs to be directed towards developing and extending the model using empirical data, if available, to test the working of the model. In a context, where most developing nations are taking steps, in terms of legislation and/or programs, to conserve and promote biodiversity and associated traditional/indigenous knowledge, research on the design of a system of incentives and contractual arrangements and their impacts will be particularly useful to policy makers. Past efforts, such as in the Kani Tribes case, have shown that most complications arise in identifying the stakeholders and agreeing upon a means of sharing of profits from TK-based innovations. A detailed and in-depth understanding of the negotiating positions, bargaining strengths, asymmetries of expectations between the traditional communities and the pharmaceutical and biotech industries can definitely help guide policy-making solving some of the problems associated with recognition and protection of intellectual property rights associated with traditional knowledge.

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