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Governance of the R&D Sector for Bio-Technology: Intellectual Property Rights and Bio-Prospecting

Mare Sarr and Timothy Swanson[1]

Abstract:

The efficient governance of information-production is analysed in the context of the bio-technology industry. Here primary R&D generates pure abstract information on the nature of biological solution concepts, while secondary R&D generates commercial products marketable to consumers. It is argued that the optimal industrial structure in these circumstances is for a unitary integrated firm to manage both stages of R&D making use of a single property right. It is shown that the impact of a second property right in the industry is to shape the terms of agreement in the creation of this integrated firm. Under reasonable assumptions, the creation of a second property facilitates the creation of this efficient integrated industry, but there is little profit-sharing between the two stages of the R&D sector. When the South is the primary location of the first stage, and the North is the primary location of the second, this indicates that the creation of another property right may have positive efficiency implications but few distributional ones. Efficient governance therefore requires the introduction of a second property right in order to be able to achieve efficient integration. .

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1 Introduction

Bio-prospecting is a form of R&D used by pharmaceutical or biotechnology firms to find and collect natural compounds necessary for the development of new drugs. It requires cooperation between the bio-prospecting firm and the community hosting the genetic resources and/or traditional knowledge. The host community provides basic or pure information on potential solution concepts, while the R&D firm supplies the practical capabilities for developing these solution concepts into marketable compounds and products. In this manner primary biological information is generated and channeled through a secondary R&D sector to become commercial products capable of addressing consumer needs.

An important issue concerns the nature of the governance mechanism that should manage the production of innovation within this R&D sector. One possibility is for the sector to operate by means of independent property rights and contracting. In this set-up, each stage of the R&D sector is incentivised by reason of property rights, and then coordination and transfers between them are managed by means of contracts. The difficulty in this situation is in providing adequate incentives at appropriate levels for a service as complex as joint R&D. Information-production is difficult to compensate correctly, and the development of multiple property rights and contracts regarding them is a complicated endeavour.

The current arrangement in this industry is indicative of the complexity of the problem. Current laws usually provide for a single property right at the secondary stage of R&D, and thus require contracting between the two independent entities. That is, most current IPR regimes fail to recognize the rights of producers of primary information in this area (often termed "traditional knowledge"), but will recognize rights in innovative products developed out of this primary information. Thus, the bio-prospecting firm will be able to claim intellectual property rights in the pharmaceuticals or plant varieties it markets, but the community that produces the

original information or genetic resource will have no rights of any kind, to either initial information or final product.

This approach is particularly problematic as it requires that the downstream firm contract with its predecessor for the provision of the correct amount of information (about biological activity or distinctive genetic resource). This places a lot of emphasis upon the capabilities of the upstream firm for the creation of downstream incentive mechanisms. In addition, this firm must attempt to achieve this efficient information-production via arms-length contracting. This is a difficult problem in mechanism design. How can a downstream firm generate incentives for upstream entities to develop information it might use, when it has little knowledge regarding its production or little capacity to restrict competing producers? (Other primary producers of the same information will be able to compete away the rents of the first innovator, irrespective of the contract.) This problem requires something more of the nature of a state governance mechanism, than a bilateral contract.

If the state does not act, what can the upstream firm do? When contractual complexity becomes too great, there may be incentives to integrate the two entities a la Coase's transactions cost theory of the firm. (Coase 1937) Under this theory, governance is best accomplished by the vertical structure that is best able to minimize the costs of transaction within the vertical industry. If the transactions costs are too great when operating independently, the separate stages of the industry should vertically integrate. (Williamson 1985) The upstream user of information would then apply its property right mechanism directly to the purpose of generating primary information.

In this paper we set out our analysis of the bio-prospecting industry within this framework. We observe the costliness and inefficiency of attempting to coordinate

the industry under existing rights structures, and enquire concerning the means for integration. We find that the introduction of a second property right at the primary stage is necessary to provide the basis for integrating the two sectors into a single integrated entity. Although this property right is critical to achieving efficient integration in the industry, it does not appear that it will impact upon the distribution of benefits significantly. For this reason, a second property right and integration within the industry, is probably more important for efficiency reasons than it is for equity.

2 Economic Analysis of cumulative innovation

We have already suggested that bio-prospecting is best viewed as an example of information-production, in which the first stage generates pure or primary information and the second stage develops this into a marketable (and patentable) product. This manner of interaction between the primary and secondary stages of an R&D industry is a good fit with the cumulative research framework developed within the I/O literature in economic theory, in which abstract basic research is built upon by developers to generate concrete innovations. (Scotchmer, 1991; Green and Scotchmer, 1995). In this section we wish to set out the general implications of this literature for the management of R&D in this bio-technology sector.

2.1 R&D Governance and Bio-Prospecting

The industrial organisation literature has analysed the cumulative nature of innovation and its implications for the design of intellectual property rights policy. Emphasis there is placed on giving first-stage innovators adequate incentives to invest and innovate, because no inventions or discovery would be possible without their contribution. It is therefore argued that first innovators should be protected via patents while the second innovator can be denied patent protection if licensing can be relied upon. (Green and Scotchmer 1993) It is striking that, in practice in the

biological sector, the opposite result has obtained. Only the secondary stage of the research process is granted property rights protection in this sector while the primary traditional stage is left unrewarded despite its crucial contribution to innovation. This raises two problems, one of efficiency and one of equity.

First, if traditional knowledge is not protected, it may first remain unknown and then may even become lost forever, which would lead to a relatively lower rate of innovation and therefore reduced levels of social welfare. Secondly, in this particular area of R&D, there is a North-South (or distributional) aspect to the I/O problem as well as an efficiency aspect. This is because we can assume here that the R&D firm will nearly always come from the stylized "North" (where the North is possessed of unique technological capability as well as access to important markets). In contrast, the stylised "South" can be assumed to be uniquely possessed of rich stocks of genetic resources and accumulated traditional knowledge (know-how, remedies, practices), without access to technological capability to develop marketable or patentable products.

Because the patent system exclusively rewards the North for its innovation, despite the South's undeniable contribution, concern about a fair division of benefits has led some observers to make the case for protecting genetic resource owners or traditional knowledge owners with intellectual property rights. In this paper, we set out to explore the questions of the number and placement of patents within the entire vertical industry (i.e. the suppliers of genetic resources as well as the manufacturers). In particular we wish to examine how the creation of additional property rights might help to enable the transformation of this sequential, diverse and divisive industry into one that might instead be unitary, integrated and efficient. What would this transformation look like? How would it occur?

2.2 Innovation and the Internalisation of Information Externalities

The economic rationale for granting property rights to innovations was first explained by Nelson (1959) and Arrow (1962). Their argument proceeds as follows. Because innovation or knowledge is a public good (non rival and non-excludable), it is likely to be under-supplied as its social value exceeds its private value. A mechanism ensuring that positive externalities are internalized is therefore necessary. The implementation of an intellectual property rights regime is one such mechanism. By granting a temporary monopoly over the use and exploitation of an innovation, intellectual property regimes give the innovator the incentive to invest by ensuring that he captures part of the social value he has generated. However, the creation of such a property right is only one means for internalizing the externalities of information-production. When there are several entities cooperating in the production of information, one possibility for governance is the use of property rights and contracting while another possibility is integration and internal coordination.

Earlier economic analysis considered R&D innovations as a stand alone process, i.e. innovations were not based to any important extent on pre-existing research. However, in many instances information is passed down through a chain of innovators as it is processed toward marketability. For example, it is not uncommon for some entities to be specialised in basic research while others are focused on the development of products based upon the primary knowledge supplied by the former. Thus, the end product results from the accumulation of information across both stages of these types of R&D industries.

An important problem noted in the sequential research literature is that, when innovation is sequential, early innovators in a non-integrated vertical industry may lack the incentive to invest if they do not hold a distinct property right. (Scotchmer 1996) This point, raised earlier, is fundamental in the literature and indicative of the

presumption in favour of primary property rights in sequential R&D. In the context of bio-prospecting this would imply the addition of a second property right within the industry, as a clear right exists to innovations occurring at the secondary stage.

This raises another important issue regarding the efficiency of the governance structure. If both innovators are granted patents and continue to operate independently, then the double monopoly distortion within the vertical industry may induce a welfare loss. When successive monopolies operate in the same vertical industry, the impact is to impose successive margins within the chain of production. This implies distortions to efficient resource allocation, even greater than those emanating from a single monopoly. (Vernon and Graham 1976). This distortion would create incentives for closer coordination or integration.

To this point we have argued that the current governance structure is inefficient, since contracting upstream to create information-generation mechanisms is usually not possible. A second property right at the primary stage might enable better incentives at that stage, but at the cost of double distortions within the vertical sector. These considerations indicate that integration within the industry is the likely way forward for incentivising information production at both levels. Integration would enable full coordination in information production, and in revenue generation, so there would be no need for multiple distortions.

The question now concerns how integration could proceed. On what basis would efficient integration occur, and how would each level be compensated in order to create incentives for efficient information generation?

2.3 Compensating Information Production: The Novelty Requirement

Compensating information production in successive R&D depends upon how "production" is determined at each level. When does the improvement of existing

information constitute an innovation, and when does it simply represent a use of that information. This issue is considered within the R&D literature under the heading of "novelty".

The novelty requirement for innovations is usually analysed in terms of the delineation of the lines between successive, independent innovations. Information diffusion is a crucial issue in cumulative research because it has important impact on both research costs and the rate of discovery. Scotchmer and Green (1990) discuss the trade-off between the protection of the innovators' profit and the benefits from the disclosure of information. These two goals are served by different sorts of patent requirements: length and breadth. Length is usually discussed in regard to the novelty requirement for successive patenting, while breadth is usually discussed in regard to the distinctiveness required to avoid patent infringement (not just to acquire one's own patent).

The profit from an innovation is greater if the patent has a longer effective life, and this depends on the timing of its replacement by the next "vintage" of technology. In this respect, a strong *novelty* requirement may be an important instrument for the management of patent-based profit, by protecting the length of a monopoly against insignificant advances. However, the disclosure of information within the public domain is socially beneficial because it accelerates the rate of discovery and reduces the aggregate cost of research by shortening the investment period. A weak novelty requirement encourages inventors to patent every small technological advance. Information becomes common and can be used to develop new products.

Assuming reverse engineering is possible, the case for a weak novelty requirement must be balanced against the fact that first innovators may well prefer secrecy over disclosure to protect their profit as opposed to what happens with a strong novelty

requirement. Besides, it is argued (Eswaran and Gallini, 1996) that a strong novelty requirement makes firms concentrate on the most socially valuable projects. For these reasons, it is usually assumed that less-frequent but more substantial steps of innovation are important for patent policy.

All of this points to the need for courts to define "novelty" in a way that recognizes substantial contributions to successive research. When two levels of R&D are integrating, it is only fairly substantial increments to existing information that should be recognized as distinct innovations.

2.4 Role of Courts in Patent Infringement in Successive R&D

It is what courts will enforce that determines the terms of contract between successive innovators. If the downstream innovator makes minor amendments to the upstream innovation, and the courts refuse to award a distinct property right, then the upstream innovator is the sole owner of all innovations in that stream. On the other hand, if the courts readily award rights to downstream innovators, then the upstream innovator will have to share the market for its information at the least, and may even be preempted if the downstream innovator has better access to the market concerned.

One of the major issues addressed in the literature of cumulative research is the question of how courts determine the division of the rents between the first generation innovator and any subsequent ones (cf. Scotchmer 1991, Green and Scotchmer 1995, Gallini and Scotchmer 2002).

The patent policy about the breadth of the patent (interpreted as the minimum improvement required to avoid infringement of the first generation product) is a key determinant of the division of the profit as well as being a factor in the novelty determination for a new patent (which in turn determines the size of the joint

industry profit). In this regard, when the value and the costs of the project are certain, a broad patent is defined to be one that instructs courts to protect the first innovator from any innovations that represent minor or relatively inconsequential improvements.

The willingness of courts to enforce a patent against incursions from products possessed of minor modifications generates important incentives for contracting. With a broad patent the second innovator is more likely to infringe the earlier technology, and is therefore more likely to sign an ex ante licensing contract (the license is signed before the second innovator decides to sink costs in innovation) to be able to develop an improved product.

Scotchmer (1996) investigates whether the second patent should be granted or denied when the first patent is infringed. Based on the assumption that the second generation product always infringes the original patent (i.e. the patent is assumed to be very broad), the author analyses how the division of profits is affected by the patentability of the second product. Restricting the study to the case where the entire commercial value of a base technology is contained in the application it facilitates, she shows that the patent system must ensure an adequate division of profit between both inventors so that each of them covers its costs. Provided ex ante licensing is feasible, there are sufficient incentives for the second innovator to invest, for an ex ante agreement allows firms to share profits in a way that avoids ex post hold up problem. So, denying patentability to the second generation product is a means to transfer profit to the first innovator.

The critical assumption here is that there is no impediment to ex ante licensing and such agreement induces no significant transaction costs. Given this assumption, granting a patent only to the first innovator combined with ex ante licensing is

sufficient to provide the right incentives. The decision to place the patent in the hands of the first innovator is due to the fact that without his investment and innovation, no second generation product can be developed. In addition, the first innovator may not be able to capture a share of the profit generated by the end product.

The possibility of contracting as well as the transaction costs will determine the extent to which firms will be involved in an agreement. If ex ante licensing is feasible then, the breadth of the patent will determine the extent of infringement and thereby the division of profits (Green and Scotchmer 1995).

In principle, ex post licensing (where the license is signed after the second innovator decides to sink costs and the new product infringes the first generation product) can also be used. However, ex post licensing is less likely to emerge in equilibrium because the second innovator lacks the incentive to invest efficiently when it bears the full research costs upfront while having to agree a share of its ex post revenue with the licensor. In fact ex post licensing along with the breadth of the patent are usually seen to serve as the "threat points" for the bargaining over an ex ante license.

2.5 Successive R&D and Industrial Structure

This summary of the I/O literature on successive R&D makes clear that the issues relating to patent rights and claims in these industries are important to the determination of the industrial structure that results. When individual entities interact in the creation of related information and innovations, it is the willingness of states to recognize these contributions and of courts to enforce these rights that determines the shares that each innovator receives. And, more importantly for our purposes, it is also this rights structure that determines the starting point for negotiations over the ultimately-agreed industrial structure. Contracting between the primary and secondary stages of R&D requires a starting point, and this starting

point depends upon the recognized property rights framework and the willingness of the courts to enforce it.

We will now take these findings forward into our discussion of how property rights in bio-prospecting can and will determine the outcome of negotiations over the structure of this industry. In particular, we wish to ask how the recognition of a second property right in the primary stage of R&D in bio-prospecting might impact upon the efficiency and equity impacts of the creation of a unitary, integrated industrial structure for R&D.

3 Economics of cumulative research in BioTech

In this section we set out an economic framework for considering the issues we surveyed above. We wish to demonstrate how the property right (and judicial) framework determines how the successive levels of R&D might be integrated. We wish to use this framework to assess both the efficiency and the distributional implications of governance within this R&D sector.

3.1 Informational Assumptions behind the Modeling of the Industry

3.1.1 Traditional Knowledge as Tacit Information

Gehl Sampath (2003) argues that biological information may be viewed on a continuum from highly uncodified (or tacit information) to highly codified (tangible information). The codified information represents information processed by the biological sector with the view to develop a marketable end product. Biotechnology or pharmaceutical companies commonly use basic information as an input for further research. For example, it is not uncommon for small and medium sized biotechnology firms to act as suppliers of information to larger firms that process the final product. The supply of traditional knowledge to these R&D firms may play a similar role as the provision of tacit information. Biotechnology and pharmaceutical companies, through bio-prospecting, may attempt to identify new principles or

approaches for curing existing diseases. A particular plant or fungus might contain an active ingredient that gives a clue or an idea on how to initiate new lines of research. (Swanson 1995) On the other hand, traditional knowledge accumulated over the centuries may be particularly useful in the screening process for potential inputs and may help increase the rate of discovery while decreasing substantially the research costs required to make it. (Rausser and Small, 2000) There is substantial evidence that traditional knowledge makes a significant contribution to the innovation process. (Evenson and Gollin, 1998) Thus, both flows of biological information and stocks of previously accumulated information can be important parts of the R&D process. For instance, from the rosy periwinkle from Madagascar – traditionally used for treating diabetes – was used by the pharmaceutical manufacturer Eli Lilly developed two anticancer drugs vincristine (against childhood leukemia) and vinblastine (against the Hodgkin's Disease). The drugs ensured Eli Lilly annual sales over $100 million by 1985 (Farnsworth 1988) and over $180 million by 1997. (Hunter 1997). Similarly, the tranquilizer reserpine is derived from the Asian rauwolfia plant – traditionally used in South-East Asia to treat mental health disorders and snakebites. Its annual market was estimated at $260 million. (Kloppenburg 1991)

3.1.2 Vertical 2-Stage Structure of R&D Industry

From these assumptions on the nature of the informational flows within this sector, we model the R&D industry (in the biological sector) as a non-integrated vertical industry of two stages. In the primary stage, a flow of information (originating within the natural environment and requiring a diverse stock of natural capital - namely land) is captured by virtue of investment in traditional human capital - in settings where human populations interact with the natural environment through observation and selection. The combination of the two factors results in a primary

sector output of pure information. In the next stage of this vertical industry, the secondary stage biological R&D process collects these informational flows (from the primary R&D stage), and invests in physical and human capital (laboratory equipment and scientists) in order to produce innovations - new products designed to meet consumers' wants and needs.

3.2 Definitions: Regions, Endowments, Efficiency

The current property rights regime rewards only the North and fails to reward the South. This paper addresses the distribution problem and suggests a possible way to allow the South to be rewarded for its contribution within the vertical industry. Economic theory posits that the most efficient way to do that is to let the two parties integrate and then protect the whole industry and let them share the joint profit. Efficiency here is considered from the producer point of view only. However, the sharing of profit is also of importance. Is it more efficient to grant the property right either to the North or to the South? What is the optimal breadth? How is the division of profit affected?

3.2.1 Industrial structure of the economy

Definitions: Consider an economy populated by two agents South and North specialized in two different sectors.

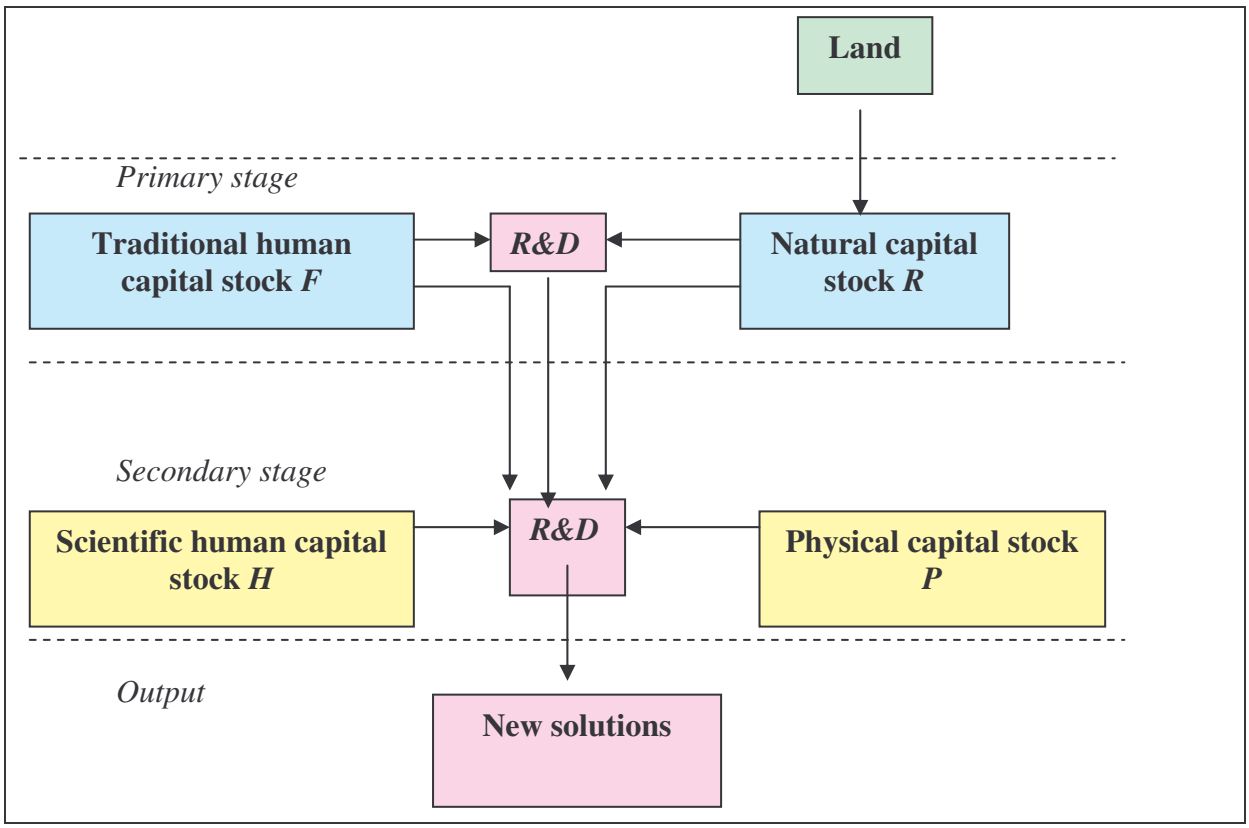
A. **South**: Endowed with genetic capital and has a comparative advantage in the production of pure information (R).

B. **North**: Endowed with human capital and has a comparative advantage in developing innovations (D) based on information (R).

C. **R&D industry**: In the first stage of this industry, the South produces pure information (R). The combination of this information with the human capital from the North results in the second stage innovation (D) incorporating (R). The innovation (D) is able to be patented, and is consumed by individuals to generate welfare.

For example, we can think of an industry where the South produces an herbal medicine that has natural curative properties. In such industry, the information encapsulated within the herbal medicine is extracted and used by the pharmaceutical or biotechnology firms from the North to develop new drugs as (D). The issues we address here relate to how well North and South cooperate in this R&D industry, and how they share the benefits. The North might or might not compensate the South for the information used to develop (D). Then the South might compete with the North by attempting to develop and market the herb (integration into D).

Figure 1: R&D stages in the biological sector.



We now wish to define the efficiency objective for an industry of this nature.

Proposition 1: *From the perspective of the producers North and South, the first best solution requires a single property right, complete specialization and a joint venture.*

In a vertical industry, it is well-known that integration brings efficiency from the producer's point of view since the joint profit is maximized. By forming a joint venture North and South integrate into a single entity able to develop new products using the comparative expertise of both partners. A single property right is then sufficient to protect the innovations made by this entity. Besides, given the complementarity of the two partners, comparative advantage will dictate full specialization within the joint venture.

Any departure from the conditions stated in proposition 1 results in loss of efficiency. The allocation of two property rights in the vertical industry leads to the problem of multiple distortionary IPR regimes, and possibly to double marginalization which decreases the joint profit. In addition, competition erodes the profit of each party. An all out competition at both stages of the industry is even more wasteful from the producers' perspective: not only does it reduce each

profit, it also causes a large loss of specialization since North and South invest in the sector where they have no comparative advantage. The opportunity cost of such behaviour is therefore particularly high. This case represents the worst possible outcome for the producers.

3.2.2 Institutional status quo

We now wish to describe the status quo ante in which the IPR system protects innovations developed by firms in the North but fails to protect information from genetic resources held by communities in the South.

Proposition 2*: If there is a single property right at the development level D and no property right is available in the information R, then either a) The North uses information R at price of zero resulting in lack of investment in R; or b) the South invests in sector D, which results in a loss of comparative advantage.*

In short, in the absence of a well-formulated property right in R, either there is little incentive to invest in the production of R or there is a loss of comparative advantage. This implies that the first best cannot be attained by the current status quo property right regime.

Now, the purpose of our paper is to contrast the status quo with the case where a property right in R is afforded to the South. We examine the potential for this to achieve the first best and explore the implications for the division of surplus in that instance.

3.3 A model of a second property right in the R&D industry

In this section we now establish the means by which the establishment of a property right in R together with a procedure for its enforcement determines the prospects for efficient integration and benefit sharing.

3.3.1 The setup of model

Description of the game

We use a game theoretical framework in which three players interact:

• North whose actions are (offer contract, invest, not invest, license if infringement, compete if no infringement).

• South whose actions are (accept, reject, license if infringement, compete if no infringement)

• Court that decides upon infringement of D

The sequence of the decisions and the interaction between the players is as follows:

1. As the first mover, the North offers the South to integrate and gives a share of the joint profit.

2. The South decides:

(a) to accept the offer, then they form a joint venture that is able to make innovation using both R and D

(b) or to reject the offer and makes use of its property right on R.

3. The North decides:

(a) not to invest and the game is over

(b) or to invest in which case the Court has to intervene.

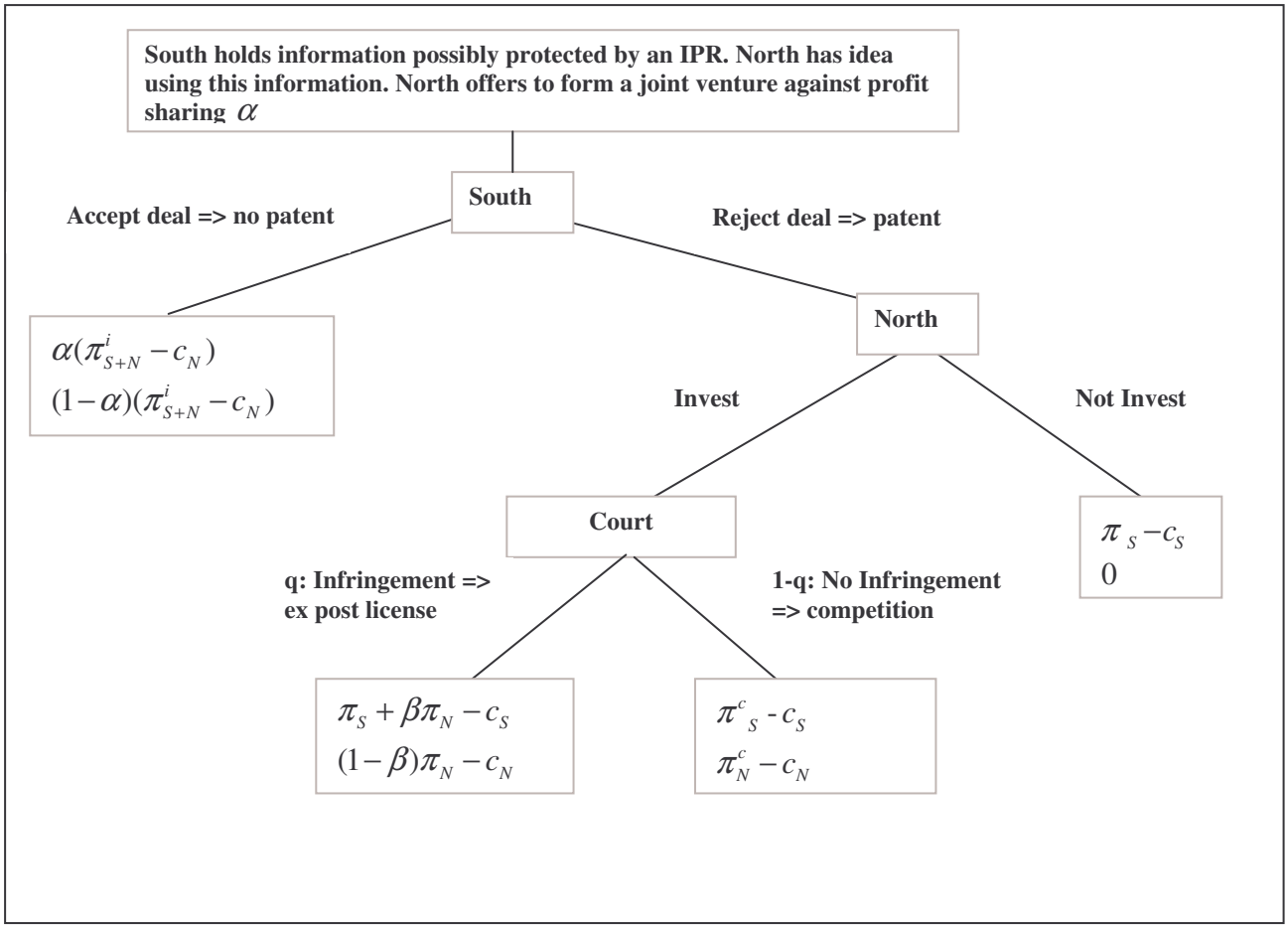
4. The makes an enforceable decision upon infringement based on the breadth of the property right.

(a) in case of infringement the North needs a license to market the new product

(b) if there is no infringement North and South compete.

Figure 2 : Game

Tree



Specification of the model:

Suppose the South is granted a property right protecting its traditional knowledge, and suppose that the North has an idea to develop a new product using this information. Since the North needs the knowledge from the South, it offers the South to integrate by forming a joint venture, against the payment of a royalty on the joint

profit. If the ex ante negotiation succeeds then a joint venture is formed and will develop a new product that can be patented. The South receives a payoff:

$$\Pi_S^i = \alpha(\pi_{N+S}^i - c_N)$$

and the North receives:

$$\Pi_N^i = (1-\alpha)(\pi_{N+S}^i - c_N)$$

where π_{N+S}^i is the integrated joint monopoly revenue earned by the joint venture, α is the share of profit offered by the North, and c_N is the total development costs incurred by the North given the South has exclusively revealed its information.

However, if the ex ante agreement fails, the South will patent its traditional knowledge. The North has to decide whether to invest or not in research and development given that information is diffused via the property right held by the South. If the North decides to invest, then a Court decides whether it infringes the right, in which case an ex post license is required. If the North does not infringe then its innovation is patented and competes with the South. Following Green and Scotchmer (1995), we formalise the product developed by the North as being of quality d. The breadth of the original property right of the South r^* is defined as the minimum improvement required to avoid infringement. Provided $d > r^*$ the North does not infringe. The North infringes with probability q, and does not infringe with probability $1-q$. The South receives an expected profit equal to:

$$\Pi_S^{ni} = q(\pi_S + \beta\pi_N) + (1-q)\pi_S^c - c_S$$

and the North expected profit is:

$$\Pi_N^{ni} = q(1-\beta)\pi_N + (1-q)\pi_N^c - c_N$$

Note that β is the share of the North profit captured by the South through ex post licensing.

In contrast if the North decides not to invest in the research at all, the South receives a profit of $\pi_S - c_S$ and the North gets nothing.

Further assumptions:

1. The joint revenue when there is a joint venture is larger than the non-integrated profit in the whole industry: $\pi_{N+S}^i \geq \pi_N + \pi_S = \pi_{N+S}^{ni}$

2. Competition erodes the revenue of both parties: $\pi_S^c < \pi_S$ and $\pi_N^c < \pi_N$.

3. Investment increases the overall profit in the vertical industry, i.e. $\pi_S^c - c_S + \pi_N^c - c_N \geq \pi_S - c_S$, which implies that $\pi_N^c - c_N \geq \pi_S - \pi_S^c > 0$.

3.3.2 Equilibrium when the South provides information of equal quality

We will now examine the basic nature of the outcome of this setup, given that the members of the bargaining entity South always offer information of the same quality. This allows us to derive a unique outcome to this bargaining situation, in which an integrated entity will result making use of a single property right, and sharing profits in a uniquely determined manner.

Proposition 3: *In an industry where the North and the South each possess important information for the production of successive innovations, if the South provides information of equal quality and transaction costs are low, then there is a unique equilibrium involving profit sharing through a joint venture where the South obtains a share* α^* *of the joint profit. This equilibrium reaches the first best and requires the existence of a single property right allocated to the joint venture.*

First, note that because the assumption that investment increases the industry profit implies that $\pi_N^c - c_N$, there cannot be an equilibrium in which the North does not invest. In our setup, the North has the first move and proposes to the South a contract that maximises its own profit subject to the South participation constraint.

The problem of the North is:

$$\max_{\alpha} (1-\alpha)(\pi_{N+S}^i - c_N)$$
$$s.t. \quad \alpha(\pi_{N+S}^i - c_N) \geq q\left[\pi_S + \beta\pi_N\right] + (1-q)\pi_S^c - c_S$$

In equilibrium, the participation constraint is binding. If that were not the case then the North could slightly decrease α, satisfy the constraint and increase its profit. This contradicts the fact that we are in the equilibrium. Therefore the participation constraint must be binding. We then obtain:

$$\alpha^* = \frac{q\left[\pi_S + \beta\pi_N\right] + (1-q)\pi_S^c - c_S}{\pi_{N+S}^i - c_N}$$

The North chooses a profit share α^* that gives the South the rent that makes her indifferent between accepting and rejecting the offer contingent on the breadth of the

original property right. As a result, the North captures the entire surplus generated by the joint venture. This is due, under our assumptions, to the North's current (and ongoing) control over the rights to the important final markets for the product. This control determines the basis upon which the entities bargain over integration, and give the North the unique ability to offer the terms on which integration may proceed.

Then, when the quality of the information held by the South is homogeneous, a joint venture is formed along the terms offered by the North. Note that when the joint venture is formed, the South reveals its information exclusively to its partner. Both North and South specialize according to their comparative advantage to produce a new product protected by a property right, which induces a single monopoly pricing. Hence, this vertical integration achieves the first best outcome for the producers.[2]

3.3.3 Distributional considerations

We have seen that the North and South immediately agree to integrate their information-generating processes into a single R&D sector. We have also seen that there is a unique equilibrium in this framework, in which the North pays the South the amount required for its participation within the integrated firm. There are several important factors that determine the amount that the South will receive.

[2] It is nevertheless important to note that such an outcome can occur only if transaction costs are low enough, i.e. if the benefits of information revelation from the first innovator exceed the costs of bargaining.

First, the Court plays an important role in the determination of the magnitude of profit sharing because it makes decisions regarding infringement. In other words the decision of the Court determining the breadth of the property rights determines the distribution of benefits between North and South. The share of profit offered to the South is related to the probability of infringement. The North has to pay license fees to the South, only if the latter decides to reject the former's offer and the Court enforces its rights.

Because of the uniqueness of the equilibrium (which is also efficient), the informational rights of the South can be substantially protected without inducing any loss of efficiency. Therefore, the maximum share received by the South (α^{*S}) in this framework is where the property right is very broad, i.e. where $r^* \to \infty$, or equivalently the probability of infringement $q \to 1$.

$$\alpha^{*S}(i.e. \ \ at \ \ \ q=1) = \frac{\pi_S + \beta\pi_N - c_S}{\pi^i_{N+S} - c_N}$$

Moreover, the larger the outside option, i.e. the profit obtained by the South by patenting (the larger π_S, β or π_N and smaller c_S), the larger α will be. In addition, because the outside option value to the South is fixed, a greater joint venture profit (larger π^i_{N+S} and smaller c_N) will lead to a lower *share* of the profit for the South. This implies that, the more efficient is integration relative to non integration (in terms of enhanced profitability), the more inequitable profit sharing becomes. This clearly shows that a second property right addresses the distributional issues only to an extent. Although the South's right enables efficiency to emerge, it may benefit little from the outcome. It gets some reward through the assignment of a broad patent ensuring her the highest possible profit, but it does not earn much of the surplus generated by integration this helps to achieve.

Proposition 4: *The optimal share of profit offered to the South a) increases in the South's outside option; and b) decreases with the joint venture profit. Because of a) the initial patent granted to the South for its information R must be very broad to enable any profit sharing by the South. Despite this improvement the sharing involves payment to the South only that amount required to secure its participation (i.e. the amount of the value of its outside option) and the North receives any residual.*

4 Conclusion

This paper has surveyed the considerations important for determining the efficient governance structure for successive R&D in the bio-technology sector. We have argued that multiple property rights and contracting mechanisms are probably inappropriate in this context, due to the complexity of information-generation at successive levels. For this reason we have focused on the idea of an integrated vertical industry, in which both levels of R&D coordinate carefully within a single entity. We have examined here how the introduction of a second property right might be capable of generating this integrated outcome, and what would determine the precise nature of that outcome.

In order to do this, the paper analyzes a simple model of the interactions between North and South in relation to traditional knowledge and bio-prospecting. Here we have assumed that the North is rich in human capital but needs essential genetic resources and knowledge that is available only in the South – in order to generate innovations in the biological sector. We use the cumulative research framework developed in the industrial organization literature to examine the possibility of assigning a property right to the basic information held by the South. In doing so, we investigate whether this can achieve efficiency and discuss the implications for the division of the profit. We find that such a move is efficient from the producers'

perspective because it is conducive to integration and therefore to the maximisation of the joint profit.

However, although there may be improvement (compared to the current status quo) when the South is afforded broad protection of its property rights, the benefit sharing still largely favours the North. Indeed the latter captures all of the surplus generated by the efficient outcome although the South has contributed to the emergence of the first best. This is due to the fact that the North retains control over the final markets and marketing of the product, and hence remains in control of the bargaining framework for integrating the two producers.

In conclusion, the governance mechanism appropriate in this context requires careful coordination between successive levels of R&D. The definition of a second property right in primary R&D may be an important step toward making efficient integration possible, and thus achieving efficient governance. Such a property right is more important for efficiency reasons, than it is for equity purposes.

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