Economics of Traditional Knowledge as Private Information[1]

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January 30, 2009

[1]We thank Tom Dedeurwaerdere, Christine Frison, Zhou Jidong, Chiou Jing-Yuan, Erwin Bulte and conference participants at BioEcon at the University of Cambridge, ENTER Jamboree at the University of Mannheim, EAERE at the University of Macedonia and FEEM Summer School for helpful comments. We gratefully acknowledge financial support from RefGov.

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1 Introduction

Bioprospecting is the purposeful search for natural compounds undertaken by pharmaceutical or biotechnology firms to find leads necessary for the development of new drugs. It requires cooperation between the bio-prospecting firm—the North—and the country hosting the genetic resources and/or traditional knowledge—the South. The host country 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 channelled through a secondary R&D sector to become commercial products capable of addressing consumer needs.

Despite the South's contribution in providing necessary primary information as inputs in the R&D process, genetic information and traditional knowledge generally do not meet patentability requirements—novelty and non-obviousness—and receive little or no compensation. The failure to protect these contributions may result in a lack of investment in genetic diversity and traditional human capital, and in inefficient flow of information across the sector. This sub-optimal situation may end up in a permanent loss of both genetic diversity and traditional knowledge and therefore a loss of valuable source of improvement of human health. Thus, to address this problem, Gehl Sampath (2005) suggests that the South's information should be protected in a similar way as the basic information provided by small and medium sized biotechnology firms to larger firms which use these inputs to process a final product. It is thought that in the face of this incentive problem, the creation of 'informational property rights' (Swanson, 1995) could provide the South enough incentive to maintain genetic diversity and traditional knowledge, and grant access to her genetic resources. However, unless the property rights assigned domestically in the South are recognised across jurisdictions, the hold-up problem analysed in Sarr and Swanson (2008) is likely to persist. The real challenge is for North and South to coordinate their legal systems in a way that allows the South to be properly compensated for investing in genetic diversity and associated human capital, and in supplying genetic material.

Our purpose in this paper is to analyse North/South interaction when such coordination is achieved. In particular, our aim is to determine the number of property rights necessary to induce an efficient flow of information within this vertical industry, as well as their placement—in addition to the patent assigned to the North. Should these rights solely protect the genetic resource-based information, or should traditional knowledge also be protected? To investigate whether both types of contributions should warrant property rights protection, or whether a single right is sufficient, we propose a clear delineation between genetic resources and traditional knowledge. Throughout this paper, we define traditional knowledge as the information that allows the North to truncate the search, i.e. to search over a smaller number of species. (Costello and Ward, 2006) This information is assumed to be the South's private information. The value of this private information lies in its efficacy in guiding the North towards the genetic resources that are most promising and useful for R&D. We explore the implications of the presence of traditional knowledge as private information both from an efficiency and a distribution perspectives.

We assume that cooperation takes place via a contract in which the proposer has the ability to make a take-it or leave-it offer. We will analyse the cases where each party in turn has this ability and is therefore given all the bargaining power. In the presence of traditional knowledge (i.e. private information) this assumption amounts to the North solving a screening problem—when he is the proposer—and the South solving a signalling problem—when she makes the offer. We find that, under complete information—absent traditional knowledge—a property right in the genetic information creates the basis for efficient contracting. When traditional knowledge is present, the emergence of an efficient outcome depends on the magnitude of the South's outside option induced by the existence of an enforceable property right in the genetic resources—in the screening case. The division of profits improves in favour of the South even without assigning a particular property right in TK. This result is obtained with a distribution assumption that is least favourable to the South since the North is given the right to make a take-it or leave-it offer. This suggests that despite the extremely unfavourable distribution, the South may capture some of the cooperative surplus even without a formal right in TK, so long as her knowledge is kept secret. In the signalling case, the South as the proposer is the residual claimant of the cooperative surplus and has therefore the proper incentive for efficient information trade with the North. Efficiency in this case hinges upon the assumption of risk neutrality and the possibility for the South to offer an *ex ante* contract, i.e. before learning her private information.

This paper is structured as follows: Section 2 provides a detailed presentation of the model. In section 3, we solve the contracting problem under symmetric information when genetic information is afforded property right protection and derive the efficient solution. In section 4, we investigate how the contractual outcomes are altered in the presence of traditional knowledge defined as the South's private information about the usefulness of the genetic resources. Finally section 5 concludes the analysis.

2 The Model

2.1 Stylised Facts

Agents. North (N) and South (S) refer to two distinct regions comprised of: (i) distinct consumer groups CG_N and CG_S; (ii) distinct firms F_N and F_S; and (iii) distinct legal institutions or courts Ct_N and Ct_S. The two regions could realise joint benefits by cooperating in the production of R&D for health services, but must coordinate their individual legal systems to generate these incentives toward cooperation. There are four crucial dimensions within which North and South interact.

Separate R&D Contributions. Firms from the North and the South, F_N and F_S, can cooperate for mutual benefit through coordination in the supply of inputs within a process of sequential R&D.

If they cooperate successfully, then a higher quality of health services is available to consumers. The South is gene rich and technology poor. The firms in the South F_S are specialised in the provision of genetic material g and traditional knowledge (TK). The North is technology rich and biodiversity poor. The firms in the North F_N use information contained in the genetic resources g and may combine them with traditional knowledge and technology in the North to search for new leads and develop new drugs d.

Separate Markets. North and South have distinct consumer groups CG_N and CG_S, and therefore separate markets for medicinal products. Consumers in the South CG_S have low income and a low willingness to pay for medicines. By contrast, consumers in the North CG_N have high income and are willing to pay high prices for drugs developed by the pharmaceutical industry.

Separate Property Rights Systems. In each region, there exists a property rights system that attempts to generate incentives for innovation by ensuring appropriation of the returns on investments in that region. Genetic resources g and traditional knowledge are conferred property rights in the South. Likewise, the drug d developed by F_N in the North has a property right declared in it. Property rights conferred by a given region exist automatically only within that region's boundaries, and must be adopted and implemented by the other region to be given effect there.

Separate Court Systems. Court systems exist in each region (Ct_S and Ct_N) for enforcement of property rights. Any right conferred in a given jurisdiction will be recognised and enforced by courts in the other region. As a consequence, the only issue that courts in the North have to resolve in case of litigation is whether the drug d has enough distinctiveness relative to F_S's genetic resources or traditional knowledge, to warrant property right protection.

Table 1: Stylised Facts: North/South interaction in the presence of TK

	South	North
Vertical Industry	• F_S: Upstream	• F_N: Downstream
Separate R&D Contributions	• Biodiversity Rich (Genetic Resources g; Traditional Knowledge TK) • Technology Poor: no d	• Biodiversity Poor: no g, TK • Technology Rich: drug development d
Separate Markets	• Low income: CG_S have low willingness to pay • Herbal medicines • F_S serves both CG_S and CG_N	• High income: CG_N have high willingness to pay • Pharmaceuticals • F_N serves only CG_N
Separate Property Rights Systems	• F_S has property right in g and TK	• F_N has property right in d
Separate Courts Systems	• Ct_S enforce rights in g and TK	• Ct_N enforce rights in d, g and in TK

2.2 Description of the sequential innovation

We model the R&D industry (in the biological sector) as a non-integrated vertical industry of two stages as described in Appendix A.1. In the primary stage of the process, the firms from the South F_S generate a flow of information originating from nature and accumulated human capital. This information is collected by firms from the North F_N to produce some innovation designed to meet consumers needs in the North.

Through observation of natural diversity, F_S may identify some biological activity in a plant variety and then use this knowledge to produce and market herbal medicines. Thus, by application of her traditional human capital h_S to the genetic capital endowment g, F_S identifies essential information e embodied within herbal medicines H. The genetic material g is assumed to be present only in the South and, for purposes of this analysis, we assume that all innovations in this industry are derived from the capital stock g. F_N, as the second innovator in this industry, is endowed with scientific capital h_N which he is able to combine with g (and e) to produce a flow of innovations d (disembodied information, e.g. identification and isolation of active principles). This innovation d is then embodied within a pharmaceutical drug, which is then amenable to IPR. This industry is depicted in Figure 6 and Figure 6.

2.3 The Fundamentals of the Model

As in Sarr and Swanson (2008), we assume that F_N and F_S are two risk neutral agents that bargain over the access to genetic resources g. In this paper, we assume that courts in the North Ct_N recognise any property right granted in the South to protect genetic information and traditional knowledge.

Assume now that F_N offers F_S a contract to be granted access to g in return for a transfer payment t. If successful negotiation is achieved, then the two parties form a joint venture within which F_N can freely use the genetic information to develop a patentable product. The two parties receive the following payoffs:

$$\Pi_S = t - c_S^a(g) \tag{1}$$

$$\Pi_N = \pi_S(g) + \pi_N(g,d) - c_N(d) - t \tag{2}$$

where the benefits π_S and π_N are continuous, increasing and concave in their arguments; d is F_N's investment in drug development; $c_S^a(g)$ and $c_N(d)$ are respectively F_S's supply cost and F_N's development cost. These costs are increasing and convex in g and d.

If no agreement is reached, F_S considers placing derivatives of her herbal medicines directly onto the market in the North. In response, F_N might develop a new drug built around the information contained in the herbal medicine. If F_N does not invest in development, F_S receives a profit of $\pi_S(g) - c_S(g)$—where $c_S(g)$ is the cost of developing the herbal medicine—and F_N gets nothing. On the other hand, if F_N decides to invest in drug development, then a court in the North decides whether it has infringed F_S's right, in which case an *ex post* license is required. Infringement happens with probability ξ. If F_N does not infringe then his innovation is patented and marketed in the Northern market. In this case, the newly patented drug will compete—competition in differentiated products—in the Northern market with the herbal medicine. The profits are then $\pi_S^c(g) - c_S(g)$ and $\pi_N^c(g,d) - c_N(d)$. We will assume that the drug produced by F_N based on F_S's information may or may not involve additional functions (due to value added by F_N). Hence, the court's ruling hinges on how distinctive F_N's innovation is relative to the F_S's.

The noncooperative expected payoffs are therefore:

$$\Pi_S^{nc} = \xi(\pi_S(\hat{g}) + \beta\pi_N(\hat{g},\hat{d})) + (1-\xi)\pi_S^c(\hat{g}) - c_S(\hat{g}) \tag{3}$$

$$\Pi_N^{nc} = \xi(1-\beta)\pi_N(\hat{g},\hat{d}) + (1-\xi)\pi_N^c(\hat{g},\hat{d}) - c_N(\hat{d}) \tag{4}$$

where β is the share of F_N's profit captured by F_S through *ex post* licensing or equivalently the damage paid by F_N for infringement; and $\hat{g}$ and $\hat{d}$ result from the first order conditions—which are omitted here.

The sequence of the decisions is summarised as follows:

1. F_S devotes resources to find genetic materials (e.g. plants) g containing useful information protected by a property right.
2. F_N offers F_S to grant her access to g and develop a new pharmaceutical in return for a transfer payment t.
3. F_S accepts or rejects the offer.
4. In case of rejection, F_N may (or may not) decide to develop a new drug based on g.
5. If a drug is developed, the Court in the North decides whether F_S's exclusive right has been violated.

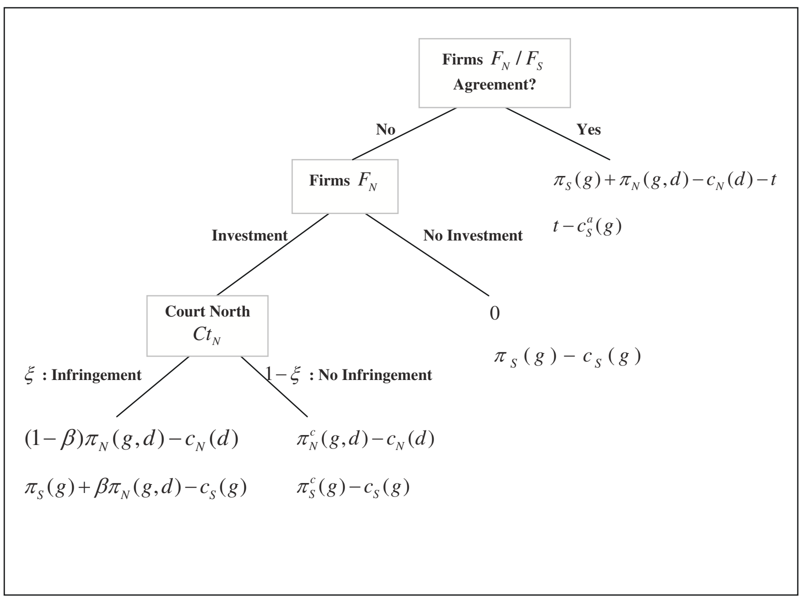


Figure 1: Decision tree

2.4 Efficiency condition

We assume again that efficiency is framed in terms of the industry's outcome. By cooperating, F_N and F_S maximise the industry joint profit:

$$\max_{g,d} \Pi_S + \Pi_N = \pi_S(g) + \pi_N(g,d) - c_S^a(g) - c_N(d) \tag{5}$$

In equilibrium, the level of genetic resources g^* and investment in drug development d^* to balance marginal revenues and marginal costs of both parts of the R&D industry:

$$\pi_S'(g^*) + \frac{\partial \pi_N}{\partial g}(g^*, d^*) = c_S^{a\prime}(g^*) \tag{6}$$

$$\frac{\partial \pi_N}{\partial d}(g^*, d^*) = c_N'(d^*) \tag{7}$$

In equation (6), the genetic resource level satisfies Bowen-Lindhal-Samuelson condition of optimal public good provision. Drug development is also undertaken optimally by F_N at marginal cost.

We now establish the means by which the establishment of a *property right protecting genetic information and/or associated traditional knowledge* together with a *procedure for its enforcement* determines the prospects for efficient contracting. The main idea is that affording a property right in the information produced by F_S—unlike the current IPR regime—may trigger cooperation and lead to an efficient outcome.[1] Paradoxically, the property right may not be used by F_S, but may serve to determine her outside option when an agreement is being discussed. The very existence of the property right ensures F_S a stream of income that will be accounted for in any negotiation.

3 Contracting genetic resources in the absence of traditional knowledge

In this section, we commence with an R&D sector, depending solely upon genetic resources and scientific method. In the following section, we discuss the relevance of an R&D sector, in which F_S has both genetic resources and traditional knowledge.

3.1 Contract offered by F_N

We assume that F_N has the ability to make a take-it or leave-it offer. This implies that F_S has no bargaining power. The problem faced by F_N is to offer contractual terms to F_S that will cause her

[1] Unlike in Sarr and Swanson (2008) where F_N and F_S must rely on the court's decision and renegotiation to reach an efficient allocation of g, here the existence of an enforceable property right in the genetic resource-based information enables the parties to reach efficiency without the court's intervention. As we will discuss below, the court sole contribution in this paper is to shape the division of profits.

to accept the offer to grant access to g. We first characterise the contract offered by F_N when the usefulness of g for R&D purposes is common knowledge. Later in section 4, we analyse how asymmetric information about the usefulness of g—interpreted as traditional knowledge—will affect the contractual outcome.

Under symmetric information, F_N proposes to F_S a contract (g,t)—access to F_S's resources g in return for a transfer payment t—that maximises his own profit subject to F_S's participation constraint, that is:

$$\begin{array}{ll}\max\limits_{g,d,t} & \pi_S(g)+\pi_N(g,d)-c_N(d)-t \\ \text{s.t.} & t-c_S^a(g)\geq \xi(\pi_S(\hat{g})+\beta\pi_N(\hat{g},\hat{d}))+(1-\xi)\pi_S^c(\hat{g})-c_S(\hat{g})\end{array}$$

Proposition 1: *In an industry where firms F_N and F_S possess important information for the production of successive innovations,*

1) If the usefulness of g is common knowledge, then there is a unique (subgame perfect) equilibrium contract (g^*,t^*) offered by F_N. This contract is characterised by the efficient allocation of genetic resources g^* and a transfer payment t^* as defined in (6) and (8).

2) The equilibrium payment t^* increases in the likelihood of infringement and with the supply of genetic material.

Proof: In the equilibrium, the participation constraint is binding. If that was not the case then $F_N$could slightly decrease t, satisfy the constraint while increasing its profit. This would contradict the fact that we are in the equilibrium. $F_S$therefore receives the value of her reservation profit so that: $t=\xi(\pi_S(\hat{g})+\beta\pi_N(\hat{g},\hat{d}))+(1-\xi)\pi_S^c(\hat{g})-c_S(\hat{g})+c_S^a(g)$

Plugging t into the objective function and deriving the first order conditions yields the efficient outcomes obtained in (6) and (7).

So the optimal transfer payment is given by:

$$t^*=\xi(\pi_S(\hat{g})+\beta\pi_N(\hat{g},\hat{d}))+(1-\xi)\pi_S^c(\hat{g})-c_S(\hat{g})+c_S^a(g^*) \tag{8}$$

Moreover it is straight forward to derive the comparative statics:

$$\frac{dt^*}{d\xi}=\pi_S(\hat{g})+\beta\pi_N(\hat{g},\hat{d})-\pi_S^c(\hat{g})>0$$

$$\frac{dt^*}{dg}=\xi\left(\pi_S'(\hat{g})+\beta\frac{\partial\pi_N}{\partial g}(\hat{g},\hat{d})\right)+(1-\xi)\pi_S^c(\hat{g})-c_S'(\hat{g})+c_S'^a(g^*)>0\blacksquare$$

When the quality of the information held by F_S is common knowledge, F_N enjoys an efficient access to g. Because of the uniqueness of this equilibrium, F_S's informational rights can be substantially protected without inducing any loss of efficiency. Therefore, the maximum share received by F_S in this framework is when the probability of infringement $\xi = 1$. However, given our assumption that F_N holds all the bargaining power, a property right in g addresses the distributional issues only to an extent since F_S does not share in the cooperative surplus.

The courts in the North play an important role in the determination of the magnitude of the transfer because they make decisions regarding infringement. It is their ruling that determines the terms of the contract between the successive innovators. If F_N makes minor amendments to F_S's innovation, and the courts refuse to award a distinct property right, then F_S is the sole owner of all innovations in that stream. On the other hand, if the courts award rights to F_N, then F_S will have to compete in the Northern market.

3.2 Contract offered by F_S

We now reverse the ordering of the firm making the offer. We assume that F_S proposes to F_N a contract (g, t) that maximises her own profit subject to F_N's participation constraint, that is:

$$\begin{array}{ll} \max\limits_{g,t} & t - c_S^a(g) \\ \text{s.t.} & \pi_S(g) + \pi_N(g,d) - c_N(d) - t \geq \xi(1-\beta)\pi_N(\hat{g},\hat{d}) + (1-\xi)\pi_N^c(\hat{g},\hat{d}) - c_N(\hat{d}) \end{array}$$

For the same reason invoked above, the participation constraint must be binding so that:

$$t = \pi_S(g) + \pi_N(g,d) - c_N(d) - \xi(1-\beta)\pi_N(\hat{g},\hat{d}) - (1-\xi)\pi_N^c(\hat{g},\hat{d}) + c_N(\hat{d})$$

Replacing t into F_S's objective function and deriving the first order conditions, we obtain the same results as in section 3.1. In addition, the optimal transfer becomes:

$$t^* = \pi_S(g^*) + \pi_N(g^*,d^*) - c_N(d^*) - \xi(1-\beta)\pi_N(\hat{g},\hat{d}) - (1-\xi)\pi_N^c(\hat{g},\hat{d}) + c_N(\hat{d}) \tag{9}$$

The results obtained here are an application of the Coase theorem. Efficiency is attained independently of the identity of the proposer. Only distribution changes via different transfer payments: compare Equation (8) to Equation (9).

4 Contracting genetic resources in the presence of traditional knowledge

We now examine how the presence of traditional knowledge (TK) might influence the contractual terms between the parties. We assume that TK has the effect of informing F_N about the most promising genetic resources for purposes of R&D. In this way, the quality of F_S's traditional knowledge lies in her ability to truncate the search, i.e. to target the most promising genetic resources, thus reducing considerably the number of resources to be searched. (Costello and Ward, 2006) We investigate here the possibility of assigning a property right in TK, where the knowledge about the genetic resources that are most useful for R&D, is F_S's private information and can only be acquired by F_N via contracting. We continue to assume that there is a property right in genetic information. At this point we make no assumption regarding the need for property rights in TK itself, and only examine how its existence impacts upon the contracts described within the previous section.

We say that F_S holds traditional knowledge when she possesses information on the prospects of heterogeneous genetic resources in regard to their usefulness for R&D. For purposes of exposition, suppose F_S has two types of information on the prospect that the genetic resources deliver a promising lead. There is a "high prospect" type $\overline{\theta}$ with probability p and a "low prospect" type $\underline{\theta}$ with probability $1-p$. High types are of higher value for two reasons: 1) they have a higher average value for producing information within the R&D process; and 2) they have a lower average cost when supplying information within the R&D process.[2] Thus, the usefulness of the genetic resources for purposes of information generation is F_S's *private information.* Together these assumptions constitute our definition of the economic meaning of TK.

As we did in section 3, we first analyse the case where F_N makes the offer and then proceed to the case where F_S has this ability.

4.1 TK as Private Information: The case of Screening by F_N

We now specify the ways in which the existence of this private information will impact upon the contracting process examined in section 3.1. F_N specifies the offered contract enabling direct access to F_S's genetic resources. A contract consists of access to F_S's resource g in return for monetary payment t. It is specified in terms of the different types of genetic resources available. A direct revelation mechanism is a menu of two contracts $\{(\overline{g}, \overline{t}), (\underline{g}, \underline{t})\}$, one for each type of resource.

An agreement will be signed if transaction costs are small enough, and the participation and incentive compatible constraints are satisfied for each type of resource. The participation constraints (or individual rationality constraints $\overline{IR}$ and $\underline{IR}$) ensure that each type receives at least her expected reservation profit.

$$\overline{V} = \overline{t} - c_S(\overline{g}) \geq \overline{\Pi}_S^{nc} \tag{10}$$

$$\underline{V} = \underline{t} - c_S(\underline{g}) \geq \underline{\Pi}_S^{nc} \tag{11}$$

[2]For example, the knowledge that these are high prospect genetic resources might both contribute to a better targeting of the resource-based information onto a specific problem (higher value of information) and also do so in a much reduced search process (lower cost of information).

This is equivalent to

$$
\begin{aligned}
\overline{V} &\geq \underline{\Pi}_S^{nc} + V_0 \qquad (12)\\
\underline{V} &\geq \underline{\Pi}_S^{nc} \qquad (13)
\end{aligned}
$$

where $\overline{\Pi}_S^{nc} = \xi(\pi_S(\hat{\overline{g}}) + \beta\pi_N(\hat{\overline{g}}, \hat{\overline{d}})) + (1-\xi)\pi_S^c(\hat{\overline{g}}) - c_S(\hat{\overline{g}})$; $\underline{\Pi}_S^{nc} = \xi(\pi_S(\hat{\underline{g}}) + \beta\pi_N(\hat{\underline{g}}, \hat{\underline{d}})) + (1-\xi)\pi_S^c(\hat{\underline{g}}) - c_S(\hat{\underline{g}})$; $\overline{\Pi}_S^{nc} = \underline{\Pi}_S^{nc} + \left(\overline{\Pi}_S^{nc} - \underline{\Pi}_S^{nc}\right) = \underline{\Pi}_S^{nc} + V_0$. The term $V_0 \equiv \overline{\Pi}_S^{nc} - \underline{\Pi}_S^{nc}$ represents the profit differential between the high and low type (i.e. the differential value of her outside option when supplying each within the non-cooperative setting).

Note that the participation constraints $\overline{IR}$ and $\underline{IR}$ are type dependent implying that the high type has better opportunities outside the proposed contract (larger expected reservation profit) than the low type. This specificity will lead to non-standard results.

The incentive compatible constraints respectively $\overline{IC}$ and $\underline{IC}$ ensure that each type is always better off revealing truthfully herself.

$$
\begin{aligned}
\bar{t} - c_S^a(\overline{g}, \overline{\theta}) &\geq \underline{t} - c_S^a(\underline{g}, \overline{\theta}) \qquad (14)\\
\underline{t} - c_S^a(\underline{g}, \underline{\theta}) &\geq \bar{t} - c_S^a(\overline{g}, \underline{\theta}) \qquad (15)
\end{aligned}
$$

Assumption A1: $\dfrac{\partial c_S^a}{\partial g} > 0$, $\dfrac{\partial^2 c_S^a}{\partial g^2} > 0$ and $\dfrac{\partial c_S^a}{\partial \theta} < 0$

Assumption A2 (Spence-Mirrlees condition): $\dfrac{\partial^2 c_S^a}{\partial \theta \partial g} < 0$

Assumption A1 says that the cost of supply is increasing and convex in the level of genetic resources provided but decreasing in the type. The latter implies that the high quality type can make transactions for access at a lower cost. This is because less search is required with high type information. Assumption A2 conveys the idea that the marginal cost decreases in type: the high type enjoys a lower marginal cost of supply.

The provider of information of low quality may misrepresent her type and obtain a payoff: $\bar{t} - c_S^a(\overline{g}, \underline{\theta}) = \overline{V} - \Phi(\overline{g})$. In addition, if the high type wants to mimic the low type, she would receive: $\underline{t} - c_S^a(\underline{g}, \overline{\theta}) = \underline{V} + \Phi(\underline{g})$; where $\Phi(g) \equiv c_S^a(g, \underline{\theta}) - c_S^a(g, \overline{\theta})$ with $\Phi > 0$ and $\Phi' > 0$ from assumptions A1 and A2. The term Φ refers to the supply cost differential of the two types for a given level of supply g.

The incentive compatibility constraints respectively $\overline{IC}$ and $\underline{IC}$ can then be re-written as:

$$\overline{V} \geq \underline{V} + \Phi(\underline{g}) \tag{16}$$

$$\underline{V} \geq \overline{V} - \Phi(\overline{g}) \tag{17}$$

F_N's problem is then:

$$\max_{\{(\overline{g},\overline{t}),(\underline{g},\underline{t})\}} \quad p\left(\pi_S(\overline{g}) + \pi_N(\overline{g},\overline{d}) - c_N(\overline{d}) - \overline{t}\right) + (1-p)\left(\pi_S(\underline{g}) + \pi_N(\underline{g},\underline{d}) - c_N(\underline{d}) - \underline{t}\right)$$

$$\text{subject to} \quad (10), \quad (11), (14), (15)$$

The problem can be re-written as follows:

$$\begin{aligned}\max_{\{(\overline{g},\overline{V}),(\underline{g},\underline{V})\}} \quad & p\left(\pi_S(\overline{g}) + \pi_N(\overline{g},\overline{d}) - c_S^a(\overline{g}) - c_N(\overline{d})\right) + (1-p)\left(\pi_S(\underline{g}) + \pi_N(\underline{g},\underline{d}) - c_S^a(\underline{g}) - c_N(\underline{d})\right) \\ & -[p\overline{V} + (1-p)\underline{V}] \\ & \text{subject to} \quad (12), \quad (13), (16), (17)\end{aligned} \tag{18}$$

This analysis leads directly to the following proposition, detailing the effects on contracting that result from the existence of private information. Proposition 2 establishes once again that the factor most important in determining the payoff to F_S is the impact, if any, of any endowment (genetic resources or traditional knowledge) upon her outside options.

Proposition 2:

When F_S has private information about the most promising genetic resources for R&D purposes, F_N may seek cooperation by offering a menu of self-selecting contracts $\{(\overline{g},\overline{t}),(\underline{g},\underline{t})\}$ to screen among the types of genetic resources. These contracts are characterised by:

2.1 $\overline{g} \geq \underline{g}$ *(Monotonicity condition)*

2.2 *For $V_0 < \Phi(\underline{g}^{SB})$, $\underline{IR}$ and $\overline{IC}$ are binding. The supply of genetic resources required by F_N is efficient for the high type $\overline{g}^{SB} = \overline{g}^*$ and distorted downwards for the low type $\underline{g}^{SB} < \underline{g}^*$. The level of $\underline{g}^{SB}$ and the transfer payments $\overline{t}^{SB}$ and $\underline{t}^{SB}$ are given by:*

$$\pi_S'(\underline{g}^{SB}) + \frac{\partial \pi_N}{\partial \underline{g}}(\underline{g}^{SB}, \underline{d}^{SB}) = c_S'^a(\underline{g}^{SB}) + \frac{p}{1-p}\Phi'(\underline{g}^{SB}) \tag{19}$$

$$\bar{t}^{SB} = \xi(\pi_S(\hat{\bar{g}}) + \beta\pi_N(\hat{\bar{g}}, \hat{\bar{d}})) + (1-\xi)\pi_S^c(\hat{\bar{g}}) - c_S(\hat{\bar{g}}) + c_S^a(\bar{g}^*) + \Phi(\underline{g}^{SB}) \quad (20)$$

$$\underline{t}^{SB} = \xi(\pi_S(\hat{\underline{g}}) + \beta\pi_N(\hat{\underline{g}}, \hat{\underline{d}})) + (1-\xi)\pi_S^c(\hat{\underline{g}}) - c_S(\hat{\underline{g}}) + c_S^a(\underline{g}^{SB}) \quad (21)$$

2.3 *For $\Phi(\underline{g}^{SB}) \leq V_0 \leq \Phi(\bar{g}^*)$, $\overline{IR}$ and $\underline{IR}$ are binding so that no information rent is given up to any type. The supply of genetic resources is efficient for both types, i.e $\bar{g}^{SB} = \bar{g}^*$ and $\underline{g}^{SB} = \underline{g}^*$. The optimal transfer payments $\bar{t}^{SB}$ and $\underline{t}^{SB}$ are given by:*

$$\bar{t}^{SB} = \xi(\pi_S(\hat{\bar{g}}) + \beta\pi_N(\hat{\bar{g}}, \hat{\bar{d}})) + (1-\xi)\pi_S^c(\hat{\bar{g}}) - c(\hat{\bar{g}}) + c_S^a(\bar{g}^*) = \bar{t}^* \quad (22)$$

$$\underline{t}^{SB} = \xi(\pi_S(\hat{\underline{g}}) + \beta\pi_N(\hat{\underline{g}}, \hat{\underline{d}})) + (1-\xi)\pi_S^c(\hat{\underline{g}}) - c(\hat{\underline{g}}) + c_S^a(\underline{g}^*) = \underline{t}^* \quad (23)$$

2.4 *For $V_0 > \Phi(\bar{g}^*)$, there are countervailing incentives and $\overline{IR}$ and $\underline{IC}$ are binding. The supply of genetic resources required by F_N is distorted upwards for the high type $\bar{g}^{CI} > \bar{g}^*$ and efficient for the low type $\underline{g}^{CI} = \underline{g}^*$. The level of $\bar{g}^{CI}$ and the transfer payments $\bar{t}^{CI}$ and $\underline{t}^{CI}$ are given by:*

$$\pi_S'(\bar{g}^{CI}) + \frac{\partial \pi_N}{\partial \bar{g}}(\bar{g}^{CI}, \bar{d}^{CI}) = c_S'^a(\bar{g}^{CI}) - \frac{1-p}{p}\Phi'(\bar{g}^{CI}) \quad (24)$$

$$\bar{t}^{CI} = \xi(\pi_S(\hat{\bar{g}}) + \beta\pi_N(\hat{\bar{g}}, \hat{\bar{d}})) + (1-\xi)\pi_S^c(\hat{\bar{g}}) - c_S(\hat{\bar{g}}) + c_S^a(\bar{g}^{CI}) \quad (25)$$

$$\underline{t}^{CI} = \xi(\pi_S(\hat{\bar{g}}) + \beta\pi_N(\hat{\bar{g}}, \hat{\bar{d}})) + (1-\xi)\pi_S^c(\hat{\bar{g}}) - c_S(\hat{\bar{g}}) + c_S^a(\bar{g}^{CI}) - \Phi(\bar{g}^{CI}) \quad (26)$$

Proof 2: See Appendix A.1.■

As indicated above, the basic result is that the impact of TK (on contracting) depends primarily on its impact on the value of the outside option. In parts 2.2 through 2.4 of Proposition 2, we see that the determining factor is whether the incremental rent appropriable by the high type (V_0)—by selling her herbal medicine in the Northern market, i.e. under non-cooperation—is less than or greater than the cost advantage appropriable via contracting, Φ.

4.2 Discussion: TK and Information Rents

The importance of private information is that it might confer an information rent upon its holder. Our model departs from the standard prediction (that informational advantage confers a rent upon the promising type only) because the participation constraints are type-dependent. Whether F_N gives up information rent and to which type depends instead upon the value of V_0, i.e. the difference between the outside option of the high type and that of the low type. When the high type enjoys a highly profitable outside opportunity relative to the low type, the contract must offer her a large transfer. This contract must also reward the low type to prevent her from misrepresenting the quality of her information since the additional cost she incurs by lying, i.e. $\Phi(\overline{g})$ is smaller than the profit differential V_0. To ensure that incentive compatibility is satisfied, F_N will give her an information rent $\underline{V} = \overline{V} - \Phi(\overline{g})$.[3] In this case F_S's informational advantage works more effectively in competition with F_N than it does in cooperation, and therefore her threat not to cooperate is credible (as in case 2.4). Thus, F_S's private information creates a bargaining advantage: the existence of TK confers a clear-cut increase in F_S's share of the production surplus.

If F_S's primary informational advantage lies in her supply costs rather than in her outside option—that is, the differential in reservation profit V_0 does not exceed the cost differential between the high type and the low type—then the benefit conferred by private information comes from the high type's ability to mimic the low type, taking advantage of the supply costs differential (as in case 2.2). In this case, the high type is able to appropriate some informational rent by reason of the asymmetric information whereas the low type is excluded from the sharing of the surplus.[4]

If, however, F_S's informational advantage lies above the cost advantage for the high type resources but below the cost of lying for the low type, then F_N is able to screen effectively between the two types and eliminate all informational advantages (as in case 2.3). Indeed, the cost differentials are sufficiently different to enable screening between them. For intermediate values of V_0, F_N can impose incentive compatible contracts where both types of genetic resources receive their expected reservation profit. This is because no agent has an incentive to misrepresent her type so that the symmetric information outcome (see section 3.1) can be implemented.

In sum, the fact that there exists private information on the genetic resources that are most promising may or may not alter the contractual terms offered to F_S. So long as the private information does not impact the outside option in a substantial manner (as defined above in Proposition 2), the contract can replicate the complete information outcome. Then there are no informational rents to be appropriated by F_S. On the other hand, if the outside option is significantly affected by the private information, the contractual terms will be altered in one of the ways described above, and this may result in additional rents for F_S accruing to either the low type or the high type information provider. These informational rents would create additional incentives for investment in the provision of these resources to the R&D process, enhancing the efficiency of the R&D process.[5]

[3] This informational rent is decreasing in $\overline{g}$. Thus an upward distortion in the supply of high quality genetic material would allow F_N to minimise this informational rent.

[4] It is important to recognise that the rent given up to the high type increases in $\underline{g}$, implying that a reduction in $\underline{g}$ will help minimise this rent. Thus, there is an incentive for F_N to distort its demand for low type downwards away from the efficient level $\underline{g}^*$ in order to minimise rent-sharing.

[5] Informational rents may contribute to their own types of inefficiencies, however, as efficiency is lost whenever F_S has an incentive to misrepresent herself to capture some information rent and appropriate some of the cooperative surplus.

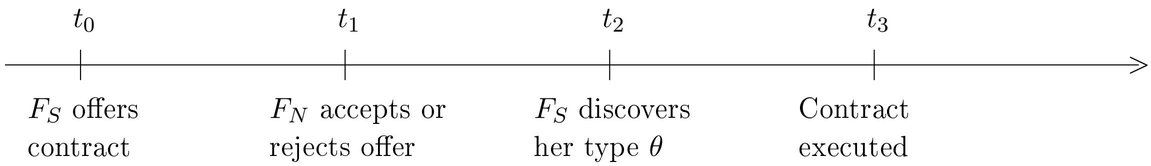
Given that F_S uses her private information to extract some informational rent, it is important to know whether this private information provides incentives to invest optimally in traditional knowledge. The answer will depend on the source of the high type advantage, i.e. the access cost advantage and the outside opportunity advantage.

When the high type's advantage derives from the cost of access, then she has strong incentive to invest in human capital to keep her edge and continue to capture informational rent. At the same time, if the low type wants to improve her position by narrowing her cost disadvantage, she too has to invest in TK. By contrast, if the high type's advantage stems from the outside opportunity differential, whether she has incentive to invest in traditional knowledge, depends on the source of the differential. If the advantage in the reservation profit comes from the quality of the information, then this will certainly induce human capital investment. However, if this differential is only vaguely related to the quality of the information that enables to truncate the search then the production of TK is unlikely to be incentivised. This would be the case if for example the advantage in the reservation profit lies in the high type's marketing ability to target effectively consumers in the North.

4.3 TK as private information: the case of Signalling by F_S

We now assume that F_S, the informed agent, has the ability to make an offer to F_N, the uninformed agent. Both high and low types would like to be seen as possessing valuable information. To be convincing, the high type should signal herself to induce F_N to accept the offer granting him access to the genetic resources and traditional knowledge against a sizable payment. We assume that F_S offers an *ex ante* contract (Laffont and Martimort, 2002). In such a contract, F_S is uncertain about the prospect of her genetic resources to be useful for the purpose of F_N's specific R&D, when she makes an offer. She only knows the probability distribution p that her information is useful to truncate the search (high type). With probability $1-p$, her information is of little use to F_N (low type). There are two reasons for the assumption of *ex ante* contracting. First, F_S may simply be unfamiliar with some diseases common in the North, when the contract is offered, so that there is no certainty about how useful her information. Second, this assumption simplifies the treatment of the signalling problem by yielding only a separating equilibrium—i.e. no pooling equilibrium will result from this contract. The timing is described as follows:

This places F_N in the situation in which he will move away from productive efficiency in order to minimise rent-sharing. That is, to minimise rent-sharing, F_N has to decrease $\underline{g}$ (in case of low V_0), and increase $\overline{g}$ (in case of large V_0) away from the productively efficient levels, respectively $\underline{g}^*$ and $\overline{g}^*$.



The problem faced by F_S is to offer an incentive compatible contract in which F_N is willing to participate. By the revelation principle, F_S can restrict, without loss of generality, to a direct revelation mechanism of the form $\{(\overline{g},\overline{t}),(\underline{g},\underline{t})\}$ contingent on the usefulness $(\overline{\theta},\underline{\theta})$ of her information. An incentive compatible contract is one in which F_S has always the incentive to signal her true type.

Given such a contract, F_S maximises her *ex ante* profit subject to her incentive constraints and F_N's *ex ante* participation constraint. We will neglect F_S's *ex ante* participation constraint since she would not offer the contract if she were worse off by doing so.

The incentive constraints require that whatever her type, F_S is always better off revealing her type after she learns it. Formally this translates into: $\overline{t}-c_S^a(\overline{g},\overline{\theta}) \geq \underline{t}-c_S^a(\underline{g},\overline{\theta})$ and $\underline{t}-c_S^a(\underline{g},\underline{\theta}) \geq \overline{t}-c_S^a(\overline{g},\underline{\theta})$. This can be re-written as in (16) and (17). Note that Assumptions A1 and A2 still hold. Because participation is voluntary, the contract must induce F_N to participate. In other words, the payoff earned by accepting the offer should be greater than or equal to his reservation profit. By rejecting the offer, F_N will receive the following expected reservation payoff:

$$\Pi_N^0 = p\overline{\Pi}_N^{nc} + (1-p)\underline{\Pi}_N^{nc}$$

where $\overline{\Pi}_N^{nc} = \xi(1-\beta)\pi_N(\hat{\overline{g}},\hat{\overline{d}})+(1-\xi)\pi_N^c(\hat{\overline{g}},\hat{\overline{d}}))-c_N(\hat{\overline{d}})$ and $\underline{\Pi}_N^{nc} = \xi(1-\beta)\pi_N(\hat{\underline{g}},\hat{\underline{d}}))+(1-\xi)\pi_N^c(\hat{\underline{g}},\hat{\underline{d}})-c_N(\hat{\underline{d}})$.

F_N's participation constraint is therefore given by:

$$p\left(\pi_S(\overline{g}) + \pi_N(\overline{g},\overline{d}) - c_N(\overline{d}) - \overline{t}\right) + (1-p)\left(\pi_S(\underline{g}) + \pi_N(\underline{g},\underline{d}) - c_N(\underline{d}) - \underline{t}\right) \geq \Pi_N^0$$

Or equivalently:

$$p\left(\pi_S(\overline{g}) + \pi_N(\overline{g},\overline{d}) - c_S^a(\overline{g}) - c_N(\overline{d}) - \overline{V}\right) + (1-p)\left(\pi_S(\underline{g}) + \pi_N(\underline{g},\underline{d}) - c_S^a(\underline{g}) - c_N(\underline{d}) - \underline{V}\right) \geq \Pi_N^0 \tag{27}$$

F_S's problem is then written as:

$$\max_{(\overline{g},\overline{V}),(\underline{g},\underline{V})} p\overline{V} + (1-p)\underline{V}$$

subject to (16), (17), (27)

Proposition 3:

Given that F_N is risk neutral, F_S can offer an efficient ex ante contract that signals her type. The contract is characterised by:

1) Monotonicity: $\overline{g} \geq \underline{g}$

2) Efficiency: $\overline{g} = \overline{g}^*$ and $\underline{g} = \underline{g}^*$

3) Transfer payment: $\overline{t}^* > \underline{t}^*$ where $\overline{t}^*$ and $\underline{t}^*$ are defined as:

$$\begin{aligned} \overline{t}^* &= p\left(\pi_S(\overline{g}^*) + \pi_N(\overline{g}^*, \overline{d}^*) - c_S^a(\overline{g}^*) - c_N(\overline{d}^*)\right) + (1-p)\left(\pi_S(\underline{g}^*) + \pi_N(\underline{g}^*, \underline{d}^*) - c_S^a(\underline{g}^*) - c_N(\underline{d}^*)\right) - \Pi_N^0 \\ &+ (1-p)\Phi(\overline{g}^*) + c_S^a(\overline{g}^*) \end{aligned} \tag{28}$$

$$\begin{aligned} \underline{t}^* &= p\left(\pi_S(\overline{g}^*) + \pi_N(\overline{g}^*, \overline{d}^*) - c_S^a(\overline{g}^*) - c_N(\overline{d}^*)\right) + (1-p)\left(\pi_S(\underline{g}^*) + \pi_N(\underline{g}^*, \underline{d}^*) - c_S^a(\underline{g}^*) - c_N(\underline{d}^*)\right) - \Pi_N^0 \\ &- p\Phi(\overline{g}^*) + c_S^a(\underline{g}^*) \end{aligned} \tag{29}$$

4) F_N's ex ante participation constraint is binding. Moreover the contract induces F_N to invest efficiently in drug development.

Proof: See Appendix A.2.■

F_S's ability to make a take-it or leave-it offer makes her the residual claimant of the cooperative surplus. Therefore, she has the proper incentive to engage in efficient information trade with F_N, which results in efficient drug development. The main issue for the high type is to convince F_N of the usefulness of her information so that she can claim a large compensation. She can convincingly signal her type by exploiting her supply cost advantage relative to the low type. By offering a large level of access to the resources, the high type can differentiate herself because the high supply cost incurred by the low type in such case will act as a deterrence and prevent the low type to imitate her.

It is important to note that the efficient and separating equilibrium results from the combination of the risk neutrality of F_N and *ex ante* contracting. In the context of the signalling problem, an *ex ante* contract will circumvent the emergence of potentially inefficient equilibria such as the pooling equilibria, where the same contractual terms are offered whatever the usefulness of F_S's information.

4.4 Role of Property Rights in TK

No property right in TK was necessary to achieve the results described in this section. The fact that TK is private information is sufficient to confer advantages upon F_S, and alter the bargaining environment which determines the level of F_S's share of the surplus. The existence of a property right in genetic resource-based information retains its importance as the value of the outside option remains dependent upon the enforcement of the right in the Northern market. If the court holds that F_N has not infringed F_S's right—i.e. if the drug is distinctive enough from the herbal medicine marketed in the Northern market—then F_S will receive little compensation under cooperation. If however, the court rules that F_N has infringed the right, then F_S will receive a substantial payoff based on her ability to license her right after the court's decision.[6]

In this way, the role of TK is likely to enhance the value of F_S's underlying genetic resources, but only if there is a potentially recognisable claim in those genetic resources to begin with. This indicates that it is not necessary for a property right to be conferred in everything of value which F_S contributes to. It is only important to create such a right in an output which F_S is able to market independent of cooperation (i.e. in competition with F_N). Once that right is recognised, F_S's other contributions may be able to be channelled through the existing right in terms of its impacts upon the outside option.

F_S will be compensated according to the marginal contribution of g on the total benefit at the industry level, i.e. $\pi'_S(g) + \dfrac{\partial \pi_N}{\partial g}(g,d)$. This marginal contribution increases as valuable traditional knowledge is used to improve F_N's success rate. Thus, F_S's private information acts as a trade secret which is revealed to F_N only against due compensation and the willingness to pay for this secret increases with the usefulness of the information to F_N.

Finally, private information works provides incentives for efficient investment in TK when the high type's advantage comes from the cost of access. In such case, the high type has the incentive to invest in generating useful information in order to capture information rent. However, when the high type's advantage comes from the reservation profit and the advantage is not directly related to the quality of the traditional knowledge, then private information may not induce efficient investment in traditional human capital.

5 Conclusion

This paper has analysed a simple model of the interaction between North and South in relation to the establishment of property rights to protect genetic resources and traditional knowledge. We have stylised the North as rich in human capital but in need of essential genetic resources and traditional knowledge only available in the South to make innovations in the life sciences industries. We examine

[6]It is straight forward to show that F_S's compensation increases with ξ both in the screening and the signalling cases.

the impacts upon the cumulative research setting of assigning a second property right to the resources held by the firms in South. In doing so, we investigate how this can achieve efficiency and discuss the implications for the division of the profit.

We find that under complete information (in the absence of TK), the creation of a second property in genetic resources is conducive to efficiency in the industry. Crucial to the division of the joint profit is the allowance to the firms in the South of an exclusive right recognised by courts in the North. This right allows them to market their products—derived from the protected genetic resources—in the North, which gives them an outside option. When such right exists, the division of the profit depends on whether the firms in the North infringe this right.

Traditional knowledge has been assumed to act as private information on the prospect of individual genetic resources to yield a successful search. In the presence of TK, the firms in the South have three possible means of generating an additional return. Either they can misrepresent the quality of their information—and hence attempt to generate an information rent—or they can hope that the existence of promising resources increases the perceived value of their outside option. Alternatively, they can actively signal the quality of their information to the firms in the North. Any factor that increases the value of their outside option—or reduces the value of the Northern firms' outside option—increases the credibility of the threat to compete (rather than cooperate) and hence enhances their payoff under cooperation. It is not necessary to establish a separate property right in TK in order to appropriate this enhanced return. The granting of a single property right to the Southern firms is probably sufficient to establish a channel whereby they are able to appropriate the value of their different types of contributions to the industry.

In general, we show that the capacity of Southern firms to share in the rents from the R&D sector to which they contribute depends on the existence of an independent property right in the genetic resources. This independent right (gives an outside option) establishes the baseline upon which contracting occurs, and creates the basis upon which Southern firms may demand compensation in line with their contribution. Importantly, this right need not ever be exercised independently, it needs only to exist in order for cooperation to occur.

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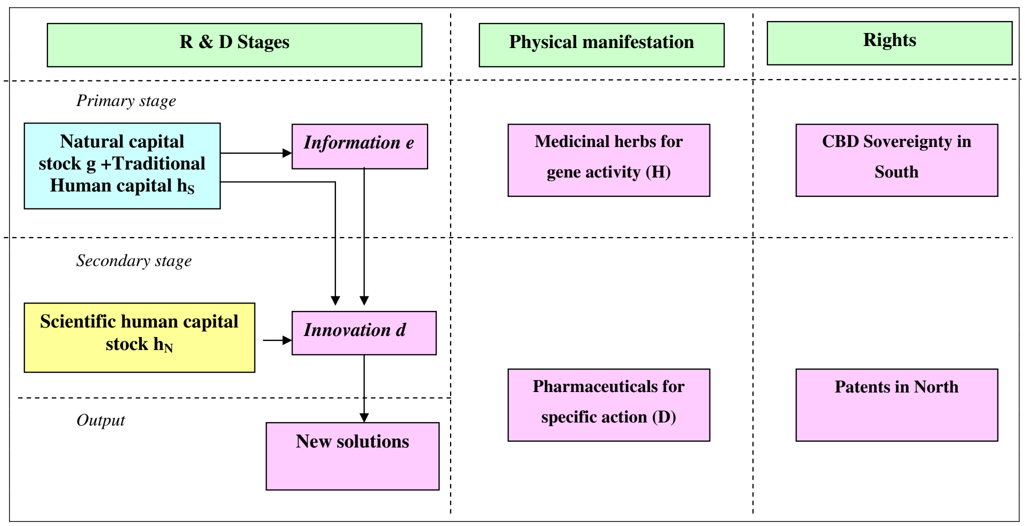
6 Appendix

A.1 Sequential R&D

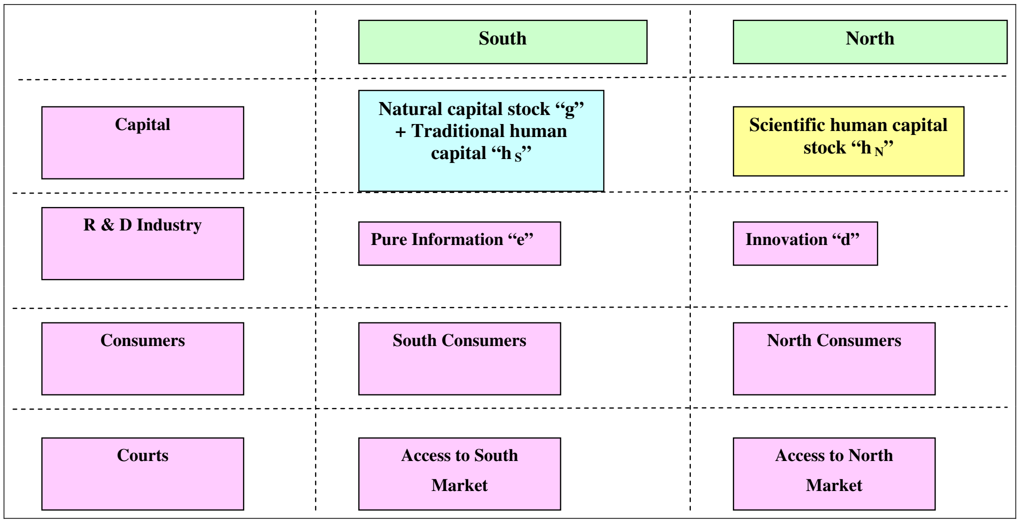
Figure 2: R&D stages in the biological sector (adapted from Goeschl and Swanson, 2002b).



"e" is the biological activity recognized by the South

"d" is the directed biological activity discovered by the North

Figure 3: Structure Model



"e" is the biological activity recognized by the South

"d" is the directed biological activity discovered by the North

A.2 Proof of Proposition 2

The combination of the two incentive constraints implies that $\Phi(\bar{g}) \geq \Phi(\underline{g})$. By Spence-Mirrless condition, $\Phi' > 0$ and hence $\bar{g} \geq \underline{g}$ (Monotonicity condition).

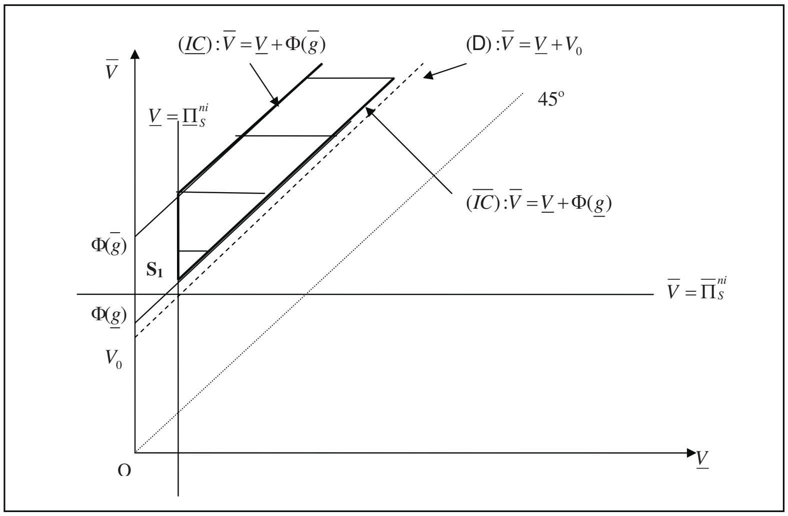
Because the participation constraints are type dependent, the search for equilibrium requires to consider several cases. Let us first represent the four constraints (12), (13), (16), and (17) in the space $(\underline{V}, \overline{V})$.

The analysis is restricted to the region delimited by the two participation constraints and located above the 45° line because the boundaries of the two incentive constraints $\overline{V} = \underline{V} + \Phi(\underline{g})$ and $\underline{V} = \overline{V} - \Phi(\bar{g})$ have positive intercepts in the space $(\underline{V}, \overline{V})$. Note that $\underline{IC}$-line is always above $\overline{IC}$-line since $\Phi(\underline{g}) \leq \Phi(\bar{g})$.

Let $E\left(\underline{\Pi}_S^{nc}, \overline{\Pi}_S^{nc}\right)$ be the intersection between the two participation constraints lines and let $\mathcal{D} = \left\{(\underline{V}, \overline{V}) | \, \overline{V} = \underline{V} + \overline{\Pi}_S^{nc} - \underline{\Pi}_S^{nc} = \underline{V} + V_0\right\}$ be the line parallel to the two incentive constraints lines passing through E. $\mathcal{D}$ represents the high type's reservation profit and shows the extent to which she has a better outside opportunity than the low type.

Case 1: $V_0 < \Phi(\underline{g}^{SB})$, i.e. $\overline{IC}$-line is above $\mathcal{D}$

Figure 4: Case 1: Low V_0



F_N would like to compensate the high type vs the low type no more than the outside option differential V_0. However, because V_0 is so small, the high type can obtain a better compensation by lying to F_N. If this happens the high type can potentially generate a cost saving of $\Phi(\underline{g})$ which is greater than the outside opportunity V_0. So, the high type has an incentive to misrepresent herself and receive an information rent. It follows that $\overline{IR}$ is slack while $\overline{IC}$ must be binding: $\overline{V} = \underline{V} + \Phi(\underline{g})$.

Besides, by lying the low type would incur an extra cost of access of $\Phi(\overline{g})$ that is greater than V_0 (since $\Phi' > 0$). Therefore, she has no incentive to lie, which implies that $\underline{IC}$ is irrelevant and $\underline{IR}$ is binding: $\underline{V} = \underline{\Pi}_S^{nc}$.

Plugging $\overline{V}$ and $\underline{V}$ in (18) and deriving the first order conditions yields:

$$\max_{\{(\overline{g},\overline{V}),(\underline{g},\underline{V})\}} \; p\left(\pi_S(\overline{g}) + \pi_N(\overline{g},\overline{d}) - c_S^a(\overline{g}) - c_N(\overline{d})\right) + (1-p)\left(\pi_S(\underline{g}) + \pi_N(\underline{g},\underline{d}) - c_S^a(\underline{g}) - c_N(\underline{d})\right)$$
$$-[p(\underline{V} + \Phi(\underline{g})) + (1-p)\underline{\Pi}_S^{nc}] \tag{30}$$

$$\frac{\partial \pi_{N+S}}{\partial \overline{g}}(\overline{g}^{SB}, \overline{d}^{SB}) = \pi_S'(\overline{g}^{SB}) + \frac{\partial \pi_N}{\partial \overline{g}}(\overline{g}^{SB}, \overline{d}^{SB}) = c_S'^a(\overline{g}^{SB}) = \frac{\partial \pi_{N+S}}{\partial \overline{g}}(\overline{g}^*, \overline{d}^*) \tag{31}$$

$$\frac{\partial \pi_{N+S}}{\partial \overline{g}}(\underline{g}^{SB}, \underline{d}^{SB}) = \pi_S'(\underline{g}^{SB}) + \frac{\partial \pi_N}{\partial \overline{g}}(\underline{g}^{SB}, \underline{d}^{SB}) = c_S'^a(\underline{g}^{SB}) + \frac{p}{1-p}\Phi'(\underline{g}^{SB}) > \frac{\partial \pi_{N+S}}{\partial \overline{g}}(\underline{g}^*, \underline{d}^*) \tag{32}$$

By continuity and concavity of $\pi_{N+S}(.)$ it follows that: $\overline{g}^{SB} = \overline{g}^*$, $\underline{g}^{SB} < \underline{g}^*$, and $\underline{g}^{SB} < \overline{g}^{SB}$. There is no allocative distortion for the high type, but there is a downward distortion for the low type: F_N requires an optimal access to the genetic resources from the high type and a sub-optimal access to the low type. These allocations give rise to the following transfer schemes:

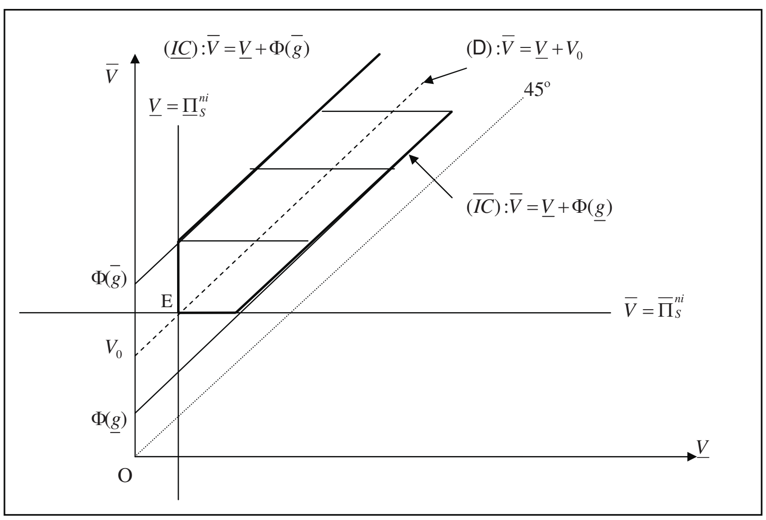
$$\overline{t}^{SB} = \xi(\pi_S(\hat{\overline{g}}) + \beta\pi_N(\hat{\overline{g}}, \hat{\overline{d}})) + (1-\xi)\pi_S^c(\hat{\overline{g}}) - c_S(\hat{\overline{g}}) + c_S^a(\overline{g}^*) + \Phi(\underline{g}^{SB}) > \overline{t}^* \tag{33}$$

$$\underline{t}^{SB} = \xi(\pi_S(\hat{\underline{g}}) + \beta\pi_N(\hat{\underline{g}}, \hat{\underline{d}})) + (1-\xi)\pi_S^c(\hat{\underline{g}}) - c_S(\hat{\underline{g}}) + c_S^a(\underline{g}^{SB}) \tag{34}$$

From the diagram, the profit maximizing point for F_N is S_1 at which both the low type participation constraint $\underline{IR}$ and the high type incentive constraint $\overline{IC}$ are binding.

Case 2: $\Phi(\underline{g}^{SB}) \leq V_0 \leq \Phi(\overline{g}^*)$, i.e. $\underline{IC}$-line is above $\mathcal{D}$ while $\overline{IC}$-line is below $\mathcal{D}$

Figure 5: Case 2: Intermediate V_0



We follow the same reasoning as in Case 1. The high type has no incentive to lie when V_0 (differential in outside option between the two types) is greater than the saving on access cost she would get by mimicking the low type. Truthful revelation of her type will guarantee her to receive V_0—that she would obtain by not cooperating. This implies that $\overline{IR}$ is binding and $\overline{IC}$ is always satisfied. The low type, on the other hand faces the same situation as in Case 1, so she has no incentive to lie. Again, her participation constraint $\underline{IR}$ is binding and her incentive constraint $\underline{IC}$ always hold.

In this case, F_N achieves the complete information outcome: $\overline{V} = \overline{\Pi}_S^{nc}$ and $\underline{V} = \underline{\Pi}_S^{nc}$.

Plugging $\bar{V}$ and $\underline{\mathrm{V}}$ in (18) and deriving the first order conditions yields:

$$\frac{\partial \pi_{N+S}}{\partial \overline{g}}(\overline{g}^{SB}, \overline{d}^{SB}) = \pi_S'(\overline{g}^{SB}) + \frac{\partial \pi_N}{\partial \overline{g}}(\overline{g}^{SB}, \overline{d}^{SB}) = c_S'^a(\overline{g}^{SB}) = \frac{\partial \pi_{N+S}}{\partial \overline{g}}(\overline{g}^*, \overline{d}^*) \tag{35}$$

$$\frac{\partial \pi_{N+S}}{\partial \overline{g}}(\underline{g}^{SB}, \underline{d}^{SB}) = \pi_S'(\underline{g}^{SB}) + \frac{\partial \pi_N}{\partial \overline{g}}(\underline{g}^{SB}, \underline{d}^{SB}) = c_S'^a(\underline{g}^{SB}) = \frac{\partial \pi_{N+S}}{\partial \overline{g}}(\underline{g}^*, \underline{d}^*) \tag{36}$$

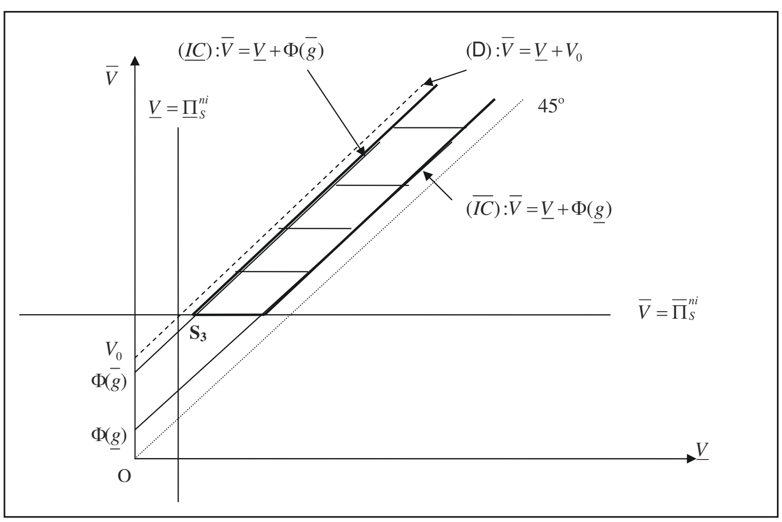
By continuity of $\pi^i_{N+S}(.)$ it follows that: $\overline{g}^{SB} = \overline{g}^*$, $\underline{g}^{SB} = \underline{g}^*$, and monotonicity ensures that $\underline{g}^* \leq \overline{g}^*$. Allocative efficiency is reached for both types: F_N will have an optimal access to the genetic resources from both types. These allocations give rise to the following transfer schemes where no rent will be given up:

$$\overline{t}^{SB} = \xi(\pi_S(\hat{\overline{g}}) + \beta \pi_N(\hat{\overline{g}}, \hat{\overline{d}})) + (1-\xi)\pi_S^c(\hat{\overline{g}}) - c(\hat{\overline{g}}) + c_S^a(\overline{g}^*) = \overline{t}^* \tag{37}$$

$$\underline{t}^{SB} = \xi(\pi_S(\hat{\underline{g}}) + \beta \pi_N(\hat{\underline{g}}, \hat{\underline{d}})) + (1-\xi)\pi_S^c(\hat{\underline{g}}) - c(\hat{\underline{g}}) + c_S^a(\underline{g}^*) = \underline{t}^* \tag{38}$$

Case 3: $V_0 > \Phi(\overline{g}^*)$, i.e. $\underline{IC}$-line is below $\mathcal{D}$

Figure 6: Case 3: High V_0



The high type faces the same situation as in Case 2 as $V_0 > \Phi(\overline{g}^*) > \Phi(\underline{g}^{SB})$, so that $\overline{IR}$ is binding and $\overline{IC}$ holds. On the contrary, the low type now has incentive to misrepresent herself. By doing so, she incurs an extra cost of access $\Phi(\overline{g}^*)$ that is smaller than the differential in reservation profit in favour of the high type, V_0. As a consequence, $\overline{IR}$ and $\underline{IC}$ are binding: $\overline{V} = \overline{\Pi}_S^{nc}$ and $\underline{V} = \overline{\Pi}_S^{nc} - \Phi(\overline{g})$. From a graphical point of view it is immediate to see that the optimal point that maximizes F_N profit or equivalently minimizes the expected rent given to the South $[p\bar{V} + (1-p)\underline{\mathrm{V}}]$ is S_3 where $\overline{IR}$ and $\underline{IC}$ bind. The low type receives an information rent (this is a case of *countervailing incentives* CI) whereas the high is offered her expected reservation profit.

Plugging $\bar{V}$ and $\underline{\mathrm{V}}$ in (18) and deriving the first order conditions yields:

$$\frac{\partial \pi_{N+S}}{\partial \overline{g}}(\overline{g}^{CI}, \overline{d}^{CI}) = \pi_S'(\overline{g}^{CI}) + \frac{\partial \pi_N}{\partial \overline{g}}(\overline{g}^{CI}, \overline{d}^{CI}) = c_S'^a(\overline{g}^{CI}) - \frac{1-p}{p}\Phi'(\overline{g}^{CI}) < \frac{\partial \pi_{N+S}}{\partial \overline{g}}(\overline{g}^*, \overline{d}^*) \tag{39}$$

$$\frac{\partial \pi_{N+S}}{\partial \overline{g}}(\underline{g}^{CI}, \underline{d}^{CI}) = \pi_S'(\underline{g}^{CI}) + \frac{\partial \pi_N}{\partial \overline{g}}(\underline{g}^{CI}, \underline{d}^{CI}) = c_S'^a(\underline{g}^{CI}) = \frac{\partial \pi_{N+S}}{\partial \overline{g}}(\underline{g}^*, \underline{d}^*) \tag{40}$$

By continuity and concavity of $\pi_{N+S}(.)$ it follows that: $\overline{g}^{CI} > \overline{g}^*$, $\underline{g}^{CI} = \underline{g}^*$, and $\underline{g}^{CI} < \overline{g}^{CI}$ (Monotonicity). There is no allocative distortion for the low type, but there is an upward distortion for the high type: The low type will supply the genetic resources optimally whereas the high type will be required to supply an excessively high level of resources. These allocations give rise to the following transfer schemes:

$$\overline{t}^{CI} = \xi(\pi_S(\hat{\overline{g}}) + \beta\pi_N(\hat{\overline{g}}, \hat{\overline{d}})) + (1-\xi)\pi_S^c(\hat{\overline{g}}) - c_S(\hat{\overline{g}}) + c_S^a(\overline{g}^{CI}) > \overline{t}^*$$

$$\underline{t}^{CI} = \xi(\pi_S(\hat{\overline{g}}) + \beta\pi_N(\hat{\overline{g}}, \hat{\overline{d}})) + (1-\xi)\pi_S^c(\hat{\overline{g}}) - c_S(\hat{\overline{g}}) + c_S^a(\overline{g}^{CI}) - \Phi(\overline{g}^{CI})$$

In all these cases, it is easy to show that given g, drug development d is chosen optimally.■

A.3 Proof of Proposition 3

As in the case of screening, the combination of (16), (17) and $\Phi' > 0$ implies that $\overline{g} \geq \underline{g}$.

The Lagrangian of the programme is given by:

$$\begin{aligned}
\mathcal{L} &= p\overline{V} + (1-p)\underline{V} + \lambda\left[\underline{V} - \overline{V} + \Phi(\overline{g})\right] \\
&+ \mu\left[p\left(\pi_S(\overline{g}) + \pi_N(\overline{g}, \overline{d}) - c_S^a(\overline{g}) - c_N(\overline{d}) - \overline{V}\right) + (1-p)\left(\pi_S(\underline{g}) + \pi_N(\underline{g}, \underline{d}) - c_S^a(\underline{g}) - c_N(\underline{d}) - \underline{V}\right) - \Pi_N^0\right]
\end{aligned}$$

where λ and μ are the Lagrange multipliers for (17), and (27). The first order conditions are:

$\overline{V}$: $\xi + \lambda - \mu\xi = 0$

$\underline{V}$: $(1-\xi) - \lambda - \mu(1-\xi) = 0$

For any probability p, $\mu = 1$ and $\lambda = 0$ solve the system formed by the two first order conditions. It means that F_N's participation constraint is binding and the low type's incentive constraint need not be. It follows that the efficient outcome can be implemented by the informed F_S by using an *ex ante* contracting. This is because the low type will tell the truth as $\underline{IC}$ is slack, and F_N receives exactly his outside option Π_N^0 so that F_S becomes the residual claimant of the surplus. From the binding participation constraint, we obtain:

$$p\overline{V} + (1-p)\underline{V} = p\left(\pi_S(\overline{g}) + \pi_N(\overline{g}, \overline{d}) - c_S^a(\overline{g}) - c_N(\overline{d})\right) + (1-p)\left(\pi_S(\underline{g}) + \pi_N(\underline{g}, \underline{d}) - c_S^a(\underline{g}) - c_N(\underline{d})\right) - \Pi_N^0 \tag{41}$$

The first order conditions with respect to $\overline{g}$ and $\underline{g}$ will yield an efficient outcome for both types $\overline{g} = \overline{g}^*$ and $\underline{g} = \underline{g}^*$. Given this efficient outcome, F_N also chooses d efficiently, i.e. $\overline{d} = \overline{d}^*$ and $\underline{d} = \underline{d}^*$.

Given that $\overline{V} > \underline{V}$ from the high type incentive constraint (16), F_S can structure her payoff so that:

$$\overline{V}^* = p\left(\pi_S(\overline{g}^*) + \pi_N(\overline{g}^*, \overline{d}^*) - c_S^a(\overline{g}^*) - c_N(\overline{d}^*)\right) + (1-p)\left(\pi_S(\underline{g}^*) + \pi_N(\underline{g}^*, \underline{d}^*) - c_S^a(\underline{g}^*) - c_N(\underline{d}^*)\right) - \Pi_N^0 + (1-p)\Phi(\overline{g}^*) \tag{42}$$

$$\underline{V}^* = p\left(\pi_S(\overline{g}^*) + \pi_N(\overline{g}^*, \overline{d}^*) - c_S^a(\overline{g}^*) - c_N(\overline{d}^*)\right) + (1-p)\left(\pi_S(\underline{g}^*) + \pi_N(\underline{g}^*, \underline{d}^*) - c_S^a(\underline{g}^*) - c_N(\underline{d}^*)\right) - \Pi_N^0 - p\Phi(\overline{g}^*) \tag{43}$$

It can be easily verified that $\overline{V}^*$ and $\underline{V}^*$ satisfy the incentive compatibility constraints (16) and (17) as well as the *ex ante* participation constraint (27).[7]

We can therefore determine the optimal transfer payments:

$$\overline{t}^* = \overline{V}^* + c_S^a(\overline{g}^*) \tag{44}$$

and

$$\underline{t}^* = \underline{V}^* + c_S^a(\underline{g}^*) \tag{45}$$

By monotonicity we know that $\overline{g}^* \geq \underline{g}^*$. Therefore, as c_S^a is increasing, we have $c_S^a(\overline{g}^*) \geq c_S^a(\underline{g}^*)$. It follows that $\overline{t}^* > \underline{t}^*$.■

[7]Subtracting (42) and (43) gives $\overline{V}^* - \underline{V}^* = \Phi(\overline{g}^*) \geq \Phi(\underline{g}^*)$ which satisfies both incentive compatibility constraints (16) and (17). Subtracting (42) to $p\overline{V}^* + (1-p)\underline{V}^* + (1-p)\Phi(\overline{g}^*)$ and combining it with $\overline{V}^* - \underline{V}^* = \Phi(\overline{g}^*)$, we show that the *ex ante* participation constraint (27) is also satisfied.