# Economics of IPR for Genetic Resources and Traditional Knowledge: North-South Cooperation in Sequential R&D*

Mare Sarr† and Tim Swanson‡

March 15, 2007

**Abstract**

This article investigates the issue of protecting genetic resources and traditional knowledge in the biological sector with intellectual property rights. Using a North-South bargaining framework, we shed light on the importance of the placement of such rights for both distributional and efficiency reasons. We show that under complete information the creation of a second IPR to protect genetic resources may paradoxically lead to an efficient outcome through integration, and help improve benefit sharing viz. the current IPR regime. The South's bargaining position and benefit may be further improved whenver traditional knowledge is private information.

**JEL Classification**: L240; O340; Q560

**Keywords**: Intellectual Property Rights; Genetic Resources; Traditional Knowledge; Sequential R&D

---

*We thank Tom Dedeurwaerdere, Christine Frison, Zhou Jidong and conference participants at BioEcon VIII and ENTER Jamboree 2007 for helpful comments. We gratefully acknowledge financial support from RefGov.

†Department of Economics, University College London, London WC1E 6BT, UK (email: m.sarr@ucl.ac.uk)

‡Department of Economics, University College London, London WC1E 6BT, UK (email: tim.swanson@ucl.ac.uk)

# 1 Introduction

Among R&D driven industries, the life sciences or biological industries (agriculture and pharmaceuticals) are distinctive in that natural capital plays an important role in supplying useful (potentially essential) information. In this sector, the R&D activities are sequential and cumulative in nature and structured in 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, genetic resources) 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 R&D output. At the other end of the vertical industry, the secondary stage biological R&D process collects the information stocks made available by the primary R&D stage, and invests in physical and human capital (laboratory equipment and scientists) to produce new R&D and new solutions designed to consumers. Appendix 1 depicts the structure of such an industry.

The industrial organization literature has analyzed at length the implications of the cumulative nature of innovation on the design of intellectual property rights (henceforth IPRs) policy. The importance of giving first innovators enough incentive to invest and innovate is particularly emphasized 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 question concerns whether a second patent should be allowed any successive innovators within the industry. (Scotchmer 1996)

However, it is striking that in the life sciences only the secondary or modern stage of the research process currently is granted property rights protection. The absence of protection for the primary traditional stage has created free access to the knowledge and information (traditional knowledge and genetic resources) produced at this level of the industry. For many years the life sciences industry has relied on this doctrine of the so-called 'common heritage' (or free access). Free access raises three problems: first, traditional knowledge may be misappropriated by R&D firms and used for their own profit; secondly, underinvestment may result in the loss of valuable knowledge; thirdly, over-exploitation of the genetic resource pool may lead to loss of biodiversity.

In 1992, the Convention on Biological Diversity (henceforth CBD) abrogated the doctrine of 'common heritage' and recognized the importance of traditional knowledge, innovations, and practices. It established the doctrine of 'national sovereignty' of host states in these informational resources (traditional knowledge and genetic resources), and in principle requires informed consent and agreement on benefit sharing prior to access. The questions raised concern how the introduction of property rights at this earlier, primary stage of the R&D sector will impact upon innovation and efficiency within the sector.

In this paper, we set out to explore the possible impact of granting an IPR to traditional knowledge and genetic resource holders from an efficiency and distributional perspective. Essential to efficiency is the possibility of cooperation across the entire R&D sector, in a manner that enables information to flow freely between the different levels of this industry. We find that allowing a second IPR and introducing a procedure for its enforcement may yield an efficient outcome by encouraging cooperation across the entire industry. Further, we find that the establishment of a second property right at the base of the R&D sector is important to creating this framework for cooperation. A property right establishes the outside option of the South and thus the basis on which a right to compensation is established, creating the capacity to share in industry rents at an efficient level.

Few economic papers have investigated the complex question of genetic resources and traditional knowledge, let alone its relationship with IPRs. Most contributions in this field come from the law or anthropology literature. Our major contribution here is to propose a bargaining framework to analyze the economic incentives for creating an efficient sequential R&D industry, and the role of IPR in developing this framework.

The paper is organized as follows: In section 2 we survey some important aspects of the economics of cumulative innovation. Section 3 presents the structure of the biological industry focusing on the contribution of traditional knowledge to justify the allocation of a second IPR. Section 4 and 5 present a simple model of the impact of a second IPR protecting traditional knowledge holders under complete and incomplete information. Section 5 concludes.

# 2 Economic Analysis of cumulative innovation

## 2.1 Economic Rationale for intellectual property rights

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/or marketing of the innovation, intellectual property regimes give the innovator the incentive to invest by ensuring he captures part of the social value he has generated. Therefore, there is a trade off between giving firms the incentive to invest and giving monopoly power to innovative firms that creates a distortion in the economy.[1]

## 2.2 Innovation in sequential research process: one or two property rights?

It is not uncommon to have firms or institutions specialized in basic research while others focus on the development of products based on the prior knowledge supplied by the former. In these industries, the end product results from the accumulation of innovation in all stages of the R&D sector. As a consequence, regarding research as a stand alone process fails to capture the specialization of research activities between firms carrying out basic research and those developing commercial products using the technology made available by the former. Hence research activities are better analyzed in the framework of sequential or cumulative innovations in which the division of labor and expertise often does not allow for vertical integration.

However, when innovation is sequential, some innovators in a non-integrated vertical industry may lack the incentive to invest or invent. A single property right that is placed at only one point within such an industry must be given effect throughout the industry, if there are to be incentives throughout. This will depend upon the transactions costs of organising the vertical industry, and the capacity for each stage to obtain a return that approaches its marginal contribution. The distribution of industry profits across sequential innovators is a key determinant of the incentives for creating future innovations.

If more than one property right is introduced within the industry to address this problem, cooperation across the vertical industry remains equally important. Successive monopolies in the same vertical structure would introduce multiple restrictions on output, producing an outcome inefficient from both the perspective of the industry and from that of society. Property rights thus create an incentive for cooperation across the industry, because of the gains that may be realised from internalising this vertical externality. In sum, multiple property rights also imply the need for cooperation across the industry if the efficiency is to be attained. In all cases, therefore, the role of property rights in sequential research is to estab-

[1] The fact that a distortion is introduced implies the analysis lies within the area of the second best. For this reason we focus on measuring the appropriation and distribution of producer surplus.

lish the bargaining framework within which cooperation must be attained, not to establish the outcome itself.

## 2.3 Placement and Patentability of the second innovation

How does the introduction of a second property right impact upon that bargaining structure? Scotchmer (1996) investigates how granting of a second patent impacts upon the profitability of the first. Based on the assumption that the second generation product always infringes the original patent (i.e. the patent is assumed to be very broad), she shows that the patent system must ensure an adequate division of profit between both inventors. Provided *ex ante* contracting is feasible, an *ex ante* agreement allows firms to share profits in a way that avoids *ex post* hold up problem.

The critical assumption here is that there are no impediments to *ex ante* contracting; i.e. that such agreements are legal and involve no significant transaction costs. Given this assumption, granting a patent only to the first innovator alone combined with *ex ante* contracting is sufficient to provide the right incentives across the industry. That is, the first-placed innovator has the correct incentives to solve the investment problems across the entire vertical sector. (Green and Scotchmer 1995).

If a single property right is placed in the vertical industry, but only with the second innovator, then the problem of motivating the first inventor remains. The second innovator need not have incentives to solve the investment problem of the first, if it does not presume that it will always be the sole innovator at that level of the industry. For example, if other firms exist at the second stage of the industry and also rely on the first innovator, then the incentive to provide incentives at the earlier stage of the industry will be dissipated across all the firms at the second stage. For this reason, a second property right may need to be introduced at the earlier stage in order to internalise the incentives for investment there.

## 2.4 The role of ex ante contracting in the division of profit

One of the major issues addressed in the literature of cumulative research is the question of the division of the rents between the first generation innovator and the subsequent ones (cf. Scotchmer 1991, Green and Scotchmer 1995, Gallini and Scotchmer 2002). In fact, cumulativeness introduces complexity in intellectual property rights regimes because it makes it more difficult to incentivise firms to invest in research. This is because each firm in the vertical industry must receive sufficient incentives to invest at each stage. However, if the first innovator's profit shrinks due to the competition from the second generation product, or if the first innovator does not receive a share of the net social value (created by the second generation product), he may not find it worthwhile to invest.

The breadth of the second stage patent (interpreted as the minimum improvement required to avoid infringement on the first generation product) is a key determinant of the division of the profit. In this regard, Green and Scotchmer (1995) show that when the value and the costs of the R&D project are certain a broad patent is particularly efficient to protect the first innovator. Indeed, with a broad patent the second innovator is more likely to infringe the earlier technology and therefore will sign an *ex ante* agreement (the agreement is signed before the second innovator decides to incur sunk costs) to be able to develop an improved product.[2]

## 2.5 Conclusion on IPR in sequential innovation

This discussion makes clear that, assuming reasonable transaction costs, the first best outcome in a vertical industry with sequential innovation is some form of vertical integration. The issue of property rights and their placement is less determinative of the final industry structure than it is of the industry division of profits. Property rights establish the bargaining framework within which bargaining surplus is divided, if and when cooperation is attained.

In the following paper, we explore these insights in the context of genetic resources, traditional knowledge and their use in the vertical industry known as the life sciences. We assume that cooperation requires the integration of all of the information-producing capacities at these various stages of the industry, and then explore how various property right systems will enable that outcome to be attained.

[2]In principle, *ex post* contracting (the license is signed after the second innovator decides to sunk costs and the new product infringes the first generation product) can also be used. However, it does not emerge in the equilibrium because the second innovator may lack the incentive to invest when it bear the full research costs while sharing his revenue with the licensor. In fact *ex post* licensing along with the breadth of the patent serve to set "threat points" for the bargaining of an *ex ante* license. Provided the second innovator adds to the joint profit, the first innovator will have incentive to invest.

# 3 Economics of cumulative research applied to Genetic Resources and Traditional Knowledge

We will assume here that the cumulative research process in the life sciences industries makes use of: a) naturally-occurring genetic and chemical information; b) traditional uses of herbal varieties and medicines; and c) modern scientific method. The industry to date has recognised intellectual property rights only over the products of the last. Here we wish to indicate the relative contributions of the various parts of this R&D sector, and how their roles differ from one another.

## 3.1 Rationale for granting intellectual property right to genetic resource or traditional knowledge holders

The rationale for granting protection over genetic resources or traditional knowledge is similar to that which exists in any sequential or vertical R&D context: incentives may be required to generate important inputs at each stage of the process. In the case of R&D within the life sciences, the traditional approach to innovation has been based in a search process often commencing with naturally-occurring genetic resources. (Simpson, Sedjo and Reid 1996) The information found within these naturally-occurring substances, once identified and linked to an identified use, may then be further analysed and refined to generate a pharmaceutical or agricultural innovation of specific usefulness (e.g. to combat a particular pest or pathogen). For this reason it is often argued that the innovations in the life sciences are built upon the sequential innovations occurring at various levels: genetic, traditional, scientific. Investment at each of these levels may be important in order to provide for the optimal flow of information and innovation through the R&D sector. Investment in naturally-occurring diversity is important to provide the fullest possible range of genetic traits available for addressing newly arriving biological problems. (Goeschl and Swanson 2002a) Investment in traditional knowledge systems is important to provide the mechanism for initially identifying those traits that may be useful, and how they might be used. (Rausser and Small 2000) Investment at the scientific level is important to apply this information to the specific purposes intended. Incentive mechanisms should take into consideration the sequential character of innovations within this context, and IPR systems should therefore provide incentives at each level.

## 3.2 Evidence of contributions of Genetic Resource and Traditional Knowledge

The best evidence of the contribution of these sectors to R&D within the life sciences arises from various pieces of empirical work in the area. We will use this work to distinguish between the the two types of contributions, genetic resources and traditional knowledge.

First, in the context of agricultural R&D, large scale studies have undertaken to factor out the contributions of the various forms of capital to the innnovation process. (Gollin and Evenson 1998; Evenson 1995) These studies have examined the database describing the plant development system in the centres for international agricultural research (IARCs). They estimated the elasticities of production for various forms of capital (physical, human, genetic) in the creation of new useful plant varieties by the IARCs. The elasticity of production within these studies for genetic resources falls around 0.30, or around a third of total contribution to innovation in this industry. It is important to note that when the pool of genetic resources concerned was already of known use or usefulness (so-called landraces used in traditional production systems), the value of their contribution increased by an order of magnitude. That is, the pool of genetic resources when combined with prior human experience of the pool was of vastly greater value than those without the combination. (Evenson 1995)

Similarly, in the context of pharmaceutical R&D, one route to successful innovation has long been known to be bio-prospecting, i.e. the search for active plant-based compounds for use in the development of new pharmaceuticals. One method for doing this is the simple retention of natural habitats for the diversity of plant forms that exist there, and the random selection and screening of that diversity for active compounds. Simpson, Sedjo and Reid (1996) estimated the contribution of natural habitats to pharmaceutical production for this purpose, and found that the marginal hectare in various parts of the world ranged in value from $0.20 to $20.63 for purposes of screening in private R&D. When the consumer surplus from pharmaceutical use was included in this calculation, the values of the natural resources were found to increase by about a factor of 140 for the most valuable "biodiversity hot spot". (Craft and Simpson 1996) Further analysis of the search process found that values increased substantially when there was prior information concerning the identities of useful genetic resources. When this prior information is incorporated into the search process, the value of the marginal hectare for bio-prospecting again increased by an order of magnitude. (Rausser and Small 2000)

Hence, the values of genetic resources derive primarily from the diversity of genetic or chemical information they represent. (Weitzman 1998) This value is then captured via a search process over this information. (Simpson, Sedjo and Reid 1996)

The role of traditional knowledge is to guide this search process initially, and to identify the basic results of the initital search; this enables a basic ranking or set of priors regarding which of the genetic resources may be most useful. (Rausser and Small 2000) This information may then be used in a more scientifically-constructed search process in laboratory conditions.

### 3.3 IPRs for Genetic Resources and/or Traditional Knowledge?

Patents are the most common IPR granted to the bio-pharmaceutical firms in the life science industries. However, stringent requirements need to be satisfied for a patent application to be successful: non-obviousness, novelty, usefulness. Non-obviousness refers to the requirement of a leap of imagination or inspiration for conferral of a patent. Simple discovery is not enough, but there must be some individual contribution shown as well. This is the primary hurdle to the recognition of IPR in genetic resources, as naturally-occuring entities are usually termed to be discoveries rather than innovations. Novelty refers to the requirement that there is no pre-existing use or prior art incorporating the innovation, i.e. it must be genuinely "new". This is the primary hurdle to the recogntion of IPR in traditional knowledge, as many if not all traditional uses of genetic resources may be shown to have existed at some other place or point in time. Hence, irrespective of the usefulness of the genetic resource or the traditional knowledge in the production of innovation, at present there is little prospect for the recognition of IPR in these stages of the sequential research process.

At the present time the R&D process in the life sciences is sequential in nature, but the sole location for the IPR is at the end of the sequence. In this paper we wish to examine how this IPR structure impacts on the incentives to invest in the various stages of R&D, and also to examine how the introduction of a second property right within the industry might affect this.

## 4 A model of the impact of a second property right in the R&D industry

We now establish the means by which the establishment of a *property right protecting genetic resources and/or traditional knowledge* together with a *procedure for its enforcement* determines the prospects for efficient integration. Our main idea is that affording a property right in the information produced by the South (unlike the current IPR regime) may trigger cooperation and lead to an efficient outcome. Paradoxically, the property right might not be used by the South, but might serve to determine her outside option when an agreement for integration into a joint venture is being discussed. The very existence of the property right may ensure the South a stream of income that will be accounted for in any negotiation.

In this section, we commence with a two stage R&D sector, depending upon genetic resources (South) and scientific method (North). In the following section, we discuss the relevance of a three stage R&D sector, in which the South has both genetic resources and traditional knowledge.

## 4.1 Description of the economy

*R&D industry*: The life sciences industry is described as a vertical industry combining useful information identified in genetic resources on the one hand, with human and physical capital on the other hand, in order to produce innovations useful in problems of a biological character (health, agriculture). Importantly, we assume that these complementary inputs are located in different regions of the world respectively in the South (she) and in the North (he). The South (she) is representative of that part of the globe possessed of most natural genetic diversity ($g$). She is the first innovator in this industry and is the precursor of information necessary for further innovations. For example, through observation of natural diversity, she may identify some biological activity in a plant variety and then use this knowledge to market derivatives from medicinal herbs in order to fight against common diseases. By doing so, the South identifies essential information $e$ embodied within the medicinal herbs $H$, by application of her traditional human capital $h_S$ to her genetic capital endowment $g$. Note once again that $g$ is assumed to be present only in the South and, for purposes of this analysis, we assume that all innovations in this industry in the capital stock $g$.

The North on the other hand, is representative of those agents located within developed countries that are engaged in R&D in the life sciences (pharmaceuticals and agricultural sciences) using laboratories and scientists, with the aim of developing patented innovations primarily for purposes of marketing them in the North. He is the second innovator in this industry and 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 $D$, which is then amenable to IPR. This industry is depicted in Appendix 1.

Complementarity between the two stages of the industry arises because the genetic resources $g$ held by the South are assumed to be an essential input for the R&D

processes of the North. (Gatti et. al. 2006)[3] The fundamental question (when such complementarity exists) is the institutional form within which this interaction will occur. It could be relatively disjoint and decentralised (via markets and property rights) or centralised and fully integrated (via vertical integration). In what follows we will assume that it is first-best for the two regions to integrate, and the sole question concerns the basis on which that integration occurs. We discuss this further below.

*IPR regime:* The problem of the life sciences industry is that it is an R&D sector based on cumulative innovation, but one in which there currently exists a single property right at the end of the sequential R&D process. This contrasts with what is commonly advocated in the industrial organization literature. For instance, Green and Scotchmer (1995), and Scotchmer (1991 and 1996) argue that protecting the early innovators in sequential innovation is essential if they are to invest in the first place. A single property right at the end of the industry leaves the problem at the initial stage of the industry unaddressed, and also creates no market-based incentives to address it. This is because a downstream innovator benefits from the upstream innovation as a public good, along with any other innovator able to make use of it. Since it is unlikely that any single downstream innovator is able to appropriate anything other than a small part of the full future value of any innovation, the incentives to encourage investments upstream are dissipated across all potential users.

In this paper, we wish to examine the efficiency impact of assigning a property right to the first stage of the industry. We will assume the existence of a property right regime granting legal protection not only to innovations made by the North (through the patent system) but also to the genetic resource-based information within the South. We also assume the existence of an institutional framework responsible for enforcing these rights, namely the Courts of the respective regions. When a right to information is claimed, the region will enforce this by asking the Court in the relevant region to grant it exclusive marketing rights regarding that information (or products containing it). In order to give effect to the new right granted to the South, Courts in the North will be asked to enforce rights of the South to the North's market (by giving exclusive rights in any information in $H$).[4] In short, the new IPR of the South is seen to be a method for acquiring exclusive marketing rights for its information in the North's markets, and the impact of that right on its bargaining position vis a vis the North's R&D sector.

For example, imagine that the South identifies a medicinal herb ($H$) that may

[3] $e$ is not essential but is an important factor for increasing the rate of success in finding new leads and for reducing costs of developing new products valued by consumers in the North. It will be examined in greater detail in the following section.

[4] We assume that the North does not pursue access to markets in the South in this game.

have some active chemical properties. After registering this herb and its potential uses with the appropriate authorities, it considers placing the derivatives of this herbal product directly onto the market in the North. On the other hand, the South might also enter into a joint venture with the North to further develop the herb. The chemical information embedded within the medicinal herb could then be identified, extracted, analysed and developed into new drugs ($D$) by pharmaceutical or biotechnology firms in the North. The North would then be able to claim IPR in the new drugs, and market it in the North for the joint venture. To a great extent these new drugs are simply competitors for the same markets that might have been served by the medicinal herb ($H$) but they come in forms that attract clearly defined intellectual property rights (IPR). At this point we will assume that the drugs produced via the North's use of the South's information are direct competitors with the South's herb ($H$), but it may or may not involve additional functions as well (due to value added by North).

The issues we address here relate to how the North and South would share the benefits in a joint venture, assuming that a joint venture is the most efficient way to proceed and that one is achieved. What factors determine what shares are achieved by each member of the venture, and how do these accord with the shares required to achieve efficiency at each level of R&D?

## 4.2 The Game

Consider a principal-agent sort of contracting framework where North is the principal and South is the risk neutral agent.[5] The industry operates in the deterministic sequential research manner set out above, with South identifying a genetic resource ($g$) containing important information ($e$) which North might wish to develop and market. Suppose that South is able to register a property right in the discovered information. It then claims exclusive rights in the marketing of an herbal medicine ($H$), and the information ($e$) which it contains. Suppose also that the North can develop a new product ($D$) based on the embedded information ($e$) without the South's consent. The South may challenge North in the North's Court, claiming a violation of its exclusive marketing rights. Before any of this actually occurs, we assume that the North offers to form a joint venture with the South, which gives

[5] We adopt the P/A framework as a matter of expositional convenience, but note that the general problem is more of the nature of a noncooperative bargaining problem. The primary implication of the P/A framework is that the North has the sole capacity to make offers and does so in a take-it-or-leave-it fashion. This assumption makes sense to us in that the bargaining concerns the basis on which South is granted access to the North's markets. The assumption implicitly provides the North with all bargaining power regarding this matter, constrained solely by the value of the South's outside option.

him access to her genetic resources ($g$) in return for a monetary transfer $t$. The North offers a take-it-or-leave-it contract $(g, t)$ to South.

The timing of the game can be summarized as follows:

1. The South develops an herbal medicine $H$ protected by an IPR using $g$ at a cost $c_S$.

2. The North offers the South a transfer $t$ in return for integrating to form a joint venture, with the South giving access to $g$ in order to enable the North to develop a new pharmaceutical $D_1$.

3. The South decides a) to accept the offer ($AO$) to integrate on the terms indicated; OR b) to reject the offer ($RO$) and markets $H$ in the North assuming exclusive marketing rights in the remedy protected by the Court of the North.

4. The North decides a) not to invest further resources in this market ($NI$) and the game is over giving South exclusive access; OR b) to invest ($I$) in developing and marketing a new pharmaceutical $D_2$ in competition with $H$, in which case the South files a lawsuit in a Court located in the North.

5. The Court in the North makes an enforceable decision regarding whether South has exclusive marketing rights for its remedy: a) in case of infringement or violation ($V$), the North needs a license ($L$) to market the new product $D_2$ in competition with $H$; OR b) if there is no infringement or no violation ($NV$) North and South compete ($C$) in the North market.

This game can be interpreted as an entry game where the South threatens to enter the markets of the North with its medicinal herb ($H$). The North has some belief that it may be able to create a competitive product ($D$) based upon the information in $H$, and be granted exclusive marketing rights to markets in the North. Based on these beliefs and the range of outcomes that might result, the North offers South the opportunity to integrate and efficiently combine factors in order to access the North's market together. The extent of protection afforded to the South's rights makes entry (i.e. rejection of the offer) a credible threat since she will receive a reservation profit that the North must take into account in the negotiation. The ultimate shares achieved in the integrated enterprise will depend entirely on the existence and magnitude of this outside option.

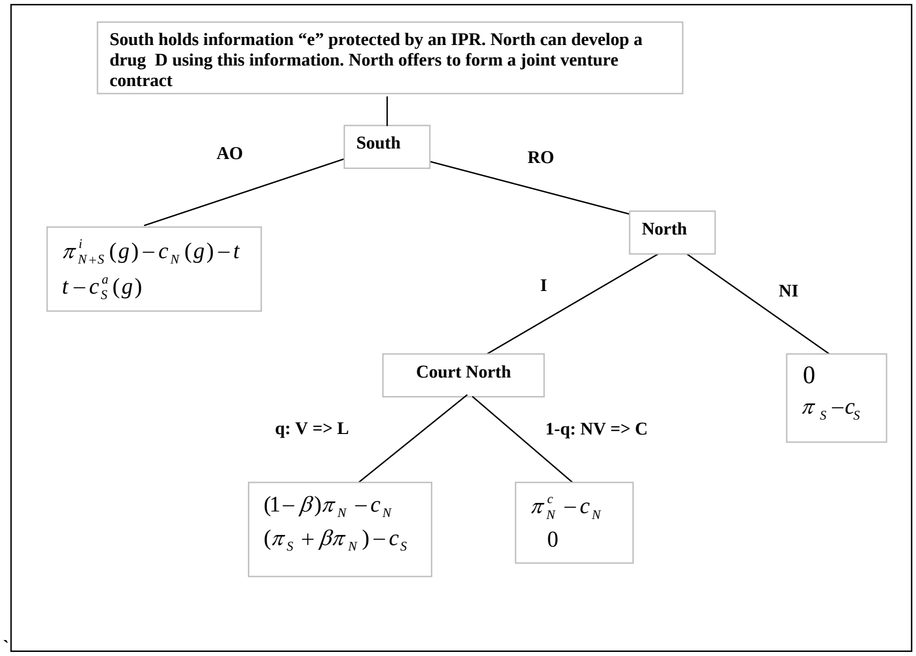



Figure 1: Game tree

## 4.3 Market Structure

The playing of the game culminates in a range of potential market structures (joint venture, competition, monopoly), and these structures then determine the potential payoffs to the players. Starting from the bottom of the game (and assuming that North decides to compete), the Court's decision determines whether the South will have exclusive access to the market or if North and South will compete for the same market. It is assumed that the resulting market structure either will be monopolistic or duopolistic (with Bertrand competition).

The precise market outcomes under the various branches of the game are as follows:

A) Absent integration and assuming that North decides not to invest in a competitive product, the South is assumed to have *monopoly* rights in the marketing of the medicinal herbs $H$ in the North's market.

B) Absent integration, but assuming that the North does invest and produce a new drug $D_2$, two market structures may arise: 1) either there is Court-determined infringement, in which case the South receives *monopoly* rights in the market and may license the North to market the drug in return for payment of its monopoly rents as a royalty; 2) or there is no Court-determined infringement, and *competition* (Bertrand) takes place between North and South with two IPRs in the market.

C) If there is agreement to integrate, a *joint venture* is formed combining the expertise of both sides to produce disembodied information $d$ embedded in the new drug $D_1$. The joint venture enjoys a monopolistic position for marketing this new drug. A single IPR is required, so South will suppress her own IPR afforded to information $e$.

## 4.4 Payoff functions

### 4.4.1 Integration: Joint Venture Payoffs

If an agreement on integration is reached then the South grants access to her genetic resources, which results in cost effective development $c_N(g)$ of this information by the North. Cost effectiveness is reflected by the assumption that $c_N$ is decreasing in $g$. We also assume that $c_N$ is convex in $g$. The integrated entity earns a joint profit amounting to:

$$\Pi^i_{N+S}(g) = \pi^i_{N+S}(g) - c_N(g) - c^a_S(g) \tag{1}$$

where $\pi^i_{N+S}(g)$ is the integrated monopoly revenue earned by the joint venture and is assumed to be increasing and concave in $g$; $c^a_S(g)$ is the supply cost for South regarding its genetic resources. This cost is increasing and convex in $g$. The joint venture profit is then shared between North and South as follows:

$$\Pi^i_N(g) = \pi^i_{N+S}(g) - c_N(g) - t \tag{2}$$

$$\Pi^i_S(g) = t - c^a_S(g) \tag{3}$$

### 4.4.2 Absent Integration: Non-Cooperative Payoffs

On the other hand, if the offer of integration is rejected, the North decides whether to invest in developing a new product $D_2$. Failing to invest leaves the North with a zero payoff while South would be a monopolist and earn a payoff of $\pi_S - c_S$, where $\pi_S$ is the South revenue and $c_S$ is the cost of developing $H$. This case is not very interesting and therefore will not be given much attention.

The North may however decide to invest in developing a new product $D_2$. Given our assumption that genetic resources constitute an essential input absent in the North, the latter will be based, at least in part, upon the information contained within the South's marketed product ($H$) and the underlying genetic resources. The South will challenge the North in a Court (in the North) who detects infringement with probability $q$; where $q \in [0, 1]$. If infringement is detected, a license is required and the South is deemed the sole supplier, receiving royalty $\beta$ on sales by North so that her total revenue amounts to $\pi_S + \beta\pi_N$ (where $\pi_N$ is the revenue generated by North). If a licensing agreement is not signed, then the South denies the North the right to market its product. However, if no infringement is detected, innovation $D_2$ is granted a patent and competes with product $H$ in the Northern market. We assume that competition (Bertrand) entirely erodes the South's profit and leaves the North with $\pi_N^c - c_N$.

In summary, if South rejects the offer to form a joint venture then North and South receive respectively expected profits equal to:

$$\Pi_N^{ni} = q(1-\beta)\pi_N + (1-q)\pi_N^c - c_N \tag{4}$$

$$\Pi_S^{ni} = q(\pi_S + \beta\pi_N - c_S) + (1-q)0 \tag{5}$$

We assume furthermore that the integrated joint profit is larger than the non-integrated profit of the whole industry $\Pi_{N+S}^i \geq \Pi_N^{ni} + \Pi_S^{ni}$ so that reaching an agreement is potentially in both sides' interest.

### 4.5 Efficiency Condition: Integrated Industry, Single Property Right

We assume here that efficiency is framed in terms of the industry's outcome.[6] In a vertical industry, it is well-known that integration brings about productive efficiency from the producers' point of view since joint profit is then the objective function. The integrated industry's problem is then:

$$\max_g \Pi_{N+S}^i(g) = \pi_{N+S}^i(g) - c_N(g) - c_S^a(g) \tag{6}$$

[6]Of course we are in the world of second-best once we introduce the possibility of patent-based monopolies. The existence of such monopolies justifies the focus on producer surplus as a social welfare criterion. Once society-sanctioned monopolisation is allowed, the issue concerns whether conditions of productive efficiency (static or dynamic) inhere. The former requires cost-based efficiency. The latter requires profit maximisation.

In equilibrium, the integrated industry chooses the level of genetic resources $g^*$ to balance the marginal revenue and the sum of the marginal costs of both parts of the R&D :

$$\frac{d\pi^i_{N+S}(g^*)}{dg} = \frac{dc_N(g^*)}{dg} + \frac{dc^a_S(g^*)}{dg} \tag{7}$$

Here the efficient level of genetic resources is supplied by the South as they are supplied at marginal cost, and the efficient level of genetic resources is used in innovation in the North (as they are also used by reference to their marginal costs of production there). The single property right within the industry is reflected by the fact that the demand for genetic resources is considered by reference to the marginal benefits received in generating patent-based profits (a single margin rather than double marginalisation).

By integrating North and South into a single entity, the industry is able to develop the new pharmaceutical $D_1$ exploiting each partner's successive research contribution, and then market it within a monopolistic market structure. Specifically, the industry accesses genetic resources from the South in a manner that enables the optimal flow of information between both North and South, resulting in efficiency gains at both levels. That is, information from the North may be used to guide the search process in the South at the same time that information from the South (i.e. $e$) may be used to guide research in the North.

**Claim**: *From the perspective of the producers North and South, the first best solution requires integration and a single property right.*

Any departure from the conditions stated in this claim results in loss of efficiency. Failing to integrate the two stages of the industry is wasteful from the producers' perspective because it can either result in restraints on the flow of information between the levels of R&D (static inefficiency), or in the possibility of profit-eroding competition (thereby eroding incentives to investment and dynamic inefficiency).

## 4.6 Integration Under Complete Information

The problem faced by the North is to offer contractual terms to the South that will cause it to accept the offer to integrate. The contractual terms assume (in case of non-agreement) that he will breach her IPR (exclusive marketing rights) in the herbal medicine, and will face a lawsuit with uncertain outcome (likelihood $q$) that the Northern Court will protect the South's IPR. The North has the first move and proposes to the South a contract $(g, t)$ (accessing the South's resources $g$ in return for a monetary transfer $t$) that maximizes his own profit subject to the South participation constraint, that is:

$$\begin{aligned} \max_{t,g} \quad & \pi^i_{N+S}(g) - c_N(g) - t \\ \text{s.t.} \quad & t - c^a_S(g) \geq q(\pi_S + \beta\pi_N - c_S) \end{aligned} \tag{8}$$

**Proposition 1**: *In an industry where both North and South possess important information for the production of successive innovations, if the likelihood of South prevailing (in case of a lawsuit over exclusive marketing rights) is common knowledge, then there is a unique equilibrium contract $(g^*, t^*)$ offered by the North. This contract is characterized by the efficient allocation of genetic resources $g^*$as defined in (7) and a transfer payment $t^* = q(\pi_S + \beta\pi_N - c_S) + c^a_S(g^*)$ which a) increases in the likelihood of the Court enforcement of the IPR; b) decreases with the South's development cost; and c) increases with the supply of resources provided to the North. This equilibrium requires full integration and the existence of a single property right allocated to the joint venture.*

Proof 1: see Appendix 2.

If the North offers the optimal contract $(g^*, t^*)$ defined by (7) and (18), then the South will agree to form a joint venture run by the North to produce the new pharmaceutical $D_1$ using her useful information. The innovation is protected by an exclusive marketing right in the North (a patent), which guarantees monopoly pricing. Hence, through this contract the North can maximize the joint profit of this venture and thus achieve the first best outcome for the producers.[7]

The transfer payment is designed to make the South indifferent between accepting and rejecting the offer, in other words the South is offered her outside option value, without any prospect of sharing in the production surplus. This is because in this framework, the North holds all the bargaining power and imposes a take-it or leave-it contract without conceding any rent. It is optimal for the North to offer the lowest payoff that need not necessarily be rejected by the South, i.e. the value of any outside option. Any parameter increasing the South's outside option value has a positive effect on the level of transfer $t^*$. Furthermore, $t^*$ decreases with the South's development costs $c_S$ and increases with the level $g^*$ of genetic resources supplied to the North. The latter is important for the maintenance of incentives for efficient investment in information-generation in the South.

[7] We are assuming that transaction costs are low enough for the contract to occur, i.e the efficiency benefits of integration exceed the costs of transactions.

## 4.7 The Importance of the South's Property Right for Efficiency

Expression (18) in Appendix 2 shows the relationship between the Court's enforcement of the South's property right and the transfer paid by the North. As the probability of detecting infringement ($q$) tends to 1, the payment offered to the South tends to $\tilde{t}^* = \pi_S + \beta\pi_N - c_S + c_S^a(g^*)$. Thus, if the Court commits to the enforcement of the South's property right, the South's return is equal to the full value that it contributes within the sequential research process. In that case, the North pays to the South the value of its contribution, and then extracts from the market any surplus value that it adds within that process .

On the other hand, as the probability of detecting infringement ($q$) tends to 0, i.e. as the innovation from the South receives little or no protection, the share of the industry profit offered to the South tends toward her cost of supply, i.e. $\tilde{t}^* = c_S^a(g^*)$. So, when the innovation from the South is not adequately protected in the North, the North needs not pay any of the R&D rents to the South. In the limit case where $q = 0$, South is only compensated for its costs of giving access to its information. In this case the North receives the full rents attributable to both stages of the R&D process.

Hence, the existence of an enforceable (and enforced) property right for the South is essential to efficient compensation of the South's contribution to the R&D process. The property right substantiates the South's threat to enter the North's market, if it is not compensated adequately, and the capacity to extract the value of its R&D contribution via the market establishes the efficient level of contribution. Without this outside option, the South has no capacity to exact any compensation within the joint venture agreement.

## 4.8 Conclusion: Integration of Activities in Sequential Research

In an industry with sequential research, the existence and promised enforcement of property rights at each level of the R&D industry is necessary for developing an efficient contract for the integration of the industry. There is no capacity for each level to earn a return based upon its relative contribution to the scale or frequency of innovation, in the absence of both a recognised IPR at that level and the Court's enforcement of the same in the market under examination. If there is no enforcement of the IPR, then the level concerned earns only the supply cost of the resources, which is likely to be entirely unrelated to its relative contribution to innovation. This means that efficient incentives for investment in sequential research may depend upon the vesting of multiple property rights, if the single one has been placed at an inappropriate level.[8]

# 5 South's TK & Integration Under Incomplete Information

We wish now to examine how the presence of traditional knowledge (TK) might influence the contractual terms between the parties. Recall that TK has the effect of informing the South on the relative usefulness of individual genetic resources for purposes of R&D. In effect, this means that TK shifts the search process over genetic resources ($g$) away from randomness, and toward a search based upon well-informed prior beliefs on which genetic resources might be most useful for an intended purpose.[9] We will now investigate the impact of a property right in TK, wherein the genetic resources that are most useful in R&D is private information to the South and only able to be acquired by the North via contract. We continue to assume that property rights in genetic resource-based information exists, and is dependent upon Court enforcement in the North. 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 bargaining process described within the previous section.

We find that asymmetric information of this type may give the South the prospect of altering the distribution of the bargaining surplus in her favor (compared to the complete information case). It will be apparent that whether or not the North shares the bargaining surplus will depend on how the reservation profit (i.e. value of the outside option) varies with the quality of the private information.

## 5.1 TK as Private Information: Implications for Bargaining

We interpret traditional knowledge to be the situation when genetic resources are heterogenous in regard to their usefulness for R&D, and only the South possesses

[8]This is bad news for the suppliers of genetic resource-based information, for which there is little or no prospect of receiving either a recognised IPR or in having a court of the North enforce it. The current prohibition on the recognition of property in "discoveries" of naturally-generated information means that these contributions will not be compensated in an amount greater than their supply costs, irrespective of their contribution to innovation in the life sciences industries.

[9]More formally, we will assume that TK informs the South on the likelihood that various genetic resources are capable of contributing to the production of an innovation (a la Rausser and Small 2000).

the information on the ranking of resources in this way. For purposes of exposition, suppose the South has two types of genetic resources: a high quality type $\overline{\theta}$ with probability $p$ and a low quality type $\underline{\theta}$ with probability $1-p$. High quality types of genetic resources 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.[10] The quality of the genetic resources for purposes of information generation is the South's *private information*. Together these assumptions constitute our definition of the economic meaning of TK.

We now wish to specify the important ways in which the existence of this private information will impact upon the contracting process over integration (as in the previous section). The North again specifies the offered contract enabling direct access to South's genetic resources. It must now specify that contract in terms of the different types of genetic resources available. A direct revelation mechanism is a menu of two contracts $\{(\overline{g}, \bar{t}), (\underline{g}, \underline{t})\}$, one for each type of resource. A contract consists of access to South's resource $g$ in return for monetary payment $t$.

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.

$$\bar{V} = \bar{t} - c^a_S(\overline{g}) \geq \overline{\Pi}^{ni}_S \tag{9}$$

$$\underline{V} = \underline{t} - c^a_S(\underline{g}) \geq \underline{\Pi}^{ni}_S \tag{10}$$

This is equivalent to

$$\bar{V} \geq \underline{\Pi}^{ni}_S + V_0 \tag{11}$$

$$\underline{V} \geq \underline{\Pi}^{ni}_S \tag{12}$$

where $\overline{\Pi}^{ni}_S = \underline{\Pi}^{ni}_S + \left(\overline{\Pi}^{ni}_S - \underline{\Pi}^{ni}_S\right) = \underline{\Pi}^{ni}_S + V_0$. The term $V_0 \equiv \overline{\Pi}^{ni}_S - \underline{\Pi}^{ni}_S$ represents the differential value received by the South for its high quality and its low quality genetic resources (i.e. the differential value of its outside option when supplying each within the competitive marketplace).

[10] For example, the knowledge that these are high quality 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).

Note that the participation constraints $\overline{IR}$ and $\underline{IR}$ are type dependent suggesting that the high type has better opportunities outside the proposed joint venture (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.

$$\bar{t} - c_S^a(\overline{g}, \overline{\theta}) \geq \underline{t} - c_S^a(\underline{g}, \overline{\theta}) \tag{13}$$

$$\underline{t} - c_S^a(\underline{g}, \underline{\theta}) \geq \bar{t} - c_S^a(\overline{g}, \underline{\theta}) \tag{14}$$

**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.

Assumption A2 conveys the idea that marginal cost decreases in type: the high type enjoys a lower marginal cost of supply.

The low quality traditional knowledge holder may misrepresent her type and obtain a payoff: $\bar{t} - c_S^a(\overline{g}, \underline{\theta}) = \bar{V} - \Phi(\overline{g}, \theta)$. In addition, if the high type wants to mimic the low type, she would receive: $\underline{t} - c_S^a(\underline{g}, \overline{\theta}) = \underline{\mathrm{V}} + \Phi(\underline{g}, \theta)$; where $\Phi(g, \theta) \equiv c_S^a(g, \underline{\theta}) - c_S^a(g, \overline{\theta})$ with $\Phi(.) > 0$ and $\dfrac{\partial \Phi}{\partial g} > 0$ from assumptions A1 and A2. The term $(\Phi)$ refers to the supply cost differential of the different types of resources (and at different levels of supply as well).

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

$$\bar{V} \;\; \geq \;\; \underline{\mathrm{V}} + \Phi(\underline{g}, \theta) \tag{15}$$

$$\underline{\mathrm{V}} \geq \bar{V} - \Phi(\overline{g}, \theta) \tag{16}$$

The problem of the North is then:

$$\max_{\{(\overline{g},\overline{t}),(\underline{g},\underline{t})\}} \quad p[\pi^i_{N+S}(\overline{g}) - c_N(\overline{g}) - \overline{t}] + (1-p)[\pi^i_{N+S}(\underline{g}) - c_N(\underline{g}) - \underline{t}]$$

$$\text{subject to } \; (9), \; (10), (13), (14)$$

The problem can be re-written as follows:

$$\begin{aligned} \max_{\{(\overline{g},\bar{V}),(\underline{g},\underline{V})\}} \quad & p\left(\pi^i_{N+S}(\overline{g}) - c_N(\overline{g}) - c^a_S(\overline{g})\right) + (1-p)\left(\pi^i_{N+S}(\underline{g}) - c_N(\underline{g}) - c^a_S(\underline{g})\right) \\ & -[p\bar{V} + (1-p)\underline{V}] \\ & \text{subject to } \; (11), \; (12), (15), (16) \end{aligned} \tag{17}$$

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 pay-off to the South is the impact, if any, of any endowment (genetic or informational) upon its outside options.

**Proposition 2:** *When the quality of the genetic resource identified by the South is private information, the North may pursue integration in face of this uncertainty by offering a menu of self-selecting contracts $\{(\overline{g},\overline{t}),(\underline{g},\underline{t})\}$ to screen among the types of genetic resources, which are characterized by :*

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

2.2 *For $V_0 < \Phi(\underline{g}^{SB},\theta)$, $\underline{IR}$ and $\overline{IC}$ are binding. The supply of genetic resources required by the North is efficient for the high type $\overline{g}^{SB} = \overline{g}^*$ and distorted downwards for the low type $\underline{g}^{SB} < \underline{g}^*$. The transfer payment $t^{SB}$ is defined by (22) for the high type and (23) for the low type.*

2.3 *For $\Phi(\underline{g}^{SB},\theta) \leq V_0 \leq \Phi(\overline{g}^*,\theta)$, $\overline{IR}$ and $\underline{IR}$ are binding so that no information rent is given up to any type. Besides $\overline{IC}$ or $\underline{IC}$ are binding if respectively $V_0 = \Phi(\underline{g}^*,\theta)$ or $V_0 = \Phi(\overline{g}^*,\theta)$. The supply of genetic resources is efficient for both types. The transfer payment $t^{SB} = t^*$ is first best and is defined by (27) for the high type and (28) for the low type.*

2.4 *For* $V_0 > \Phi(\overline{g}^*, \theta)$*, there are countervailing incentives and only* $\overline{IR}$ *and* $\underline{IC}$ *are binding. The supply of genetic resources required by the North is distorted upwards for the high type* $\overline{g}^{CI} > \overline{g}^*$ *and efficient for the low type* $\underline{g}^{CI} = \underline{g}^*$*. The transfer payment* $t^{CI}$ *is defined by (34) for the high type and (35) for the low type.*

Proof 2: see Appendix 4.

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 (i.e. the value of the genetic resource if South uses it in competition with North). In parts 2.2 through 2.4 of Proposition 2, we see that the determining factor is whether the differentiable rent appropriable by the South (in competition with the North) ($V_0$) is less than or greater than the cost advantage appropriable via integration ($\Phi$). If the South's informational advantage works more effectively in competition with the North than it does in cooperation, then its threat not to cooperate is credible (as in case 2.4). In only these cases does the South's private information create a bargaining advantage and then the existence of TK confers a clear-cut increase in the South's share of the production surplus.

## 5.2 Implications for Integration: 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 high quality resource) because the participation constraints are type-dependent. Whether the North 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 quality genetic resource enjoys a highly profitable outside opportunity, the contract must offer South a large transfer in these circumstances, which incidentally rewards the low quality genetic resource as well in that it induces South to misrepresent the quality of resources. The low type has the incentive to misrepresent the quality of resources whenever she is ensured to cover at least the cost she incurs by lying, i.e. $\Phi(\overline{g}, \theta)$. To ensure that incentive compatibility is satisfied, the North will give her an information rent $\underline{V} = \overline{V} - \Phi(\overline{g}, \theta)$.[11]

If the South's primary informational advantage lies in its supply costs rather than in its competitive position, then the only benefit conferred by private information is

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

when the South is able to pass off some "low quality" information at "high quality" supply costs (as in case 2.2). Then the low quality genetic resources are able to appropriate some informational rent by reason of the asymmetric information. If the differential in reservation profit $V_0$ does not exceed the rent that high quality resources can earn by mimicking the low quality, then the former will undoubtedly lie. In this case, the supply of high quality genetic resources appropriates part of the bargaining surplus through her information rent whereas the low quality resources are excluded from the sharing of the bargaining surplus.[12]

If the South's informational advantage lies below the cost advantage for "high quality" resources but above that for "low quality", then the North is able to screen effectively between the two types and eliminate all information advantages (as in case 2.3). Then there is insufficient competitive advantage to cause the threat not to cooperate to be credible, and the cost differentials are sufficiently different to enable screening between them. That is, for intermediate values of $V_0$, the principal 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 complete information outcome can be implemented.

In sum, the fact that there exists private information in the quality of genetic resources may or may not alter the contractual terms offered to the South. So long as the private information does not impact the outside option in a substantial manner (as defined above in Proposition 2), the North can replicate the complete information outcome in its offered contract. Then there are no informational rents to be appropriated. 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 the South accruing to either the low quality or the high quality resources it supplies. 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.[13]

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

[13] Informational rents may contribute to their own types of inefficiencies, however, as efficiency is lost whenever the South has an incentive to misrepresent herself to capture some information rent and appropriate some of the bargaining surplus. This places the North in the situation in which he will move away from productive efficiency in order to minimise rent sharing. That is, to minimize rent-sharing, the North 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 $\overline{g}^*$.

### 5.3 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 the South, and alter the bargaining environment which determines the level of South's share in the joint venture. 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 Court's willingness to enforce the South's rights in North's markets. Weak commitment will leave her with negligible share of profits while strong commitment will allow her to enjoy a share based on the outside option this creates.

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

## 6 Conclusion

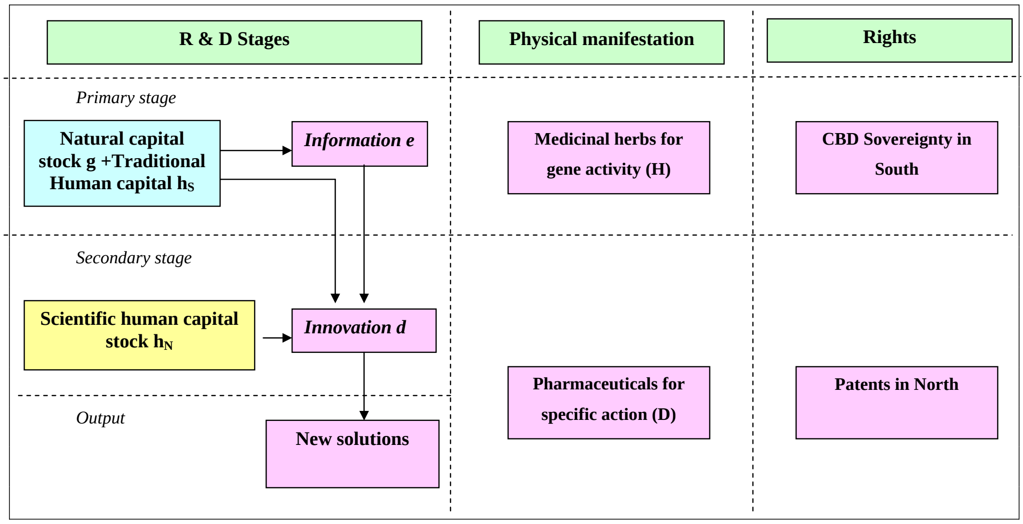
This paper has analyzed a simple model of the interaction between North and South in relation to traditional knowledge and genetic resources. We have stylised the North as rich in human capital but in need of essential genetic resources and traditional knowledge only available in the South to make innovations in the life sciences industries. We examine the impacts upon the cumulative research setting of assigning a second property right to the resources held by the 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, the creation of a second property right may be conducive to integration and therefore to efficiency in the industry. Crucial to the division of the joint profit is the allowance of an exclusive right of access to the Northern markets by the South. If the South is only allowed equal access, then it only earns a competitive return. This is complicated by the fact that the South is reliant upon the Courts of the North to enforce its independent rights of access, and the impact of these rights is wholly dependent upon the level of their enforcement.

Traditional knowledge has been assumed to act as private information on the quality of individual genetic resources. In the case of TK, the South has two possible means of generating an additional return. Either it can misrepresent the quality of some of its resources (and hence attempt to generate a supra-competitive return) or it can hope that the existence of high quality resources increases the perceived value of its outside option. Any factor that increases the value of an outside option increases the credibility of the threat to compete (rather than cooperate) and hence enhances the payoff under intergration. 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 South is probably sufficient to establish a channel whereby it is able to appropriate the value of its various types of contributions to the industry.

In general, we show that the South's capacity to share in the rents from the R&D sector to which it contributes depends on the existence of an independent right of access to the markets concerned. These independent rights (or outside options) establish the baseline upon which bargaining occurs, and create the basis on which South may demand compensation in line with its contribution. Importantly, these rights need not ever be exercised independently, they need only to exist in order for efficient cooperation to occur.

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

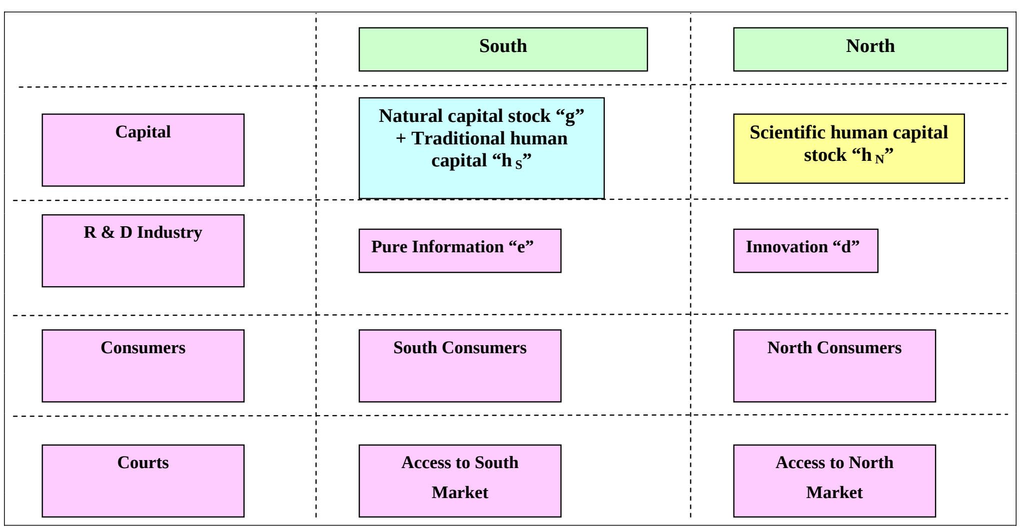



**"e" is the biological activity recognized by the South**

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

# Appendix 1: Sequential R&D

Figure 3: Structure Model




**"e" is the biological activity recognized by the South**

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

# Appendix 2: Proofs 1 and 2

**Proof 1:** In equilibrium, the participation constraint is binding. If that was not the case then the North could slightly decrease $t$, satisfy the constraint while increasing its profit. The South therefore receives the value of her reservation profit. We then obtain:

$$t^* = \Pi_S^{ni} + c_S^a(g) = q(\pi_S + \beta\pi_N - c_S) + c_S^a(g) \tag{18}$$

The first order condition plugging $t^*$ into the objective function yields the efficient solution, that is: $\frac{d\pi^i_{N+S}(g^*)}{dg} = \frac{dc_N(g^*)}{dg} + \frac{dc_S^a(g^*)}{dg}$

Moreover it is straight forward to derive the comparative statics:

$$\frac{dt^*}{dq} = \pi_S + \beta\pi_N - c_S > 0$$

$$\frac{dt^*}{d\beta\pi_N} = q > 0$$

$$\frac{dt^*}{dc_S} = -q < 0$$

$$\frac{dt^*}{dg} = \frac{dc_S^a(g^*)}{dg} > 0$$

■

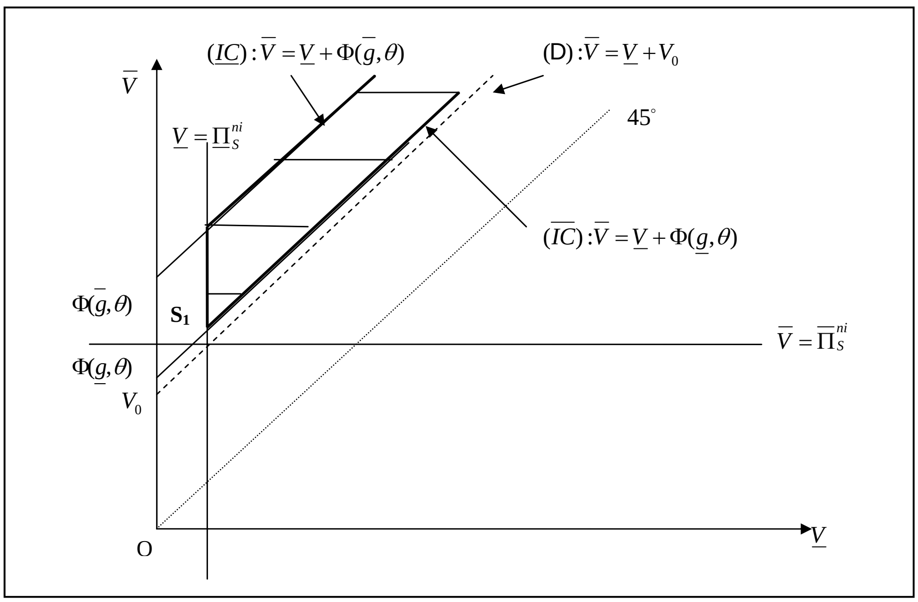
**Proof 2:** The combination of the two incentive constraints implies that $\Phi(\underline{g}, \theta) \leq \Phi(\bar{g}, \theta)$. By the Spence-Mirrless condition, $\frac{\partial \Phi}{\partial g} < 0$ and hence $\overline{g} \geq \underline{g}$ (Monotonicity condition).

Because the participation constraints are type dependent, the search for equilibrium requires to consider several cases. A diagrammatic proof will be provided. Let us first represent the four constraints (11), (12), (15), and (16) in the space $(\underline{\mathrm{V}}, \bar{V})$.

We are only interested in the region delimited by the two participation constraints and located above the 45° line. This is because the boundaries of the two incentive constraints $\bar{V} = \underline{\mathrm{V}} + \Phi(\underline{g}, \theta)$ and $\underline{\mathrm{V}} = \bar{V} - \Phi(\overline{g}, \theta)$ have positive intercepts in the space $(\underline{\mathrm{V}}, \bar{V})$. Note that $\underline{IC}$-line is always above $\overline{IC}$-line since $\Phi(\underline{g}, \theta) \leq \Phi(\bar{g}, \theta)$. Let $E\left(\underline{\Pi}_S^{ni}, \overline{\Pi}_S^{ni}\right)$ be the intersection between the two participation constraints lines and let $\mathcal{D} = \left\{(\underline{\mathrm{V}}, \bar{V}) | \, \bar{V} = \underline{\mathrm{V}} + \overline{\Pi}_S^{ni} - \underline{\Pi}_S^{ni} = \underline{\mathrm{V}} + V_0\right\}$ be the line parallel to the two incentive constraints lines passing through $E$. $\mathcal{D}$ represents the extent to which high quality type has a better outside opportunity than the low quality type. If $\overline{IC}$-line is below $\mathcal{D}$ then $\mathcal{D} \in \left\{(\underline{V}, \bar{V}) | \, \bar{V} \geq \underline{V} + \Phi(\underline{g}, \theta)\right\}$ where $\overline{IC}$ is satisfied. Similarly, when $\overline{IC}$-line is above $\mathcal{D}$ then $\mathcal{D} \in \left\{(\underline{V}, \bar{V}) | \, \bar{V} \leq \underline{V} + \Phi(\overline{g}, \theta)\right\}$, i.e. the region where $\overline{IC}$ is satisfied. Thus, the solutions to the problem depend on the relative position of $\mathcal{D}$ with respect to $\underline{IC}$-line and $\overline{IC}$-line . We consider three cases for potential solution candidates.

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

Figure 4: Case 1: $V_0 < \Phi(\underline{g}^{SB}, \theta)$




Because $\underline{IC}$-line is always above $\overline{IC}$-line (from the monotonicity condition), it follows that if $\overline{IC}$-line is above $\mathcal{D}$ then this is also true for $\underline{IC}$-line. As a result, $\mathcal{D}$ lies in the region where $\underline{IC}$ always holds whereas $\overline{IC}$ is never satisfied. In other words, the low type has incentive to tell the truth whereas the high type will misrepresent herself. Because the low type always tells the truth (i.e. $\underline{IC}$ is irrelevant), $\underline{IR}$ is binding: $\underline{V} = \underline{\Pi}_S^{ni}$. Moreover, the incentive constraint has to be satisfied for the high type to accept the contract, so $\overline{IC}$ will also be binding: $\bar{V} = \underline{V} + \Phi(\underline{g}, \theta)$.

Plugging $\bar{V}$ and $\underline{V}$ in (17) and deriving the first order conditions yields:

$$\max_{\{(\overline{g},\bar{V}),(\underline{g},\underline{\mathrm{V}})\}} \quad p\left(\pi^i_{N+S}(\overline{g}) - c_N(\overline{g}) - c^a_S(\overline{g})\right) + (1-p)\left(\pi^i_{N+S}(\underline{g}) - c_N(\underline{g}) - c^a_S(\underline{g})\right)$$
$$-[p(\underline{\mathrm{V}} + \Phi(\underline{g},\theta)) + (1-p)\underline{\Pi}^{ni}_S] \tag{19}$$

$$\frac{d\pi^i_{N+S}(\overline{g}^{SB})}{d\overline{g}} = \frac{dc_N(\overline{g}^{SB})}{d\overline{g}} + \frac{dc^a_S(\overline{g}^{SB})}{d\overline{g}} = \frac{d\pi^i_{N+S}(\overline{g}^*)}{d\overline{g}} \tag{20}$$

$$\frac{d\pi^i_{N+S}(\underline{g}^{SB})}{d\underline{g}} = \frac{dc_N(\underline{g}^{SB})}{d\underline{g}} + \frac{dc^a_S(\underline{g}^{SB})}{d\underline{g}} + \frac{p}{1-p}\Phi_{\underline{g}}(\underline{g}^{SB},\theta) > \frac{d\pi^i_{N+S}(\underline{g}^*)}{d\underline{g}} \tag{21}$$

By continuity and concavity of $\pi^i_{N+S}(.)$ 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: The North requires an optimal access to the genetic resources the high type and a sub-optimally low access to the low type. These allocations give rise to the following transfer schemes:

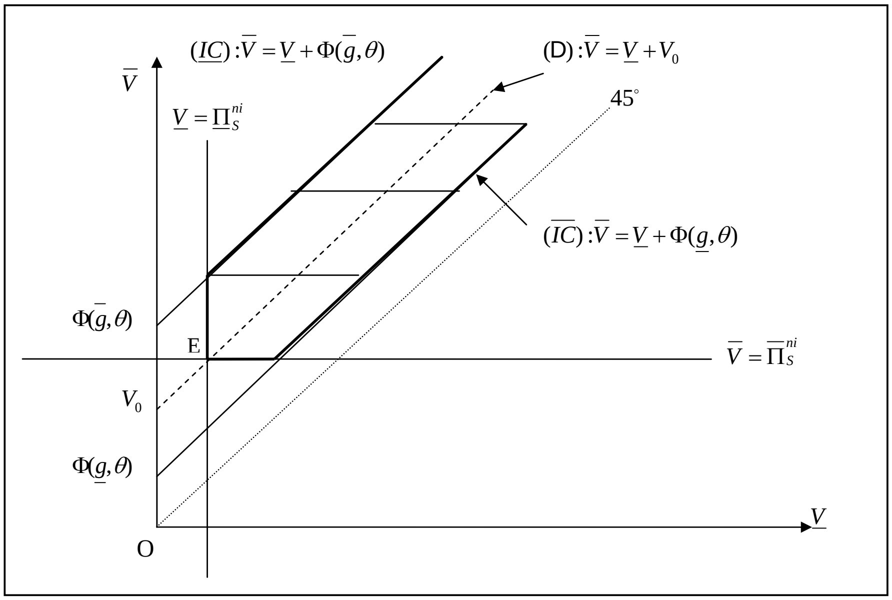
$$\overline{t}^{SB} = \overline{q}(\overline{\pi}_S + \beta\pi_N - \overline{c}_S) + c^a_S(\overline{g}^*) + \Phi(\underline{g}^{SB},\theta) > \overline{t}^* \tag{22}$$

$$\underline{t}^{SB} = \underline{q}(\underline{\pi}_S + \beta\pi_N - \underline{c}_S) + c^a_S(\underline{g}^{SB}) \tag{23}$$

From the diagram, the profit maximizing point for the North 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: $\Phi(\underline{g}^{SB},\theta) \leq V_0 \leq \Phi(\overline{g}^*,\theta)$, i.e. $\underline{IC}$-line is above $\mathcal{D}$ while $\overline{IC}$-line is below $\mathcal{D}$**

Figure 5: **Case 2:** $\Phi(\underline{g}^{SB},\theta) \leq V_0 \leq \Phi(\overline{g}^{*},\theta)$




Because $\underline{IC}$-line is above $\mathcal{D}$ and $\overline{IC}$-line is below $\mathcal{D}$, line $\mathcal{D}$ belongs to the region where both $\underline{IC}$ and $\overline{IC}$ are satisfied, i.e. the agent always tells the truth whatever her type. This implies that the North can optimally impose an equilibrium where both participation constraints are binding since the incentive constraints have become irrelevant when $\Phi(\underline{g}^{SB},\theta) < V_0 < \Phi(\overline{g}^{*},\theta)$. On the other hand, if $V_0 = \Phi(\overline{g}^{*},\theta)$ then $\overline{IR}$ and $\underline{IC}$ must be binding in the equilibrium, which implies that $\underline{IR}$ is binding as well. If $V_0 = \Phi(\underline{g}^{SB},\theta)$ then $\underline{IR}$, $\overline{IR}$ and $\overline{IC}$ are all binding.

*Case 2a:* $\Phi(\underline{g}^{SB},\theta) < V_0 < \Phi(\overline{g}^{*},\theta)$

In this case, the expected profit provided to the South is minimized at $S_2 = E\left(\underline{\Pi}_S^{ni}, \overline{\Pi}_S^{ni}\right)$ where only the two participation constraints bind. No information rent is therefore given up to any type. In this case, the North manage to achieve the complete information outcome: $\bar{V} = \overline{\Pi}_S^{ni}$ and $\underline{\mathrm{V}} = \underline{\Pi}_S^{ni}$.

Plugging $\bar{V}$ and $\underline{\mathrm{V}}$ in (17) and deriving the first order conditions yields:

$$\max_{\{(\overline{g},\bar{V}),(\underline{g},\underline{V})\}} \quad p\left(\pi^i_{N+S}(\overline{g})-c_N(\overline{g})-c^a_S(\overline{g})\right)+(1-p)\left(\pi^i_{N+S}(\underline{g})-c_N(\underline{g})-c^a_S(\underline{g})\right)$$
$$-[p\overline{\Pi}^{ni}_S+(1-p)\underline{\Pi}^{ni}_S] \tag{24}$$

$$\frac{d\pi^i_{N+S}(\overline{g}^{SB})}{d\overline{g}}=\frac{dc_N(\overline{g}^{SB})}{d\overline{g}}+\frac{dc^a_S(\overline{g}^{SB})}{d\overline{g}}=\frac{d\pi^i_{N+S}(\overline{g}^{*})}{d\overline{g}} \tag{25}$$

$$\frac{d\pi^i_{N+S}(\underline{g}^{SB})}{d\underline{g}}=\frac{dc_N(\underline{g}^{SB})}{d\underline{g}}+\frac{dc^a_S(\underline{g}^{SB})}{d\underline{g}}=\frac{d\pi^i_{N+S}(\underline{g}^{*})}{d\underline{g}} \tag{26}$$

By continuity of $\pi^i_{N+S}(.)$ it follows that: $\overline{g}^{SB}=\overline{g}^*$, $\underline{g}^{SB}=\underline{g}^*$, and monotonicity ensures that $\underline{g}^*<\overline{g}^*$. Allocative efficiency is reached for both types: The North 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:

$$\overline{t}^{SB}=\overline{q}(\overline{\pi}_S+\beta\pi_N-\overline{c}_S)-\overline{c}_S+c^a_S(\overline{g}^*)=\overline{t}^* \tag{27}$$

$$\underline{t}^{SB}=\underline{q}(\underline{\pi}_S+\beta\pi_N-\underline{c}_S)+c^a_S(\underline{g}^{SB})=\underline{t}^* \tag{28}$$

*Case 2b:* $V_0=\Phi(\overline{g}^*,\theta)$

In this case, the expected profit provided to the South is minimized at $S_2=E\left(\underline{\Pi}^{ni}_S,\overline{\Pi}^{ni}_S\right)$ where the two participation constraints as well as the low type incentive constraint are binding: $\bar{V}=\overline{\Pi}^{ni}_S$, $\underline{V}=\underline{\Pi}^{ni}_S$ and $\overline{V}=\underline{\Pi}^{ni}_S+\Phi(\overline{g}^*,\theta)$. In this case, the North again achieves the first best outcome.

Plugging $\bar{V}$ and $\underline{V}$ in (17) yields:

$$\max_{\{(\overline{g},\bar{V}),(\underline{g},\underline{V})\}} \quad p\left(\pi^i_{N+S}(\overline{g})-c_N(\overline{g})-c^a_S(\overline{g})\right)+(1-p)\left(\pi^i_{N+S}(\underline{g})-c_N(\underline{g})-c^a_S(\underline{g})\right)$$
$$-[p\overline{\Pi}^{ni}_S+(1-p)\underline{\Pi}^{ni}_S] \tag{29}$$

The solution to this problem is identical to the one solved in case 2a and will therefore yield the same optimal contracts.

*Case 2c:* $V_0=\Phi(\underline{g}^{SB},\theta)$

In this case, the expected profit provided to the South is minimized at $S_2 = E\left(\underline{\Pi}_S^{ni}, \overline{\Pi}_S^{ni}\right)$ where the two participation constraints as well as the high type incentive constraint are binding: $\bar{V} = \overline{\Pi}_S^{ni}$, $\underline{\mathrm{V}} = \underline{\Pi}_S^{ni}$ and $\overline{V} = \underline{\Pi}_S^{ni} + \Phi(\underline{g}^{SB}, \theta)$. In this case, the North manage to achieve the first best outcome.

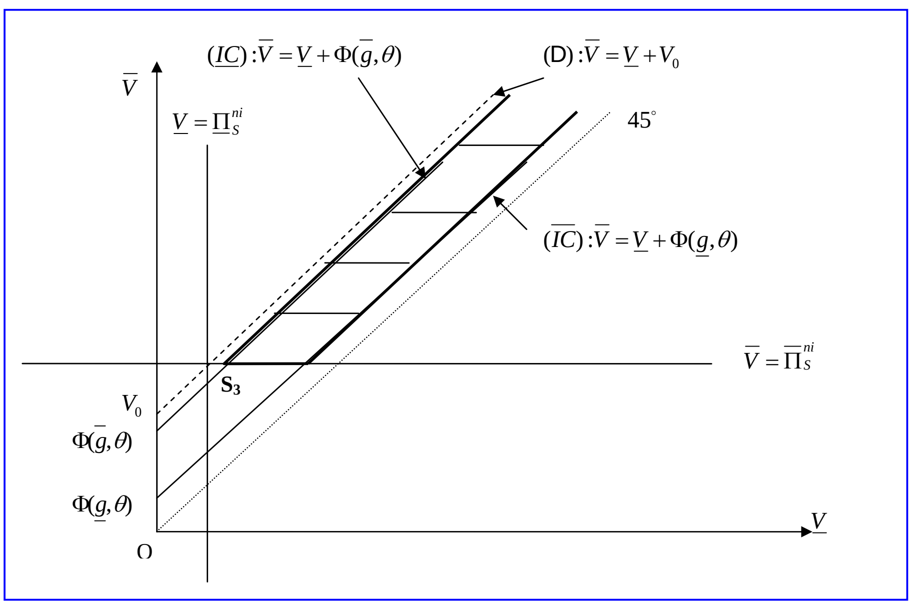
Plugging $\bar{V}$ and $\underline{\mathrm{V}}$ in (17) yields:

$$\max_{\{(\overline{g},\bar{V}),(\underline{g},\underline{\mathrm{V}})\}} \quad p\left(\pi_{N+S}^{i}(\overline{g}) - c_N(\overline{g}) - c_S^a(\overline{g})\right) + (1-p)\left(\pi_{N+S}^{i}(\underline{g}) - c_N(\underline{g}) - c_S^a(\underline{g})\right) - [p\overline{\Pi}_S^{ni} + (1-p)\underline{\Pi}_S^{ni}] \tag{30}$$

The solution to this problem is identical to the one solved in case 2a and 2b and will therefore yield the same optimal contracts.

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

Figure 6: **Case 3:** $V_0 > \Phi(\overline{g}^*, \theta)$




First note that $\mathcal{D}$ belongs to the region where $\underline{IC}$ does not hold since it lies above $\underline{IC}$-line. In other words, in this region the low type has incentive to misrepresent her true type. Indeed, $V_0$ is now so large that the low quality type is now attracted by the contract offered to the high type. In addition, the high type will always truthfully reveal herself since $\mathcal{D}$ belongs to the region where $\overline{IC}$ holds[14]. As a consequence the solution in this case is to make $\overline{IR}$ and $\underline{IC}$ binding: $\overline{V} = \overline{\Pi}_S^{ni}$ and $\underline{V} = \overline{\Pi}_S^{ni} - \Phi(\overline{g}, \theta)$ . From a graphical point of view it is immediate that the optimal point that maximizes the North 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 (17) and deriving the first order conditions yields:

$$\max_{\{(\overline{g},\bar{V}),(\underline{g},\underline{\mathrm{V}})\}} \; p\left(\pi^i_{N+S}(\overline{g}) - c_N(\overline{g}) - c^a_S(\overline{g})\right) + (1-p)\left(\pi^i_{N+S}(\underline{g}) - c_N(\underline{g}) - c^a_S(\underline{g})\right) - \left(p\overline{\Pi}_S^{ni} + (1-p)\left(\overline{\Pi}_S^{ni} - \Phi(\overline{g},\theta)\right)\right) \tag{31}$$

$$\frac{d\pi^i_{N+S}(\overline{g}^{CI})}{d\overline{g}} = \frac{dc_N(\overline{g}^{CI})}{d\overline{g}} + \frac{dc^a_S(\overline{g}^{CI})}{d\overline{g}} - \frac{1-p}{p}\Phi_{\overline{g}}(\overline{g}^{CI},\theta) < \frac{d\pi^i_{N+S}(\overline{g}^{*})}{d\overline{g}} \tag{32}$$

$$\frac{d\pi^i_{N+S}(\underline{g}^{CI})}{d\underline{g}} = \frac{dc_N(\underline{g}^{CI})}{d\underline{g}} + \frac{dc^a_S(\underline{g}^{CI})}{d\underline{g}} = \frac{d\pi^i_{N+S}(\underline{g}^{*})}{d\underline{g}} \tag{33}$$

By continuity and concavity of $\pi^i_{N+S}(.)$ 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 a sub-optimally high access to her resources. These allocations give rise to the following transfer schemes:

$$\overline{t}^{CI} = \overline{q}(\overline{\pi}_S + \beta\pi_N - \overline{c}_S) + c^a_S(\overline{g}^{CI}) > \overline{t}^* \tag{34}$$

$$\underline{t}^{CI} = \overline{q}(\overline{\pi}_S + \beta\pi_N - \overline{c}_S) + c^a_S(\underline{g}^{CI}) - \Phi(\overline{g}^{CI},\theta) \tag{35}$$

■

[14] This is because $\mathcal{D}$ is above $\overline{IC}$-line (as $\underline{IC}$-line is above $\overline{IC}$-line)

# References


[1] Chang H. (1995): *Patent Scope, Antitrust Policy, and Cumulative Innovation*, The RAND Journal of Economics, 26: 34-57.

[2] Craft, A. B., and R. D. Simpson (2001): *The Social Value of Biodiversity in New Pharmaceutical Product Research*. Environmental and Resource Economics, 18: 1-17.

[3] Eswaran M. and N. Gallini (1996): *Patent Policy and the Direction of Technological Change*, The RAND Journal of Economics, 27: 722-746.

[4] ETC Group (2004): *Communiqué*, Issue 85 January/February

[5] Evenson, R. (1995): *The Valuation of Crop Genetic Resource Preservation, Conservation and Use*. Paper prepared for the Commission on Plant Genetic Resources, Rome.

[6] Evenson, R., D. Gollin, and V. Santaniello (eds) 1998: *Agricultural Values of Genetic Resources*. CABI: London.

[7] Gallini N. and S. Scotchmer (2002): *Intellectual Property: When is it the Best Incentive System?*, in Jaffe A. et al. Eds., Innovation Policy and the Economy, MIT Press, 51-78.

[8] Gatti R., T. Goeschl, B. Groom and T. Swanson (2006): *The Biodiversity Bargaining Problem*, Working Paper.

[9] Gehl Sampath P. (2005): *Regulating Bio-prospecting: Institutions for Drug Research, Access and Benefit-Sharing*, United Nations University Press.

[10] Goeschl, T. and T. Swanson (2002a): *The social value of biodiversity for R&D*. Environmental and Resource Economics, 22: 477-504.

[11] Goeschl T. and T. Swanson (2002b): *The Economics of R&D within the Biological Sector and its Optimal Management*, World Bank Working Paper.

[12] Green J. and S. Scotchmer (1995): *On the Division of Profit in Sequential Innovation*, The RAND Journal of Economics, 26: 20-33.

[13] Jullien B. (2000): *Participation Constraints in Adverse Selection Models*, Journal of Economic Theory, 93: 1-47.

[14] Laffont J.J. and D. Martimort (2002): *The Theory of Incentives: The Principal-Agent Model*. Princeton University Press.

[15] LEGROS P. AND A. NEWMAN (2002): *Courts, Contracts, and Interference.* European Economic Review, 46: 734-744.

[16] RAUSSER, G.C. AND A. SMALL (2000): *Valuing research leads: bioprospecting and the conservation of genetic resources.* Journal of Political Economy, 108(1): 173-206.

[17] RODRIGUEZ-STEVENSON G. (2000): *Trade Secrets: The Secret to Protecting Indigenous Ethnobiological (Medicinal) Knowledge*, Journal of International Law and Politics, 32: 1119-1174.

[18] ROHT-ARRIAZA N. (1996): *On Seeds and Shamans: The Appropriation of the Scientific and Technical Knowledge of Indiginous and Local Communities*, Michigan Journal of International Law, 17:919-965.

[19] SCOTCHMER S. AND J. GREEN (1990): *Novelty and Disclosure in Patent Law*, The RAND Journal of Economics, 21: 131-146.

[20] SCOTCHMER S. (1991): *Standing on the Shoulders of Giants: Cumulative Research and the Patent Law*, The Journal of Economic Perspective, 5: 29-41.

[21] SCOTCHMER S. (1996): *Protecting Early innovators: Should Second-Generation Products be Patentable?*, The RAND Journal of Economics, 27: 322-331.

[22] SIMPSON D. AND A. CRAFT (1996): *The Social Value of Using Biodiversity in New Pharmaceutical Product Research.* Discussion Paper 96-33. Washington D.C.: Resources for the Future.

[23] SIMPSON, D., R. SEDJO AND J. REID (1996): *Valuing biodiversity for use in pharmaceutical research.* Journal of Political Economy, 104(1): 163-185.

[24] SWANSON T. (1995): *The Appropriation of Evolution's Values* in Ed. Swanson "Intellectual Property Rights and Biodiversity Conservation", Cambridge University Press.

[25] VIEILLEFOSSE A. (2003): *Dissertation MSc. Environmental and Resource Economics*, University College London.

[26] WEITZMAN, M. (1998): *The Noah's ark problem.* Econometrica, 66(6): 1279-1298.