FONDAZIONE ENI ENRICO MATTEI

NOTA DI LAVORO

79.2011

Intellectual Property and Biodiversity: When and Where are Property Rights Important?

By **Mare Sarr**, School of Economics, University of Cape Town, South Africa

Tim Swanson, Department of Economics, Graduate Institute of International and Development Studies, Switzerland

Climate Change and Sustainable Development Series
Editor: Carlo Carraro

Intellectual Property and Biodiversity: When and Where are Property Rights Important?

By Mare Sarr, School of Economics, University of Cape Town, South Africa
Tim Swanson, Department of Economics, Graduate Institute of International and Development Studies, Switzerland

Summary
An important issue in the life sciences industries concerns the nature of the incentive mechanism that should govern the production of innovation within this R&D sector. We look at the specific problem of coordinating the supply of inputs across very different agents - North and South - that must each supply inputs in order to generate innovations from the industry. The current arrangement in this industry provides for a single property right at "end of the pipeline", i.e. where marketing of the innovation occurs. This property rights scenario raises two problems, one of efficiency and one of equity. The key question asked here pertains to the number and placement of property rights that should be instituted to address this property rights failure. Should one establish new property rights in traditional knowledge alone; property rights in genetic information alone; or in both? We demonstrate that in a world in which traditional knowledge and genetic information are complements in the production of R&D, a resolution of the property rights failure in genetic information also may resolve the allocation failure in traditional knowledge even in the absence of a distinct property right. The reason is that traditional knowledge of the nature of private information is comparable to a trade secret. Traditional knowledge holders may use this informational advantage to improve their benefit by capturing some informational rent. A new property right is important to enable bargaining and coordination to occur across the industry, but a single property right is probably sufficient to enable coordination between the two agents.

Keywords: Biodiversity Prospecting, Traditional Knowledge, Genetic Resources, Intellectual Property Rights, Sequential R&D

JEL Classification: Q56, O34, L24

We thank Erwin Bulte, Jing-Yuan Chiou, Tom Dedeurwaerdere, Christine Frison, Timo Goeschl and Jidong Zhou, 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 and ERSA (Economic Research Southern Africa).

Address for correspondence:

Tim Swanson
Department of Economics
Graduate Institute of International and Development Studies
Case Postale 136
1211 Geneva 21
Switzerland
E-mail: tim.swanson@graduateinstitute.ch

Intellectual Property and Biodiversity: when and where are property rights important?*

Mare Sarr† Tim Swanson‡

Abstract

An important issue in the life sciences industries concerns the nature of the incentive mechanism that should govern the production of innovation within this R&D sector. We look at the specific problem of coordinating the supply of inputs across very different agents—North and South—that must each supply inputs in order to generate innovations from the industry. The current arrangement in this industry provides for a single property right at "end of the pipeline", i.e. where marketing of the innovation occurs. This property rights scenario raises two problems, one of efficiency and one of equity. The key question asked here pertains to the number and placement of property rights that should be instituted to address this property rights failure. Should one establish new property rights in traditional knowledge alone; property rights in genetic information alone; or in both? We demonstrate that in a world in which traditional knowledge and genetic information are complements in the production of R&D, a resolution of the property rights failure in genetic information also may resolve the allocation failure in traditional knowledge even in the absence of a distinct property right. The reason is that traditional knowledge of the nature of private information is comparable to a trade secret. Traditional knowledge holders may use this informational advantage to improve their benefit by capturing some informational rent. A new property right is important to enable bargaining and coordination to occur across the industry, but a single property right is probably sufficient to enable coordination between the two agents.

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

JEL Classification: Q56; O34; L24

---

*We thank Erwin Bulte, Jing-Yuan Chiou, Tom Dedeurwaerdere, Christine Frison, Timo Goeschl and Jidong Zhou, 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 and ERSA (Economic Research Southern Africa).

†School of Economics, University of Cape Town, Private Bag, Rondebosch 7701, South Africa. Email: mare.sarr@uct.ac.za

‡Department of Economics, Graduate Institute of International and Development Studies, Case Postale 136, 1211 Geneva 21, Switzerland. Email: tim.swanson@graduateinstitute.ch

"We don't want to forbid companies from using our genetic resources or traditional knowledge—but they have to reward the indigenous people fairly", Andrés Valladolid (Peruvian National Commission Against Biopiracy).

1 Introduction

The life sciences industries provide an interesting example of the need for global cooperation in the management of an important natural resource, i.e. biodiversity. For biodiversity to provide continuing inputs into human welfare requires cooperation between the life sciences firms developing marketable products in countries with large markets for pharmaceuticals—the North—and the firms/communities in countries hosting the genetic resources and/or traditional knowledge where the information is found—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 from a primary producer through a secondary R&D sector in order to then become commercial products capable of addressing consumer needs.

We have examined the need for global cooperation in the management of biodiversity elsewhere. (Gatti *et al.* 2011) In this paper, we examine the manner in which private industry could be an important part of the process by which such cooperation might be engendered. The flows of value that should reach the providers of important inputs can be as readily channelled by private firms as by public entities, if an appropriate property right structure is put into place. The need for public sector involvement generally flows from a private property right failure, if one such exists.

There is a lot of evidence that property right failures do inhere in this industry. The bitter and lengthy disputes over derivatives of the Neem tree and maca extracts are illustrative of this situation. In the infamous Neem tree cases (Shiva 1996; Bullard 2005), a coalition of NGOs has challenged the patents held by US firm W.R. Grace both in the US Patent Office (US PTO) and the European Patent Office (EPO) invoking lack of novelty. The inventions, it is alleged, were simply extensions of traditional processes used for millennia for making neem-based products in India.[1] Recently, the Peruvian National Commission Against Biopiracy (supported by local firms and civil society organizations) has successfully challenged patents in the Japanese Patent Office and in France for products largely based on Andean traditional knowledge. It is also preparing a legal challenge in US courts against the patent granted to the New Jersey company PureWorld Botanicals for exclusive commercial distribution of an extract of maca's active libido-enhancing compounds (Vecchio, 2007).[2]

[1] W.R. Grace & Co was awarded a patent by the US PTO for its method of stabilising azadirachtin in solution and the stabilised solution itself—Azadirachtin is the active chemical compound contained in the neem tree. W.R. Grace & Co was also granted another patent by the EPO for a method for controlling fungi on plants also derived from the neem tree. While the former patent was upheld by the US PTO, the latter was eventually revoked by the EPO in 2005 (Bullard 2005).

[2] Maca is a tuberous root used by the Andean people for centuries as a food crop and medicinal plant to enhance sexual performance and fertility in humans and livestock.

The reason that these disputes exist is that property rights in genetic resources and traditional knowledge are ill-defined in the North. 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 protection. The failure to protect these contributions then results in a lack of investment in genetic diversity and traditional human capital, and in inefficient flow of information across the sector.[3] This sub-optimal situation may lead to a permanent loss of both genetic diversity and traditional knowledge and therefore a loss of valuable source of improvement of human health.[4] Therefore the challenge for North and South is to coordinate their legal systems in a way that allows the South to be properly compensated for investing in genetic diversity and the associated human capital, and in supplying genetic material. In the absence of such coordination, bitter and costly legal disputes and underinvestment in essential inputs are likely to persist.

We decompose the production function for innovations in this industry into a three-part affair, involving the South's genetic resources and traditional knowledge as well as the North's technology. We further propose a clear delineation between genetic resources and traditional knowledge. We define genetic resources to be the "library of evolutionary information" that is to be found in host countries of the South (Sarr *et al.* 2008). We define traditional knowledge to be the "search services" provided that narrow the extent of the library that must be searched in order to identify a solution concept to a particular type of problem. Therefore, traditional knowledge is treated as a form of information (flowing from traditional forms of human capital) held by the South that allows the North to truncate the search for new leads, i.e. to search over a smaller quantity of genetic resources. This bifurcation between the value of the base information and the value of a directed search over it has been indicated throughout the literature (Rausser and Small, 2000; Costello and Ward, 2006).

Our purpose in this paper is to analyse North/South interaction in the context of this non-integrated industry, as they bargain over the use of these three inputs. In particular, our aim is to determine the number and placement of property rights necessary within this industry to induce an efficient flow of information. What more is needed to get efficient contracting to occur within this industry? Should these rights solely protect traditional knowledge, or should they protect the genetic resource-based information alone, or both?

In Sarr and Swanson (forthcoming), we show that protecting genetic information alone creates the basis for efficient contracting in many cases. But, when traditional knowledge is present as a trade secret, i.e. as the South's private information, efficiency arises under certain conditions only. In particular, when the North

[3] The importance of giving first innovators enough incentive to invest and innovate is particularly emphasized by Green and Scotchmer (1995) and Scotchmer (1996) because no inventions or discovery would be possible without their contribution.

[4] 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 inhere.

proposes the contract (screening case), the emergence of an efficient outcome depends on the magnitude of the South's outside option afforded by the existence of an enforceable property right in the genetic resources. Conversely, when the South proposes an *ex ante* contract—i.e. before learning her private information—efficiency emerges as she is the residual claimant of the cooperative surplus and has therefore the proper incentive for efficient information trade with the North (signalling case). Efficiency in this case hinges upon the assumption of risk neutrality and the possibility for the South to offer an *ex ante* contract.

This paper is structured as follows. Section 2 presents the set-up of the model. Section 3 analyzes the contracting outcome when genetic information is protected by property rights in the absence of traditional knowledge. In section 4, we investigate how the contractual terms change as we introduce traditional knowledge as the South's private information. Finally section 5 concludes the analysis.

2 The Model

This model builds upon the structure set out in Gatti *et al.* (2011). There, the authors set out the basic structure of an industry spread out across two very different parts of the world (termed North and South). These different parts of the world were distinct from one another in several important respects: endowments, industries and institutions. With regard to endowments, the South was heavily endowed with natural capital, and the North with technology (human capital). With regard to industries, the South was endowed with traditional information and industries, while the North was endowed with R&D. With regard to institutions, each sector had its own system of property rights and courts to define and determine them. We examined in that paper the manner in which cooperation and conflict might determine outcomes at the level of global bargaining between the regions.

In this paper, we wish to examine cooperation and conflict at a more micro level. We wish to look at how the industries within these different regions (still termed North and South) might be able to achieve cooperation across this non-integrated industry. We also want to understand how the courts and property right systems act to determine how and whether the cooperative outcome is achieved, and the nature of that outcome.

2.1 Stylised Facts

As in Gatti *et al.* (2011), 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 in genetic resources and accumulated human capital. In a vertically integrated industry, this information would then be channelled to firms in the North F_N where they would combine it with northern technology and marketing to place pharmaceuticals on the market 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 (or traditional knowledge) 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 intellectual property right protection (IPR). This industry is depicted in Figure 2 and Figure 3.

The basic elements of the model are outlined here:

Two Agents. North (N) and South (S) refer to two distinct regions comprised of: (i) distinct firms F_N and F_S; and (ii) distinct markets protected by 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.

Distinct Inputs within a Vertical Industry. 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.

Distinct Products provided to Separate Markets. North and South have distinct markets for medicinal products. This results from the control of access to the consumers in each region by the courts there, by reason of the enforcement of property right systems that exist in each region. 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. Firms that identify genetic resources g and traditional knowledge have recognised property rights in the South. Likewise, the drug d developed by F_N in the North has a recognised property right 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. Court systems exist in each region (Ct_S and Ct_N) for enforcement of property rights. From previous rulings, the agents attempting to cooperate will have some common knowledge about both the likelihood of a court system protecting a given property right claim, and the consequences that flow from the court doing so (see section 3 below).

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 h)	• Technology Rich: drug development d
Separate Markets	• Herbal medicines • F_S has property right in g and TK • Ct_S decides enforcement of rights in g and TK	• Pharmaceuticals d • F_N has property right in d • Ct_N decides on enforcement of rights in d, g and TK

2.2 Cooperation and Conflict within a non-integrated Industry

We assume that F_N and F_S are two risk neutral agents that bargain over the use of their combined inputs (genetic resources g and traditional knowledge h from the South and technology from the North) in order to generate useful pharmaceutical products for marketing in the North. We wish to examine the anticipated results from contracting under various assumptions regarding the property right and informational structure within the industry. To do so, we first outline the anticipated outcomes from various bargaining processes, given the potential outcomes of cooperation and conflict within the industry.

Assume first that F_N offers F_S a contract to be granted access to g and h_S in return for a transfer payment t. If successful negotiation is achieved, then F_N can use a subset of genetic information (g_N) and traditional knowledge applied (h_S) to develop a patentable product.

In the *cooperative* outcome then, the two parties receive the following payoffs:

$$\Pi_S^c(g_N, h_S) = t - c_S^a(g_N, h_S) \tag{1}$$

$$\Pi_N^c(g_N, h_S) = \pi_N(g_N, h_S) - c_N(g_N, h_S) - t \tag{2}$$

where π_S and π_N are increasing and concave in their respective arguments; c_S^a and c_N are respectively F_S's access or supply cost of inputs and F_N's development cost. While c_S^a is increasing and convex in all arguments, c_N is increasing and convex in g_N but decreasing in h_S. Traditional knowledge has the effect of lowering drug development costs for example by allowing F_N to increase its chance of finding new leads and developing successful new drugs (Costello and Ward 2006).

Now we turn to the chain of events that will ensue in the event that cooperation is not achieved. If no agreement is reached, F_S considers placing her herbal medicines directly onto the market in the North. The problem with this is that (in absence of complete and certain protection of the embedded information) the marketing by F_S will release some or all of the information it has produced. In response to such marketing (and by use of the released information), F_N is able to develop a new drug built using the information contained in the herbal medicine. If F_N does not invest in development, F_S receives a profit of $\pi_S(g_S, h_S) - c_S(g_S, h_S)$—where $c_S(g_S, h_S)$ 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 or not it has infringed F_S's right to its information. In this case a cooperative outcome is achieved (out of conflict) by reason of court's decision regarding the respective property rights of the parties.

In the situation where the court becomes involved in the matter, there are three possible outcomes. First, the court in the North may find that the firm from the South holds no property rights in the underlying innovation, in which case the firm from the South receives no compensation. Secondly, the court may find that such rights exist but that no infringement of those rights has occurred, with the same result. Finally, the court may find that the product released by F_N infringes the rights of F_S. Only in this last case is an *ex post* license for the sale of the drug required.

We will assume that a finding of infringement results in a situation where F_S will share in the net revenues received in the marketing of the competing drug marketed by F_N. We further assume that the share of profits appropriated by the Southern firm is a known parameter β, determined by reference to earlier court judgements regarding intellectual property infringement case law. We will also assume that both parties apply a commonly perceived likelihood (ξ) of a finding of infringement.

If F_N is not found to have infringed the rights of F_S then the drug created by F_N is independently 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 $\pi_S^c(g_S, h_S) - c_S(g_S, h_S)$ and $\pi_N^c(g_N, h_S) - c_N(g_N, h_S)$. 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).[5]

Therefore, the *non-cooperative* expected payoffs can be stated to be:

$$\Pi_S^{nc} = \xi\left[\pi_S(\hat{g}_S, \hat{h}_S) + \beta\pi_N(\hat{g}_N, \hat{h}_S)\right] + (1-\xi)\pi_S^c(\hat{g}_S, \hat{h}_S) - c_S(\hat{g}_S, \hat{h}_S) \tag{3}$$

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

[5]The maca case is a good illustration. Local producers sell maca concoction on the local market and export a wide range of maca-based products—from powders and pills to jams and candies—to Japan, the United States, Germany, Belgium and Canada (Vecchio, 2007). The production of these products are based on traditional knowledge. The maca derivatives developed and patented by the US firm PureWorld rely heavily on Andean traditional knowledge without acknowledging nor compensating the contribution of the TK holders.

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

In summary, the sequence of decisions, taking the industry through the options regarding cooperation and conflict, may be set out as follows:

1. F_S devotes resources to invest in TK h_S and to find genetic materials (e.g. medicinal plants) g containing useful information resulting in herbal medicine H.
2. F_N offers F_S a transfer payment t to grant her access to biological resources and TK used in the production of H.
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 and h_S.
5. If a drug is marketed by F_N, the Court in the North decides whether F_S's exclusive right has been violated.

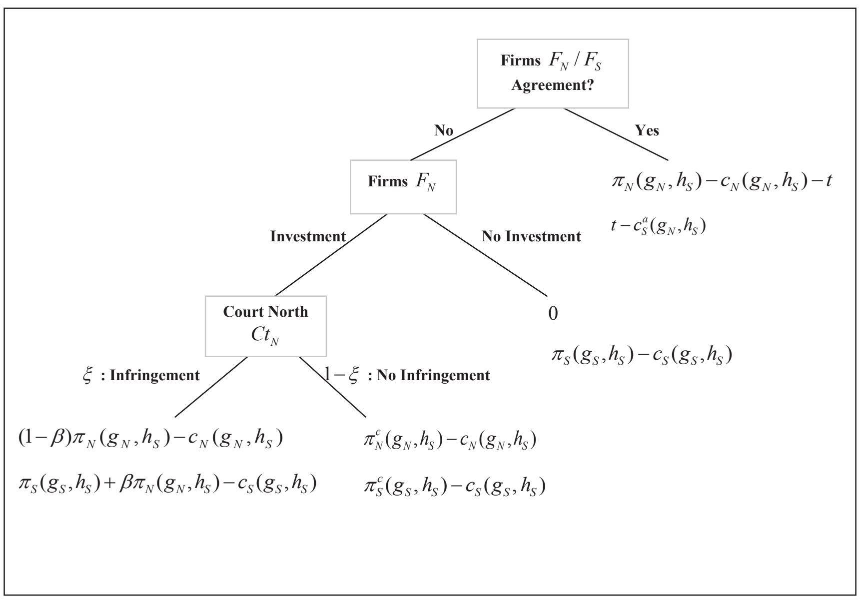


Figure 1: Decision tree

In short, we are using this sequential process to describe the parameters relevant to the industries choice between conflict and cooperation, and how these parameters will determine a) whether coordination is achieved within the industry; and b) the distribution of rents that occurs under that cooperative solution. In our view, the industry should be able to achieve cooperation from the outset, and to generate a single innovation (d) that is placed onto the market in the North, without competition from any other product containing that innovation. The importance of the alternative outcomes lies in their determination of the distribution of rents that results in the cooperative outcome.

Hence, if terms are not agreed via cooperation, then the industry is able to place competing innovations onto the market, and the courts will determine the outcome of this competition. The game structure above sets out all of the various possible outcomes that flow from this competition. And the initial contractual terms and the distribution of benefits achieved, will depend upon how the parties view this entire process, the conflictual outcomes and the prospect of various court findings.

We now turn to examine how compensation for the South's various inputs (g and TK) will be determined within this process.

3 Compensation in a non-integrated Vertical Industry

The issue of compensation within vertical industries has been examined extensively within the economics literature (See Lafontaine and Slade, 2007 for a complete literature survey). The issues addressed in this literature concern the compensation received at the various levels of the vertical industry, depending upon the importance of incentivising inputs supplied at each level (Lafontaine and Slade 2001), the importance of a property rights structure (Grossman and Hart 1986), the transactions costs of remaining non-integrated (Williamson 1985) and the costs of non-coordination. All of these issues are of course very important in the context of the industry we are considering, and we will therefore look at the problem of structure within a range of contexts.

Initially we are going to consider the industry in its most simplistic format: it will consist of two players, with only a single property right inhering in the product at the end of the industry (see diagram in Appendix A.1). There will be no problems of information - and so no incentivising constraints. The agent at the end of the industry (Firm F_N) will be able to sell the final product to consumers on account of this property right, and it is able to secure the required inputs from the earlier stages of the industry (Firm F_S) if it has the participation of that agent.

We argue that if there is full information and F_N has the capacity to shape the terms of the contract—because of its situation at the end of the vertical industry and its proximity to market—the bargaining problem degenerates into a standard principal/agent problem where the agent F_S has a weak bargaining position. The Management Science literature provides rationale for the use of the standard principal/agent framework. This literature has explored the division of labour and profits in a vertical industry with cumulative innovations involving large pharmaceutical firms specialised in developing and marketing new products and smaller biotech firms specialised in basic research. In this context, Lerner and Merges (1998) provide anecdotal evidence of cases where large pharmaceutical firms (such as Ciba-Geigy) exploited their stronger bargaining power to negotiate contracts that gave them almost "total control over" smaller biotech partners (e.g. ALZA Corporation). Rothaermel (2001) also provides ample evidence suggesting that pharmaceutical firms are in a "strong bargaining position—due to their specialized downstream assets"—relative to biotech firms they contract with. Furthermore, Kinukawa and Motohashi (2010) shows that "pharmaceutical firms tend to extract more surplus than their biotech suppliers, in that the contract prices of biotechnologies have been lower than their market value due to the stronger bargaining power of the former".

3.1 Contracting genetic resources in the absence of traditional knowledge: Case of Symmetric information

We have described the situation in which the Firm F_N is a monopsonist in a vertical industry, a problem first analysed by Martin Perry (1978). Perry examined the incentives for vertical integration, whereas we are considering the contracting process between the monopsonist and its suppliers within a vertical industry. In this situation the question to be examined is how the payment from the monopsonist to the supplier is determined. We consider the case where the supplier has the option of integrating forward into the monopsonist's market in order to offer its inputs directly to consumers in direct competition with the final product d.

In this section, we are assuming that F_S has a potentially enforceable property right in g but that F_N is a monopsonist purchaser of that input and the holder of enforceable property rights in d. In this situation, we believe that the monopsonist purchaser has the power to announce the terms of the contract on offer. This is because any offer made by the supplier is simply revealing her information.[6] The objective of F_N then is to offer the minimum required payment to F_S in order to acquire her participation in the supply of inputs g for the production of d. Note that we also make the assumption that traditional knowledge is absent so that h_S will not feature in the payoff functions.

Therefore, in this context, F_N proposes to F_S a contract (g_N, t)—access to F_S's genetic resources in return for a transfer payment t—that maximises his own profit subject to F_S's participation constraint, that is:

$$\begin{aligned} \max_{g_N, t} \quad & \pi_N(g_N) - c_N(g_N) - t \\ \text{s.t.} \quad & t - c_S^a(g_N) \geq \Pi_S^{nc} \end{aligned}$$

Proposition 1: *Suppose firm F_N offers a take-it or leave-it contract accepted by firm F_S:*

[6] Although we are commencing our analysis with the symmetric information case, the presence of private information will turn out to be important in this analysis, and so there is no incentive for the supplier to announce potential contract terms, and so volunteer information to the monopsonist.

1) If F_S's genetic information is granted property rights protection, then F_N offers an efficient contract (g_N^*, t^*) defined as in (6) and (7).

2) The equilibrium payment t^* increases in the likelihood that the court finds firm F_N to infringe firm F_S's property right.

Proof 1: In the equilibrium, F_N will set t to make the participation constraint 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. The problem becomes:

$$\max_{g_N} \pi_N(g_N) - c_N(g_N) - c_S^a(g_N) - \Pi_S^{nc} \tag{5}$$

The first order condition yields the efficient solution where

$$\frac{d\pi_N}{dg_N}(g_N^*) = \frac{dc_N}{dg_N}(g_N^*) + \frac{dc_S^a}{dg_N}(g_N^*) \tag{6}$$

The transfer payment is then given by:

$$t^* = \Pi_S^{nc} + c_S^a(g_N^*) \tag{7}$$

Moreover it is straight forward to derive the following comparative static:
$\frac{dt^*}{d\xi} = \pi_S(\hat{g}_S) + \beta\pi_N(\hat{g}_N) - \pi_S^c(\hat{g}_S) > 0$■.

3.2 Discussion

The compensation problem here devolves to the outcome characterized by equations (6) and (7). Given our assumption that F_N has the capacity to frame this contract (on account of its property right in the final product d) the creation of a property right in genetic resources g addresses the distributional issues only to a very small extent. The maximum share received by F_S in this framework is obtained when the probability of a finding of infringement by northern courts is equal to 1, that is $\xi = 1$. The courts in the North play an important role in the determination of the magnitude of the transfer in making these decisions regarding infringement.[7] F_S is compensated for its costs of supplying genetic resources in addition to its outside option which reflects the

[7]This is indicative of the meaning of the present legal disputes between North and South in the courts of the North. To the extent that northern courts disallow the conferment of exclusive marketing rights to firms of the North in drugs relying upon genetic resources from the South, they are implicitly recognising the exclusive rights to genetic resources in the South.

expected value of any products that might be marketed in competition with F_N. When the genetic resource right is recognised, that payment then includes some potential return on F_S inputs into the production of the joint product d. When the genetic resource right is not recognised, the payment to F_S includes only the payment for entering the market with the herbal product.

In short, when F_N initiates the contract, the firms are not really bargaining over the division of joint surplus; instead, F_S is simply being compensated for its participation in the vertical industry (see Gatti *et al.* 2011 for a similar result). Compensation for participation includes the costs of supply as well as a payment for refraining from competition. Therefore, a property right in genetic resources is important for generating some recognition of the South's role in the vertical industry, but it does not have much impact on the distribution of the production surplus within that industry.

4 Compensating Traditional Knowledge - is a property right necessary?

In this section, we examine how the presence of traditional knowledge (TK) might influence the contractual process and the compensation terms between the parties. We consider TK to be an informational input: private information held by the potential suppliers of g. Specifically, we will 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 contracting in regard to 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.

4.1 Traditional Knowledge as Private Information

We now set out how this baseline analysis is altered by the presence of TK, i.e. the private information held by the firm in the South. We examine here the case where the North has the capacity to structure the contractual terms.

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.[8] 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.

We now specify the ways in which the existence of this private information will impact upon the contracting process. F_N specifies the offered contract enabling direct access to F_S's genetic resources. A contract consists of access to F_S's genetic resources 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 $\{(\overline{g}_N, \overline{t}), (\underline{g}_N, \underline{t})\}$, 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.

$$\overline{V} = \overline{t} - c_S^a(\overline{g}_N, \overline{\theta}) \geq \overline{\Pi}_N^{nc} \tag{8}$$
$$\underline{V} = \underline{t} - c_S^a(\underline{g}_N, \underline{\theta}) \geq \underline{\Pi}_S^{nc} \tag{9}$$

This is equivalent to

$$\overline{V} \geq \underline{\Pi}_S^{nc} + V_0 \tag{10}$$
$$\underline{V} \geq \underline{\Pi}_S^{nc} \tag{11}$$

where $\overline{\Pi}_S^{nc} = \xi\left[\pi_S(\hat{g}_S, \overline{\theta}) + \beta\pi_N(\hat{\overline{g}}_N, \overline{\theta})\right] + (1-\xi)\pi_S^c(\hat{g}_S, \overline{\theta}) - c_S(\hat{g}_S, \hat{\overline{g}}_N, \overline{\theta})$; $\underline{\Pi}_S^{nc} = \xi\left[\pi_S(\hat{g}_S, \underline{\theta}) + \beta\pi_N(\hat{\underline{g}}_N, \underline{\theta})\right] + (1-\xi)\pi_S^c(\hat{g}_S, \underline{\theta}) - c_S(\hat{g}_S, \hat{\underline{g}}_N, \underline{\theta})$; $\overline{\Pi}_S^{nc} = \underline{\Pi}_S^{nc} + \left(\overline{\Pi}_S^{nc} - \underline{\Pi}_S^{nc}\right) = \underline{\Pi}_S^{nc} + V_0$. 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 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.

[8]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).

$$\bar{t} - c_S^a(\overline{g}_N, \overline{\theta}) \geq \underline{t} - c_S^a(\underline{g}_N, \overline{\theta}) \quad (12)$$

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

Assumption 1: $\frac{\partial c_S^a}{\partial g_N} > 0$, $\frac{\partial^2 c_S^a}{\partial g_N^2} > 0$ and $\frac{\partial c_S^a}{\partial \theta} < 0$

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

Assumption 1 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 2 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: $\bar{t} - c_S^a(\overline{g}_N, \underline{\theta}) = \overline{V} - \Phi(\overline{g}_N)$. In addition, if the high type wants to mimic the low type, she would receive: $\underline{t} - c_S^a(\underline{g}_N, \overline{\theta}) = \underline{V} + \Phi(\underline{g}_N)$; where $\Phi(g_N) \equiv c_S^a(g_N, \underline{\theta}) - c_S^a(g_N, \overline{\theta})$ with $\Phi > 0$ and $\Phi' > 0$ from assumptions 1 and 2. The term Φ refers to the cost differential of the two types for a given level of supply g_N.

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

$$\overline{V} \geq \underline{V} + \Phi(\underline{g}_N) \quad (14)$$

$$\underline{V} \geq \overline{V} - \Phi(\overline{g}_N) \quad (15)$$

F_N's problem is then:

$$\max_{\{(\overline{g}_N, \bar{t}), (\underline{g}_N, \underline{t})\}} \quad p\left[\pi_N(\overline{g}_N) - c_N(\overline{g}_N) - \bar{t}\right] + (1-p)\left[\pi_N(\underline{g}_N) - c_N(\underline{g}_N) - \underline{t}\right]$$

subject to (8), (9), (12), (13)

The problem can be re-written as follows:

$$\max_{\{(\overline{g}_N, \overline{V}), (\underline{g}_N, \underline{V})\}} \quad p\left[\pi_N(\overline{g}_N) - c_N(\overline{g}_N) - c_S^a(\overline{g}_N, \overline{\theta})\right] + (1-p)\left[\pi_N(\underline{g}_N) - c_N(\underline{g}_N) - c_S^a(\underline{g}_N, \underline{\theta})\right] - [p\overline{V} + (1-p)\underline{V}] \quad (16)$$

subject to (10), (11), (14), (15)

This analysis leads directly to the following proposition, detailing the effects on contracting that result from the existence of private information. Proposition 2 establishes 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 $\{(\overline{g}_N, \overline{t}), (\underline{g}_N, \underline{t})\}$ to screen among the types of genetic resources. These contracts are characterised by:

1.1 $\overline{g}_N \geq \underline{g}_N$ *(Monotonicity condition)*

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

$$\frac{\partial \pi_N}{\partial \overline{g}_N}(\overline{g}_N^*) = \frac{\partial c_N}{\partial \overline{g}_N}(\overline{g}_N^*) + \frac{\partial c_S^a}{\partial \overline{g}_N}(\overline{g}_N^*, \overline{\theta})$$

$$\frac{\partial \pi_N}{\partial \underline{g}_N}(\underline{g}_N^{SB}) = \frac{\partial c_N}{\partial \underline{g}_N}(\underline{g}_N^{SB}) + \frac{\partial c_S^a}{\partial \underline{g}_N}(\underline{g}_N^{SB}, \overline{\theta}) + \frac{p}{1-p}\frac{\partial \Phi}{\partial \underline{g}_N}(\underline{g}_N^{SB})$$

$$\begin{aligned} \overline{t}^{SB} &= \underline{\Pi}_S^{nc} + \Phi(\underline{g}_N^{SB}) + c_S^a(\overline{g}_N^*, \overline{\theta}) \\ \underline{t}^{SB} &= \underline{\Pi}_S^{nc} + c_S^a(\underline{g}_N^{SB}, \underline{\theta}) \end{aligned}$$

1.3 *For $\Phi(\underline{g}_N^{SB}) \leq V_0 \leq \Phi(\overline{g}_N^*)$, $\overline{IR}$ 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 $\overline{g}_N^{SB} = \overline{g}_N^*$ and $\underline{g}_N^{SB} = \underline{g}_N^*$. The optimal level of $\underline{g}_N^*$ and transfer payments $\overline{t}^{SB}$ and $\underline{t}^{SB}$ are given by:*

$$\frac{\partial \pi_N}{\partial \underline{g}_N}(\underline{g}_N^*) = \frac{\partial c_N}{\partial \underline{g}_N}(\underline{g}_N^*) + \frac{\partial c_S^a}{\partial \underline{g}_N}(\underline{g}_N^*, \underline{\theta}) +$$

$$\begin{aligned} \overline{t}^{SB} &= \overline{\Pi}_S^{nc} + c_S^a(\overline{g}_N^*, \overline{\theta}) \\ \underline{t}^{SB} &= \underline{\Pi}_S^{nc} + c_S^a(\underline{g}_N^*, \underline{\theta}) \end{aligned}$$

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

$$\frac{\partial \pi_N}{\partial \overline{g}_N}(\overline{g}_N^{CI}) = \frac{\partial c_N}{\partial \overline{g}_N}(\overline{g}_N^{CI}) + \frac{\partial c_S^a}{\partial \overline{g}_N}(\overline{g}_N^{CI}, \overline{\theta}) - \frac{1-p}{p}\frac{\partial \Phi}{\partial \overline{g}_N}(\overline{g}_N^{CI})$$

$$\begin{aligned} \overline{t}^{CI} &= \overline{\Pi}_S^{nc} + c_S^a(\overline{g}_N^{CI}, \overline{\theta}) \\ \underline{t}^{CI} &= \overline{\Pi}_S^{nc} - \Phi(\overline{g}_N^{CI}) + c_S^a(\underline{g}_N^*, \underline{\theta}) \end{aligned}$$

Proof 2: See Appendix A.2.■

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 1.2 through 1.4 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.

We will now turn to the case where F_S is able to make the offer to F_N and then discuss the meaning of these results.

4.2 Traditional Knowledge and Information Rents

We have now analysed the nature of the contracting that would occur within this industry, given that traditional knowledge is treated as private information within a contractual relationship regarding genetic resource transfers. The first point to make concerns the importance of the attachment of TK to the genetic resource rights—for purposes of reaching a negotiated resolution. Basically, the absence of any court-recognised rights in either TK or genetic resources (i.e. when $\xi = 0$) will result in the lowest valued outside option being available to the South. This represents the lower bound, and no additional value accrues to TK over that captured from the competitive marketing of the traditional medicine (H). In short, without a property right being conferred upon both agents, there is no basis for bargaining over the division of joint surplus. The party without a property right is simply offered its participation costs.

On the other hand, if there is some prospect of recognition of an exclusive right to genetic resources ($\xi > 0$), then it is possible to add the value of private information to that of genetic resources. 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. $\Phi(\overline{g}_N)$ is smaller than the profit differential V_0. To ensure incentive compatibility, F_N will give her an information rent $\underline{V} = \overline{V} - \Phi(\overline{g}_N)$.[9] 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 1.4 of Proposition 2). 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 1.2 of Proposition 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.[10]

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 1.3 of Proposition 2). 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; that is, no information rent is given away. This is because no agent has an incentive to misrepresent her type so that the symmetric information outcome (see section 3) 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

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

[10]It is important to recognise that the rent given up to the high type increases in $\underline{g}_N$, implying that a reduction in $\underline{g}_N$ 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 $\underline{g}_N^*$ in order to minimise rent-sharing.

for investment in the provision of these resources to the R&D process, enhancing the efficiency of the R&D process.[11]

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 The Role of Property Rights in Resolving Conflict

We have been considering how property rights might be used to generate cooperative outcomes within a non-integrated vertical industry, such as often exists within the life sciences. We find that property rights are both important and unimportant in aiding cooperation and surplus-sharing.

The first point is that a recognised right in genetic resources is critical to encouraging bargaining within this industry. Without a recognised and enforceable right in genetic resources, the contribution of the South is only recognised to the extent of its supply costs and its threat of entry. There is not an explicit term in the compensation formula recognising the inputs of South into joint production, unless there the courts of the North offer to enforce rights in g against firms from the North. Despite this, there is little enhanced sharing of product from the creation of such a right. The basis of compensation of such inputs continues to be primarily the minimum required compensation for participation by such suppliers.

The result is the converse in the case of TK. In the context of this input, it is very likely that some rent-sharing can result, even without the presence of an explicit property right in TK. 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

[11] 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. 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 $\underline{g}_N$ (in case of low V_0), and increase $\overline{g}_N$ (in case of large V_0) away from the productively efficient levels, respectively $\underline{g}^*_N$ and $\overline{g}^*_N$.

retains its importance as the value of the outside option remains dependent upon the enforcement of this 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. Since F_S depends upon the underlying right to genetic resource information to protect its release of information on the market, this much is necessary to protect both.[12]

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 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. Essentially, 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. Keeping this information secret enables F_S to extract some information rent and thereby appropriate part of the production surplus under the conditions discussed in section 4.1. In general, keeping traditional knowledge as private information might compromise efficiency but favour the South as far as the distribution of profits is concerned.

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 the impacts upon the cumulative research setting of assigning a second property right to the resource-based information 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 show that the creation of a property right in genetic resources in the absence of traditional knowledge—under complete information— yields an efficient supply of resources. Crucial to the division of the joint profit is that this exclusive right be recognised by courts in the North. This right allows the genetic resources holder to market her products—derived from the protected genetic resources—in the North, which gives her an outside option. When such right exists, the division of the profit depends on whether the firms in the North infringe this right. Note also that in this framework, the firm offering the contract will reap all the cooperative surplus. So, a property right in genetic resources is crucial to bargaining, but not that important to determining the division of surplus.

[12] It is straight forward to show that F_S's compensation increases with ξ.

On the other hand, when traditional knowledge is defined as the private information held by the South on the prospect of individual genetic resources to yield a successful search, its role in bargaining is the converse. In the presence of traditional knowledge, the firms in the South have various 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. 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.

Critically, it is not necessary to establish a separate property right in traditional knowledge to appropriate this enhanced return. The granting of a single property right (to g) 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.

Essentially, 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 them a greater outside option and establishes the baseline upon which contracting occurs, and hence creates the basis upon which Southern firms may demand compensation in line with their contribution. Importantly we also show that it is not necessary to have a "property right in each and every thing" in order to have more equitable contractual terms. Once each agent is possessed of a single right, this may be sufficient to induce bargaining. Other valuable inputs may be able to earn their returns through association with the input in which a property right is recognised. Thus, we demonstrate that—to the extent that TK is private information—separate property right is not necessary to earn a separate return on this input.

Overall, we can say very little about efficiency in an industry such as this one—by definition an industry replete with government-protected monopolies lies within the realm of the second best. It does seem crucial that such industries should be subject to incentive systems that are able to adequately reward all agents supplying important inputs to production. We have shown that a privately organised industry that provides for a single property right at the "end of the pipeline"—i.e. where marketing of the innovation occurs—is likely to reward essential suppliers by means of the lowest possible participation payment. This arrangement may not provide incentives for those agents to invest in the ongoing supply of those inputs in accordance with Hart and Moore (1990). We have established that it is critical to create at least as many property rights as there are agents to incentivise the various private agents along the supply chain to bargain over and to distribute joint surplus. We have also shown that it is not as important to create as many property rights as there are inputs.

References

[1] Bullard, L., 2005. *A Briefing Paper on the First Legal Defeat of a Biopiracy Patent: The Neem Case.* Brussels: Research Foundation for Science, Technology and Ecology. Available at http://www.ifoam.org/press/press/pdfs/Briefing_Neem.pdf [Accessed 5 May 2006].

[2] Costello, C. and M. Ward, 2006. Search, Bioprospecting and Biodiversity Conservation. *Journal of Environmental Economics and Management*, 52: 615–626.

[3] Gatti, R., T. Goeschl, B. Groom, and T. Swanson, 2011. The Biodiversity Bargaining Problem *Environmental and Resource Economics*, 48: 409–428.

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

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

[6] Green, J. and S. Scotchmer, 1995. On the Division of Profit in Sequential Innovation. *RAND Journal of Economics*, 26: 20–33.

[7] Grossman, S. and O. Hart, 1986. The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration. *Journal of Political Economy.* 94: 691–719.

[8] Hart, O. and Moore, J., 1990. Property Rights and the Nature of the Firm. *Journal of Political Economy*, 98: 1119-1158.

[9] Kinukawa, S. and Motohashi, K., 2010: Bargaining in Technology Markets: An empirical study of biotechnology alliances. *RIETI Discussion Paper Series*, 10-E-200.

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

[11] Lafontaine, F. and M. Slade, 2001. Incentive Contracting and the Franchising Decision. in K. Chatterjee and W. Samuelson (eds.). *Game Theory and Business Applications.* Kluwer Academic Press, 133-188.

[12] Lafontaine, F. and M. Slade, 2007. Vertical Integration and Firm Boundaries: The Evidence. *Journal of Economic Literature.* 45(3): 629–685.

[13] Lerner, J. and Merges, R.P., 1998. The Control of Technology Alliances: An Empirical Analysis of the Biotechnology Industry. *Journal of Industrial Economics*, 46(2): 125–156.

[14] Perry, M., 1978. Vertical Integration: The Monopsony Case. *American Economic Review.* 68: 561–570.

[15] 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.

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

[17] Rothaermel, F.T., 2001. Complementary assets, strategic alliances, and the incumbent's advantage: an empirical study of industry and firm effects in the biopharmaceutical industry. R*esearch Policy* 30: 1235–1251.

[18] Sarr, M. and Swanson, T., 2008. IPR and North-South Hold-up Problem in Sequential R&D. Mimeo.

[19] Sarr, M., T. Goeschl, and T. Swanson, 2008. The Values of Conserving Genetic Resources for R&D. *Ecological Economics*, 67: 184–193

[20] Sarr, M. and T. Swanson, (forthcoming). Economics of IPR for Genetic Resources: North-South Cooperation in Sequential R&D. *International Journal of Ecological Economics & Statistics.*

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

[22] Shiva, V., 1996. Piracy by Patent: The Case of the Neem Tree. In J. Mander and E. Goldsmith (eds)*. The Case Against the Global Economy: And for a Turn Toward the Local.* Sierra Club: San Francisco.

[23] Simpson, D., R. Sedjo and J. Reid, 1996. Valuing Biodiversity for Use in Pharmaceutical Research. *Journal of Political Economy*, 104(1): 163–185.

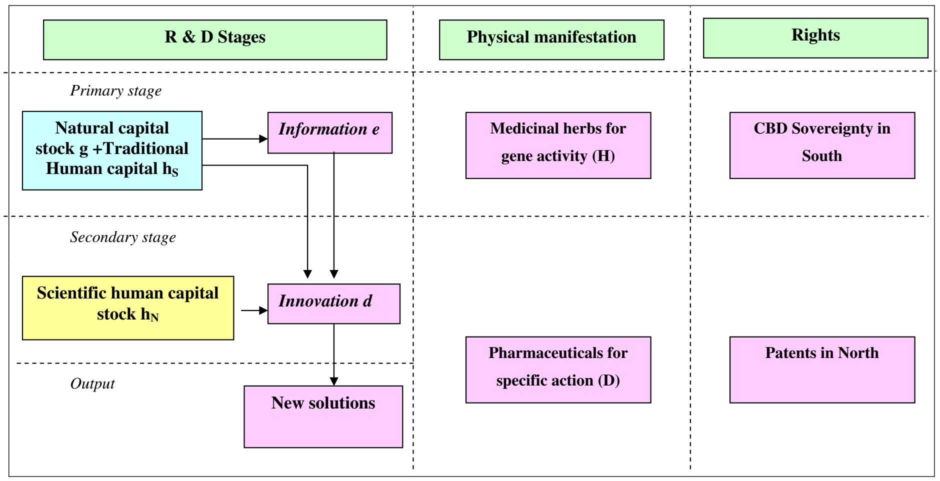
[24] Swanson, T., 1995. The Appropriation of Evolution's Values. In T. Swanson (ed): *Intellectual Property Rights and Biodiversity Conservation*, Cambridge University Press.

[25] Vecchio, R., 2007. Indigenous people, commerce clash over bioprospecting, *Associated Press*, Sunday, January 7, 2007.

[26] Williamson, O., 1985. *The Economic Institutions of Capitalism.* New York: Free Press.

6 Appendix A.1 Sequential R&D

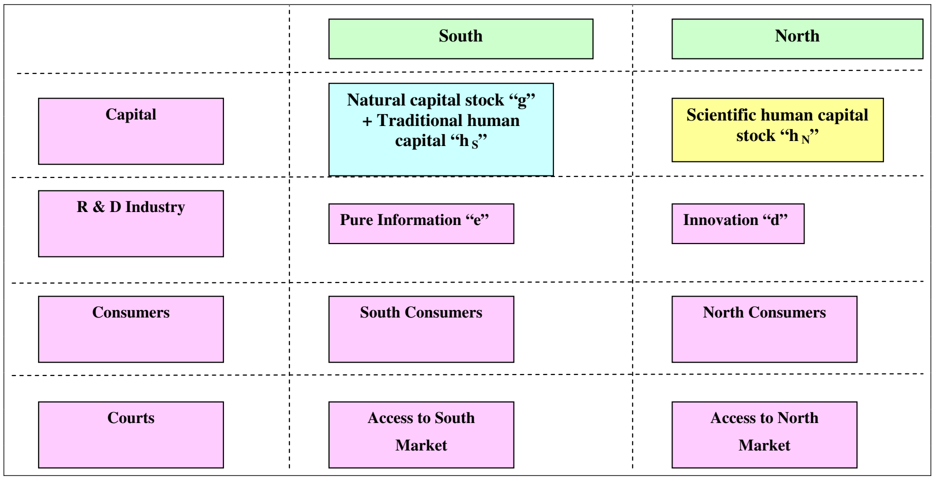
Figure 2: R&D stages in the biological sector (adapted from Goeschl and Swanson, 2002)



"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

7 Appendix A.2 Proof of Proposition 2

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

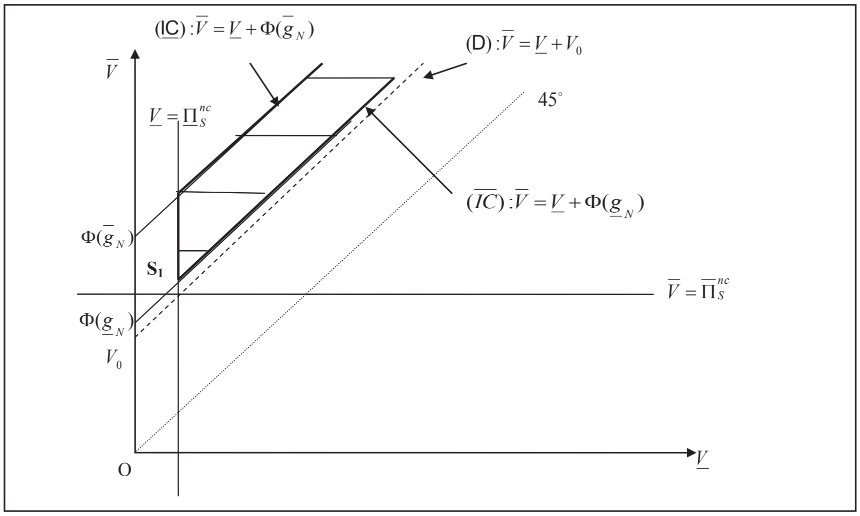
Because the participation constraints are type dependent, the search for equilibrium requires to consider several cases. Let us first represent the four constraints (10), (11), (14), and (15) in the space $(\underline{V}, \overline{V})$.

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 $\overline{V} = \underline{V} + \Phi(\underline{g}_N)$ and $\underline{V} = \overline{V} - \Phi(\overline{g}_N)$ have positive intercepts in the space $(\underline{V}, \overline{V})$. Note that $\underline{IC}$-line is always above $\overline{IC}$-line since $\Phi(\underline{g}_N) \leq \Phi(\overline{g}_N)$.

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: $V_0 < \Phi(\underline{g}_N^{SB})$**, 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 $\Phi(\underline{g}_N)$ 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: $\overline{V} = \underline{V} + \Phi(\underline{g}_N)$.

Besides, by lying the low type would incur an extra cost of access of $\Phi(\overline{g}_N)$ 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 (16) and deriving the first order conditions yields:

$$\max_{\{(\overline{g}_N, \overline{V}), (\underline{g}_N, \underline{V})\}} \quad p\left[\pi_N(\overline{g}_N) - c_N(\overline{g}_N) - c_S^a(\overline{g}_N, \overline{\theta})\right] + (1-p)\left[\pi_N(\underline{g}_N) - c_N(\underline{g}_N) - c_S^a(\underline{g}_N, \underline{\theta})\right] \\ -[p(\underline{\Pi}_S^{nc} + \Phi(\underline{g}_N)) + (1-p)\underline{\Pi}_S^{nc}] \tag{17}$$

$$\frac{\partial \pi_N}{\partial \overline{g}_N}(\overline{g}_N^*) = \frac{\partial c_N}{\partial \overline{g}_N}(\overline{g}_N^*) + \frac{\partial c_S^a}{\partial \overline{g}_N}(\overline{g}_N^*, \overline{\theta}) \tag{18}$$

$$\frac{\partial \pi_N}{\partial \underline{g}_N}(\underline{g}_N^{SB}) = +\frac{\partial c_N}{\partial \underline{g}_N}(\underline{g}_N^{SB}) + \frac{\partial c_S^a}{\partial \underline{g}_N}(\underline{g}_N^{SB}) + \frac{p}{1-p}\frac{\partial \Phi}{\partial \underline{g}_N}(\underline{g}_N^{SB}) > \frac{\partial \pi_N}{\partial \underline{g}_N}(\underline{g}^*) \tag{19}$$

By continuity and concavity of $\pi_N(.)$ it follows that: $\overline{g}_N^{SB} = \overline{g}_N^*$, $\underline{g}_N^{SB} < \underline{g}_N^*$, and $\underline{g}_N^{SB} < \overline{g}_N^{SB}$. 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:

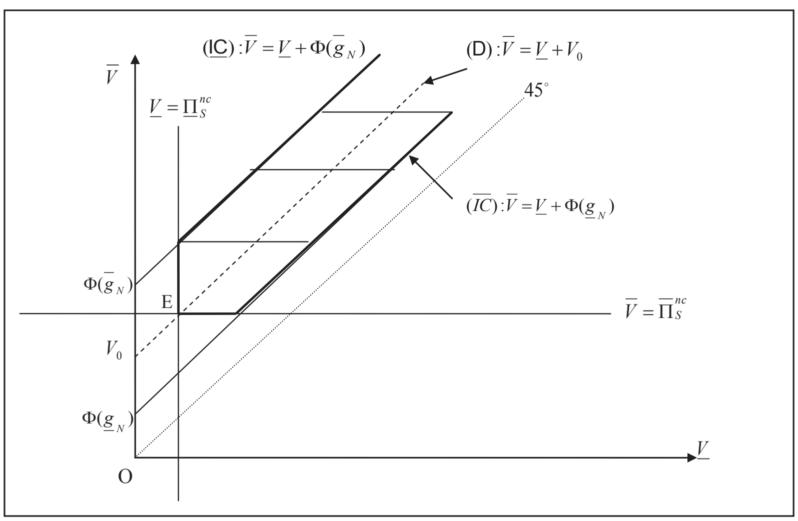
$$\overline{t}^{SB} = \underline{\Pi}_S^{nc} + \Phi(\underline{g}_N^{SB}) + c_S^a(\overline{g}_N^*, \overline{\theta}) \tag{20}$$

$$\underline{t}^{SB} = \underline{\Pi}_S^{nc} + c_S^a(\underline{g}_N^{SB}, \underline{\theta}) \tag{21}$$

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: $\Phi(\underline{g}_N^{SB}) \leq V_0 \leq \Phi(\overline{g}_N^*)$, 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 (16) and deriving the first order conditions yields:

$$\frac{\partial \pi_N}{\partial \overline{g}_N}(\overline{g}_N^*) = \frac{\partial c_N}{\partial \overline{g}_N}(\overline{g}_N^*) + \frac{\partial c_S^a}{\partial \overline{g}_N}(\overline{g}_N^*) \tag{22}$$

$$\frac{\partial \pi_N}{\partial \underline{g}_N}(\underline{g}_N^*) = \frac{\partial c_N}{\partial \underline{g}_N}(\underline{g}_N^*) + \frac{\partial c_S^a}{\partial \underline{g}_N}(\underline{g}_N^*) \tag{23}$$

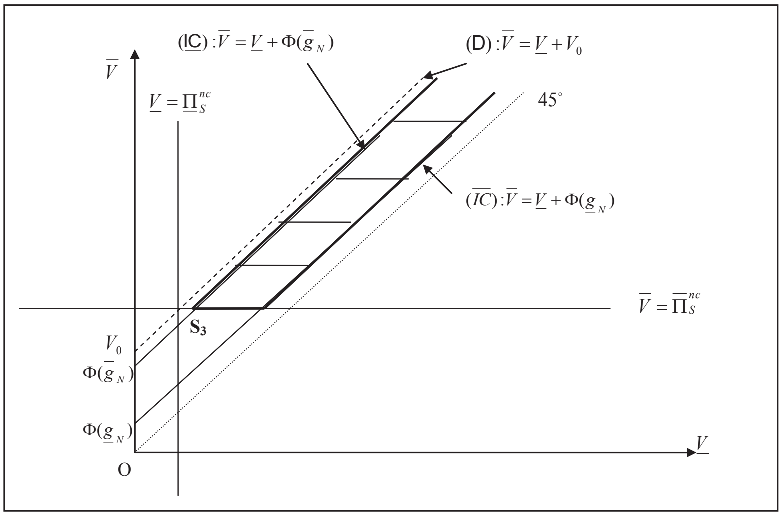
By continuity of $\pi_N(.)$ it follows that: $\overline{g}_N^{SB} = \overline{g}_N^*$, $\underline{g}_N^{SB} = \underline{g}_N^*$, and monotonicity ensures that $\underline{g}_N^* \leq \overline{g}_N^*$. Allocative efficiency is reached for both types: F_N will have an optimal access to the genetic resources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

$$\overline{t}^{SB} = \overline{\Pi}_S^{nc} + c_S^a(\overline{g}_N^*, \overline{\theta}) \tag{24}$$

$$\underline{t}^{SB} = \underline{\Pi}_S^{nc} + c_S^a(\underline{g}_N^*, \underline{\theta}) \tag{25}$$

Case 3: $V_0 > \Phi(\overline{g}_N^*)$, 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 $V_0 > \Phi(\overline{g}_N^*) > \Phi(\underline{g}_N^{SB})$, 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 $\Phi(\overline{g}_N)$ 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 $\underline{V} = \overline{\Pi}_S^{nc} - \Phi(\overline{g}_N)$. 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 $[p\bar{V} + (1-p)\underline{V}]$ 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 $\underline{V}$ in (16) and deriving the first order conditions yields:

$$\frac{\partial \pi_N}{\partial \overline{g}_N}(\overline{g}_N^{CI}) = \frac{\partial c_N}{\partial \overline{g}_N}(\overline{g}_N^{CI}) + \frac{\partial c_S^a}{\partial \overline{g}_N}(\overline{g}_N^{CI}) - \frac{1-p}{p}\frac{\partial \Phi}{\partial \overline{g}_N}(\overline{g}_N^{CI}) < \frac{\partial \pi_N}{\partial \overline{g}}(\overline{g}^*) \tag{26}$$

$$\frac{\partial \pi_N}{\partial \underline{g}_N}(\underline{g}_N^{CI}) = \frac{\partial c_N}{\partial \underline{g}_N}(\underline{g}_N^{CI}) + \frac{\partial c_S^a}{\partial \underline{g}_N}(\underline{g}_N^{CI}) = \frac{\partial \pi_N}{\partial \underline{g}_N}(\underline{g}_N^*) \tag{27}$$

By continuity and concavity of $\pi_N(.)$ it follows that: $\overline{g}_N^{CI} > \overline{g}_N^*$, $\underline{g}_N^{CI} = \underline{g}_N^*$, and $\underline{g}_N^{CI} < \overline{g}_N^{CI}$ (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:

$$\bar{t}^{CI} = \overline{\Pi}_S^{nc} + c_S^a(\bar{g}_N^{CI}, \bar{\theta})$$

$$\underline{t}^{CI} = \overline{\Pi}_S^{nc} - \Phi(\bar{g}_N^{CI}) + c_S(\underline{g}_N^*, \underline{\theta})$$

■

NOTE DI LAVORO DELLA FONDAZIONE ENI ENRICO MATTEI

Fondazione Eni Enrico Mattei Working Paper Series

Our Note di Lavoro are available on the Internet at the following addresses:

http://www.feem.it/getpage.aspx?id=73&sez=Publications&padre=20&tab=1
http://papers.ssrn.com/sol3/JELJOUR_Results.cfm?form_name=journalbrowse&journal_id=266659
http://ideas.repec.org/s/fem/femwpa.html
http://www.econis.eu/LNG=EN/FAM?PPN=505954494
http://ageconsearch.umn.edu/handle/35978
http://www.bepress.com/feem/

NOTE DI LAVORO PUBLISHED IN 2011

SD	1.2011	Anna Alberini, Will Gans and Daniel Velez-Lopez: Residential Consumption of Gas and Electricity in the U.S.: The Role of Prices and Income
SD	2.2011	Alexander Golub, Daiju Narita and Matthias G.W. Schmidt: Uncertainty in Integrated Assessment Models of Climate Change: Alternative Analytical Approaches
SD	3.2010	Reyer Gerlagh and Nicole A. Mathys: Energy Abundance, Trade and Industry Location
SD	4.2010	Melania Michetti and Renato Nunes Rosa: Afforestation and Timber Management Compliance Strategies in Climate Policy. A Computable General Equilibrium Analysis
SD	5.2011	Hassan Benchekroun and Amrita Ray Chaudhuri: "The Voracity Effect" and Climate Change: The Impact of Clean Technologies
IM	6.2011	Sergio Mariotti, Marco Mutinelli, Marcella Nicolini and Lucia Piscitello: Productivity Spillovers from Foreign MNEs on Domestic Manufacturing Firms: Is Co-location Always a Plus?
GC	7.2011	Marco Percoco: The Fight Against Geography: Malaria and Economic Development in Italian Regions
GC	8.2011	Bin Dong and Benno Torgler: Democracy, Property Rights, Income Equality, and Corruption
GC	9.2011	Bin Dong and Benno Torgler: Corruption and Social Interaction: Evidence from China
SD	10.2011	Elisa Lanzi, Elena Verdolini and Ivan Haščič: Efficiency Improving Fossil Fuel Technologies for Electricity Generation: Data Selection and Trends
SD	11.2011	Stergios Athanassoglou: Efficiency under a Combination of Ordinal and Cardinal Information on Preferences
SD	12.2011	Robin Cross, Andrew J. Plantinga and Robert N. Stavins: The Value of Terroir: Hedonic Estimation of Vineyard Sale Prices
SD	13.2011	Charles F. Mason and Andrew J. Plantinga: Contracting for Impure Public Goods: Carbon Offsets and Additionality
SD	14.2011	Alain Ayong Le Kama, Aude Pommeret and Fabien Prieur: Optimal Emission Policy under the Risk of Irreversible Pollution
SD	15.2011	Philippe Quirion, Julie Rozenberg, Olivier Sassi and Adrien Vogt-Schilb: How CO2 Capture and Storage Can Mitigate Carbon Leakage
SD	16.2011	Carlo Carraro and Emanuele Massetti: Energy and Climate Change in China
SD	17.2011	ZhongXiang Zhang: Effective Environmental Protection in the Context of Government Decentralization
SD	18.2011	Stergios Athanassoglou and Anastasios Xepapadeas: Pollution Control with Uncertain Stock Dynamics: When, and How, to be Precautious
SD	19.2011	Jūratė Jaraitė and Corrado Di Maria: Efficiency, Productivity and Environmental Policy: A Case Study of Power Generation in the EU
SD	20.2011	Giulio Cainelli, Massimiliano Mozzanti and Sandro Montresor: Environmental Innovations, Local Networks and Internationalization
SD	21.2011	Gérard Mondello: Hazardous Activities and Civil Strict Liability: The Regulator's Dilemma
SD	22.2011	Haiyan Xu and ZhongXiang Zhang: A Trend Deduction Model of Fluctuating Oil Prices
SD	23.2011	Athanasios Lapatinas, Anastasia Litina and Eftichios S. Sartzetakis: Corruption and Environmental Policy: An Alternative Perspective
SD	24.2011	Emanuele Massetti: A Tale of Two Countries:Emissions Scenarios for China and India
SD	25.2011	Xavier Pautrel: Abatement Technology and the Environment-Growth Nexus with Education
SD	26.2011	Dionysis Latinopoulos and Eftichios Sartzetakis: Optimal Exploitation of Groundwater and the Potential for a Tradable Permit System in Irrigated Agriculture
SD	27.2011	Benno Torgler and Marco Piatti. A Century of *American Economic Review*
SD	28.2011	Stergios Athanassoglou, Glenn Sheriff, Tobias Siegfried and Woonghee Tim Huh: Optimal Mechanisms for Heterogeneous Multi-cell Aquifers
SD	29.2011	Libo Wu, Jing Li and ZhongXiang Zhang: Inflationary Effect of Oil-Price Shocks in an Imperfect Market: A Partial Transmission Input-output Analysis
SD	30.2011	Junko Mochizuki and ZhongXiang Zhang: Environmental Security and its Implications for China's Foreign Relations
SD	31.2011	Teng Fei, He Jiankun, Pan Xunzhang and Zhang Chi: How to Measure Carbon Equity: Carbon Gini Index Based on Historical Cumulative Emission Per Capita
SD	32.2011	Dirk Rübbelke and Pia Weiss: Environmental Regulations, Market Structure and Technological Progress in Renewable Energy Technology — A Panel Data Study on Wind Turbines
SD	33.2011	Nicola Doni and Giorgio Ricchiuti: Market Equilibrium in the Presence of Green Consumers and Responsible Firms: a Comparative Statics Analysis

SD	34.2011	Gérard Mondello: Civil Liability, Safety and Nuclear Parks: Is Concentrated Management Better?
SD	35.2011	Walid Marrouch and Amrita Ray Chaudhuri: International Environmental Agreements in the Presence of Adaptation
ERM	36.2011	Will Gans, Anna Alberini and Alberto Longo: Smart Meter Devices and The Effect of Feedback on Residential Electricity Consumption: Evidence from a Natural Experiment in Northern Ireland
ERM	37.2011	William K. Jaeger and Thorsten M. Egelkraut: Biofuel Economics in a Setting of Multiple Objectives & Unintended Consequences
CCSD	38.2011	Kyriaki Remoundou, Fikret Adaman, Phoebe Koundouri and Paulo A.L.D. Nunes: Are Preferences for Environmental Quality Sensitive to Financial Funding Schemes? Evidence from a Marine Restoration Programme in the Black Sea
CCSD	39.2011	Andrea Ghermanti and Paulo A.L.D. Nunes: A Global Map of Costal Recreation Values: Results From a Spatially Explicit Based Meta-Analysis
CCSD	40.2011	Andries Richter, Anne Maria Eikeset, Daan van Soest, and Nils Chr. Stenseth: Towards the Optimal Management of the Northeast Arctic Cod Fishery
CCSD	41.2011	Florian M. Biermann: A Measure to Compare Matchings in Marriage Markets
CCSD	42.2011	Timo Hiller: Alliance Formation and Coercion in Networks
CCSD	43.2011	Sunghoon Hong: Strategic Network Interdiction
CCSD	44.2011	Arnold Polanski and Emiliya A. Lazarova: Dynamic Multilateral Markets
CCSD	45.2011	Marco Mantovani, Georg Kirchsteiger, Ana Mauleon and Vincent Vannetelbosch: Myopic or Farsighted? An Experiment on Network Formation
CCSD	46.2011	Rémy Oddou: The Effect of Spillovers and Congestion on the Segregative Properties of Endogenous Jurisdiction Structure Formation
CCSD	47.2011	Emanuele Massetti and Elena Claire Ricci: Super-Grids and Concentrated Solar Power: A Scenario Analysis with the WITCH Model
ERM	48.2011	Matthias Kalkuhl, Ottmar Edenhofer and Kai Lessmann: Renewable Energy Subsidies: Second-Best Policy or Fatal Aberration for Mitigation?
CCSD	49.2011	ZhongXiang Zhang: Breaking the Impasse in International Climate Negotiations: A New Direction for Currently Flawed Negotiations and a Roadmap for China to 2050
CCSD	50.2011	Emanuele Massetti and Robert Mendelsohn: Estimating Ricardian Models With Panel Data
CCSD	51.2011	Y. Hossein Farzin and Kelly A. Grogan: Socioeconomic Factors and Water Quality in California
CCSD	52.2011	Dinko Dimitrov and Shao Chin Sung: Size Monotonicity and Stability of the Core in Hedonic Games
ES	53.2011	Giovanni Mastrobuoni and Paolo Pinotti: Migration Restrictions and Criminal Behavior: Evidence from a Natural Experiment
ERM	54.2011	Alessandro Cologni and Matteo Manera: On the Economic Determinants of Oil Production. Theoretical Analysis and Empirical Evidence for Small Exporting Countries
ERM	55.2011	Alessandro Cologni and Matteo Manera: Exogenous Oil Shocks, Fiscal Policy and Sector Reallocations in Oil Producing Countries
ERM	56.2011	Morgan Bazilian, Patrick Nussbaumer, Giorgio Gualberti, Erik Haites, Michael Levi, Judy Siegel, Daniel M. Kammen and Joergen Fenhann: Informing the Financing of Universal Energy Access: An Assessment of Current Flows
CCSD	57.2011	Carlo Orecchia and Maria Elisabetta Tessitore: Economic Growth and the Environment with Clean and Dirty Consumption
ERM	58.2011	Wan-Jung Chou, Andrea Bigano, Alistair Hunt, Stephane La Branche, Anil Markandya and Roberta Pierfederici: Households' WTP for the Reliability of Gas Supply
ES	59.2011	Maria Comune, Alireza Naghavi and Giovanni Prarolo: Intellectual Property Rights and South-North Formation of Global Innovation Networks
ES	60.2011	Alireza Naghavi and Chiara Strozzi: Intellectual Property Rights, Migration, and Diaspora
CCSD	61.2011	Massimo Tavoni, Shoibal Chakravarty and Robert Socolow: Safe vs. Fair: A Formidable Trade-off in Tackling Climate Change
CCSD	62.2011	Donatella Baiardi, Matteo Manera and Mario Menegatti: Consumption and Precautionary Saving: An Empirical Analysis under Both Financial and Environmental Risks
ERM	63.2011	Caterina Gennaioli and Massimo Tavoni: Clean or "Dirty" Energy: Evidence on a Renewable Energy Resource Curse
ES	64.2011	Angelo Antoci and Luca Zarri: Punish and Perish?
ES	65.2011	Anders Akerman, Anna Larsson and Alireza Naghavi: Autocracies and Development in a Global Economy: A Tale of Two Elites
CCSD	66.2011	Valentina Bosetti and Jeffrey Frankel: Sustainable Cooperation in Global Climate Policy: Specific Formulas and Emission Targets to Build on Copenhagen and Cancun
CCSD	67.2011	Mattia Cai, Roberto Ferrise, Marco Moriondo, Paulo A.L.D. Nunes and Marco Bindi: Climate Change and Tourism in Tuscany, Italy. What if heat becomes unbearable?
ERM	68.2011	Morgan Bazilian, Patrick Nussbaumer, Hans-Holger Rogner, Abeeku Brew-Hammond, Vivien Foster, Shonali Pachauri, Eric Williams, Mark Howells, Philippe Niyongabo, Lawrence Musaba, Brian Ó Gallachóir, Mark Radka and Daniel M. Kammen: Energy Access Scenarios to 2030 for the Power Sector in Sub-Saharan Africa
CCSD	69.2011	Francesco Bosello, Carlo Carraro and Enrica De Cian: Adaptation Can Help Mitigation: An Integrated Approach to Post-2012 Climate Policy
ES	70.2011	Etienne Farvaque, Alexander Mihailov and Alireza Naghavi: The Grand Experiment of Communism: Discovering the Trade-off between Equality and Efficiency
CCSD	71.2011	ZhongXiang Zhang: Who Should Bear the Cost of China's Carbon Emissions Embodied in Goods for Exports?

CCSD	72.2011	Francesca Pongiglione: Climate Change and Individual Decision Making: An Examination of Knowledge, Risk Perception, Self-interest and Their Interplay
CCSD	73.2011	Joseph E. Aldy and Robert N. Stavins: Using the Market to Address Climate Change: Insights from Theory and Experience
CCSD	74.2011	Alexander Brauneis and Michael Loretz: Inducing Low-Carbon Investment in the Electric Power Industry through a Price Floor for Emissions Trading
CCSD	75.2011	Jean-Marie Grether, Nicole A. Mathys and Jaime de Melo: Unravelling the Worldwide Pollution Haven Effect
ES	76.2011	Benjamin Elsner: Emigration and Wages: The EU Enlargement Experiment
CCSD	77.2011	ZhongXiang Zhang: Trade in Environmental Goods, with Focus on Climate-Friendly Goods and Technologies
ES	78.2011	Alireza Naghavi, Julia Spies and Farid Toubal: International Sourcing, Product Complexity and Intellectual Property Rights
CCSD	79.2011	Mare Sarr and Tim Swanson: Intellectual Property and Biodiversity: When and Where are Property Rights Important?