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An Economic Model for Bioprospecting Contracts

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ABSTRACT

This paper explores the use of a micro-economic model aiming at the analysis of bioprospecting contracts' provisions and parties. It focuses the attention on the pharmaceutical industry as the representative biodiversity buyer, presenting an original theoretical framework that explains the main contract characteristics or stylized facts. Against this background, it takes account the main contractors involved in these private contracts, i.e. biodiversity sellers and biodiversity buyers, analyzing both the magnitude and distribution of the respective payoffs. Furthermore, particular attention is given to the impact of bioprospecting contracts, and patenting, on social welfare. All in all, the impacts of bioprospecting contracts and patenting on social welfare are mixed. This is because the positive welfare impacts, associated with the potential discovery of a new drug product, productivity gains, non-monetary benefit sharing or transfers and royalty revenues, are to be balanced with the negative welfare impact resulting from the legal creation of a monopoly and the related well-known effect on the consumer surplus. Finally, the potential redistribution effects are limited and a potential enforcement of this objective may jeopardize the desirability of the contract since this action will bring a significant increase in the contracts administration costs.

Keywords: bioprospecting contract; genetic resource; biodiversity buyer; biodiversity seller; patenting; welfare analysis; benefit sharing.

JEL classificaiton: D21, D23, D61, L14, Q57

1. INTRODUCTION

The Convention on Biological Diversity (CBD), launched after the Earth Summit in Rio de Janeiro in 1992, clarified and recognised the sovereign property rights of each country over their own biodiversity resources. By attempting to rule out open access to bioprospecting, the CBD (CBD 1992) has established an important legal and economic principle: biodiversity conservation has a (market and non market) value. Therefore, biodiversity value can be negotiated and embodied in some kind of governance structures. Stylized facts show that the most frequently adopted governance structure is represented by long-term contracts, mostly signed between public research institutions and biotechnological- pharmaceutical multinationals, all over the world. The CBD has stated the important legal principle that each country has sovereign property rights over the biodiversity within its jurisdiction and is able to obtain truthful information about the use of the genetic resource, control the access procedures and equitably negotiate the benefit-sharing items with the biodiversity prospectors.

In this new institutional context, a legal framework is established for the reciprocal contracts between the parties interested in bioprospecting, i.e. interested in collecting, sampling and screening genetic resources, including plants, animals, micro-organisms, as well as sharing indigenous knowledge with significant potential to develop new market products. The result has been, a remarkable increase in the number of bio-prospecting contracts between the “biodiversity buyers”, notably linked to the pharmaceutical industry (e.g. Glaxo) and “biodiversity sellers”, mainly local research institutes operating in geographical areas where a broad range of biodiversity is present (e.g. INBio in Costa Rica). In addition, it is also observed an increasing international institutions (e.g. ICBG) involved in the samples screening activities (Bhat 1999; Ten Kate and Laird 1999; Dedeurwaerdere 2005).

Against this background, the present paper contains an economic analysis of bioprospecting contracts. In particular, we adopt microeconomic analysis in order to derive original insights that help to capture and understand the main motivations of the stakeholders involved in this particular negotiation. This is important because understanding how and why economic agents use contracts to coordinate their activities is crucial to understanding the organization and efficiency of economic exchange. Our research work, therefore, aims at understanding if bioprospecting contracts (modelled on the basis of the analysis of stylized facts) are the most proper negotiating instrument to ensure the efficiency of the exchange among parties and the efficiency of the (selected) markets. . It is important to highlight that the study follows a standard microeconomic neoclassical approach, and does not focus on understanding whether such contracts are the most “transaction costs minimizing governance structure”, in a purely transaction costs economics (TCE) approach. The latter point is material for further research.

The paper is organized as follows. Section 2 contains a review of a number of existing contracts worldwide in order to identify the main provisions and parties. Section 3 presents an original theoretical framework that explains the observed and reviewed stylized facts so as to study the different steering forces involved in the two parties objective functions. Section 4 explores a welfare analysis of the bioprospecting contracts and patenting. Section 5 concludes.

2. REVIEW OF EXISTING BIOPROSPECTING CONTRACTS

This paragraph provides a review of existing bioprospecting contracts in order to analyze the relevant legal and economic provisions and study significant relationship between the contracts provisions and organizational structure. Table 1 contains a review of the most important provisions in a sample of 8 selected contracts, stipulated world-wide. A well-known case is the bioprospecting contract between the INBio-national biodiversity institute of Costa Rica, and Merck Pharmaceutical Ltd. in 1991. Merck was granted the right to evaluate the commercial prospects of a limited number of plant, insect, and microbial samples collected in Costa Rica's 11 conservation areas, from which INBio gained US$1 million over two years and equipment for processing samples and scientific training from Merck. In addition, the agreement addressed a share of potential royalties and technology transfer to develop local sample preparation and screening capabilities. INBio agreed to invest 10% of all the payments and half of the royalties by Merck into the Conservation Areas (Mulholland and Wilman 1998; Merson 2000; Nunes and Bergh 2001; Artuso 2002).

Table 1: A review on the existing bioprospecting contracts

Contractors and Legal Nature of the parties	Date of Signature, Duration and Possibility to Renew	Contract Payment of biodiversity	R&D, Patenting and Biodiversity Protection Obligations	Other Obligations
INBio (national biodiversity institute of Costa Rica, non-profit, public interest organization &Merck (private company)	1991 (2 years) Renewable	Lump-sum transfer	- Royalties Sharing -Technology transfer to develop local preparations and screening capabilities - Obligation for the private company to financially contribute to protect biodiversity	No Exclusive contracts - Common use of the resource
ICBG (International Cooperative Biodiversity Group, U.S: governmental venture) & Bristol-Myers Squibb, Monsanto, and Glaxo Wellcome (consortium of private companies)	1993 (5 years) Renewable	Lump-sum transfer	- No Royalties Sharing - No technology transfer to develop local preparations and screening - Obligation for the private company to financially contribute to protect biodiversity	No Exclusive contracts - Common use of the resource
European botanical Gardens (EU public institutions) & U.S. Phytera (private company)	1996 (11 years) Renewable	Payment per plant	'-Royalties Sharing - No technology transfer to develop local preparations and screening - No Obligation for the private company to financially contribute to protect biodiversity	Exclusive contracts - Common use of the resource

Table 1: A review on the existing bioprospecting contracts (cont.)

TBGRI (Tropical Botanical Garden and Research Institute in Kerala, public institutions) & Arya Vaidya Pharmacy Coimbator Ltd (private company)	1996 (11 years) Renewable	Lump-sum transfer	- Royalties Sharing -Technology transfer to develop local preparations and screening capabilities. Investment in the Kani Community for human capital formation - Obligation for the private company to financially contribute to protect biodiversity	Exclusive contracts - Common use of the resource
Yellowstone National Park (U.S. public institution) & Diversa (private company)	1997 (10 years) Renewable	Lump-sum transfer	Royalties Sharing - No Technology transfer to develop local preparation and screening capabilities. - No Obligation for the private company to financially contribute to protect biodiversity	No Exclusive contracts - Common use of the resource
CSIR (The Bio/Chemtek division of South Africa's Commission on Scientific and Industrial Research, public institution) & Diversa (private company)	1998 (9 years) Renewable	No monetary transfer	No Royalties Sharing Technology transfer to develop local preparations and screening capabilities for traditional healers No Obligation for the private company to financially contribute to protect biodiversity	Exclusive contracts - Common use of the resource
Brazilian Extracta (public institution) & Glaxo Wellcome (private company)	1999 (3 years) Non Renewable	Lump-sum transfer	Royalties Sharing Technology transfer to develop local preparation and screening capabilities Obligation for the private company to financially contribute to protect biodiversity	No Exclusive contracts - Common use of the resource
Department of Chemistry University of South Pacific (public institution) & Smith Kline Beecham (private company)	1995 (3 years) Renewable	Non Monetary	Royalties Sharing Technology transfer to develop local preparation and screening capabilities. Investment in the Verata Community for human capital formation Obligation for the private company to financially contribute to protect biodiversity	Exclusive contracts - Common use of the resource

Sources: (Breibart 1997; ICBG 1997; Mulholland and Wilman 1998; Neto and Dickson 1999; Ten Kate and Laird 1999; Merson 2000; Artuso 2002; Greer and Harvey 2004; Dedeurwaerdere et al. 2005)

Genetic resources are crucial inputs at different research and development (R&D) stages, and thus institutional interests results in different contractual specifications. For instance, industries of botanical medicines, personal care and commercial agriculture traditionally depend upon plant genetic resources, but biotechnological companies and pharmaceutical companies always acquire material as raw samples, extracts from plant genetic resources or 'value-added' genetic resources (Ten Kate and Laird 1999; 2000).

Despite difference in peculiarities, the selected contracts present a set of common features and provisions. First, despite the various entities of the existing bioprospecting contracts, and the wide range of stakeholders, it is possible to identify two main parties to the agreement.

1) *Biodiversity Sellers* (BS) generally are public institutions of various type (botanic gardens, universities, research institutions, and gene banks). The BS have an important role as a contractor with the (pharmaceutical) private companies, since they serve private companies with the screened samples, novel compounds and discovered research leads derived from their field collections in association with the appropriate freedom for new drug development. In addition, they are responsible for obtaining a granted permission of access to genetic resources, or indigenous knowledge, and collaborate with the private companies in the development and market commercialisation of these resources. In doing this, they have to make separate contracts or other agreements with both source suppliers and private companies. In addition, BS (formally or informally) negotiate with the *source suppliers*[1] so as to obtain the permission to exploit the access to the genetic resource. Such permission, therefore, enables BS to conduct field collection.

2) *Biodiversity Buyers* (BB) mostly are pharmaceutical multinational companies and represent the other contractual party. This stakeholder is characterized on the basis of its notable research and development (R&D) efforts on the commercial use of the genetic resources. Although various private companies build their business on the commercialisation of genetic resources, the pharmaceutical industry undoubtedly represents the largest global market. Some figures indicate that global sales of pharmaceuticals are estimated to exceed $300 billion per annum, of which the component derived from genetic resources or pure natural products accounts for some $75-150 billion (Grifo et al. 1997; Ten Kate and Laird 1999). In fact, it is characterised by investing a higher proportion of sales in R&D than most other industries, such as botanical medicines, personal care, commercial agriculture, and crop protection companies, but also incurring a higher risk in drug discovery and development process (See Table 2). For this reason, pharmaceutical companies play a crucial role as an important steering engine in driving the progress of bio-prospecting contracts. In this context, the next section focuses on the economic analysis of the pharmaceutical industry only. Therefore, the stakeholder originally referred to as BB will represent pharmaceutical companies/industry in the remaining body of the text.

Table 2 Comparison of duration and cost of typical research and development programmes in different industry sectors.

Sector	Years to develop	Cost (US$ m)
Pharmaceutical	10-15 or more	231-500
Botanical medicines	Less than 2 to 5	0.15-7
Commercial agricultural seed	8 to12	1-2.5
Transgene	4 or more	35-75
Ornamental horticulture	1 to 20 or more	0.05-5
Crop Protection	2 to 5 (biocontrol agent)	1-5
	8 to 14 (chemical pesticide)	40-100
Industrial enzymes	2 to 5	2-20
Personal care and cosmetic	Less than 2 to 5	0.15-7

Source: Ten Kate and Laird 1999, page 9

Second, the agreements' core provision is an exchange obligation: parties trade the possibility to get screened samples of biological material, in exchange to a monetary payment (in some cases this is not due) and some other reciprocal obligations. The most important contractual obligations are three:

1) the possibility (or not) to share royalties revenues in case, the pharmaceutical multinationals can patent a new drug discovery, thanks to the R&D activities performed on the genetic material sold in the contract;

2) the possibility (or not) for the pharmaceutical multinationals to transfer R&D technology and screening capabilities to the local institutions; and/or the possibility (or not) to form local human capital;

3) the possibility (or not) for the pharmaceutical multinationals to financially contribute to protect biodiversity with the partial transfer of the total royalty revenues.

Moreover, contracts generally prescribe for accessories provisions like the possibility to make a common use of the resource and whether the contract attributes an exclusive exploitation right or not.

Third, all the contracts are long-term (mostly) renewable contracts. In addition, the contract prescribes for the payment of a biodiversity price, whose amount and payment scheme is different in every contract. The contract value reflects the parties' valuation of the contract. Some contracts provide for a monetary quantification of such valuations (for example, Merck paid US$ 1.135 million to INBio for the samples supply and screen and U.S. Phytera agreed to pay the EU botanical gardens $15 per plant) .

Finally, the parties agree to share (in different proportions) the royalties' returns in case that bioprospecting activities lead to successful drugs, which obtain a discovery patent. Some other contracts do not provide monetary transfers (for instance, the collaboration between the traditional healers and CSIR in bioprospecting has only promoted the development of a data base of information on traditional uses of South African plants, which can help CSIR and its partners to make preferential selection on the plants for

screening. Moreover, a formal agreement also makes the benefit-sharing arrangements come into force between the traditional healers and CSIR).

3. MODELLING BIOPROSPECTING CONTRACTS

3.1. Introduction

This section provides a model that formally explains the interrelationships between contractors, bioprospecting contracts and pharmaceutical markets. The model will allow us to better interpret the strategic behaviour of contractors, and to ultimately evaluate the performance of bioprospecting contracts, which aim at ensuring the exclusive access to the genetic resources, upon the equitable and fair sharing of the benefits between the involved parties. Figure 1 shows the contribution of genetic resources at different stages of the pharmaceutical research, in terms of the sources of new drugs (herbs or natural products) or a source of leads for synthesising new compound structures or products (Ten Kate and Laird 2000; Onaga 2001).

In reality, the access to GR can be facilitated by a set of other accessory negotiations (for instance, authorizations/or collateral agreements concerning the provision, or transfer, of the samples, chemical compounds and genetic information derived from extracting and screening activities in the research institutes or universities) with third interested parties (for instance local populations). It, therefore, links the biodiversity sellers with the private companies through a set of mutual agreements on the sharing of both monetary and non-monetary benefits on the use of genetic materials and their derivatives.

Originally, collection, discovery and development were sequential processes in pharmaceutical research, but they now tend to be conducted in parallel by both the pharmaceutical industry and some collaborative intermediate institutes in order to reduce the development time. The industry alone is responsible for conducting the drug development, but sometimes requires the biodiversity sellers (that usually are public research institutions) to complete the fundamental research for drug discovery, including the field collection, establishment of screening libraries, and discovery of active compounds for pharmaceutical research. Hence, pharmaceutical companies are legally entitled to the exclusive use of the given samples in association with the freedom of developing these samples into natural products, research leads or synthetic compounds for new drug discovery.

In the present study, we attempt to provide a formal analysis of the bioprospecting contract, by highlighting the two main parties' objective functions and objective function maximization, in order to provide a primer theoretical structure to the contract and analyze the main (market) impacts (for a theoretical study of contracts in the electricity and art markets, see Onofri, 2003(a) and (b)). The impact of patents will be formalised in terms of their specific effects on the parties and considerations, and respective impacts on the costs and benefits for all the involved contractors. In the next subsections, we shall identify and assess the magnitude of such impacts.

The BS is granted exclusive access to the genetic resource and patent their discoveries from the area under consideration. In many cases, BS refers to local research institutes or universities. This geographical affinity contributes to the formation of a firm or of a close relationship with the national or local government in the

source country. As a matter of fact, these same institutions often represent the country to negotiate international cooperation agreements with the private companies. As far as benefits-sharing rules are concerned, the transfer of technology from the BS to the source suppliers contributes to strengthening the research ability and efficiency of the source-based institutes. In effect, we can observe a potential increase in the added-value of genetic resources, increasing the possibilities to renew the existing contract or to set up new ones. One important characteristic is that many international research organizations (such as ICBG) carry out several research programs in different countries. For this reason, the research results and database generated in all collaborative countries will be shared within the involved institutes. As a consequence, the sharing of systematic information on processing genetic resources can contribute to reducing the financial costs of field collection for both companies and institutes. In other words, it will be possible to provide higher quality samples or synthetic compounds, or obtain the same sample processing results with a lower field collection effort, and thus reduce the pressure of habitat loss and species extinction. (ICBG 1997; Rausser and Small 2000).

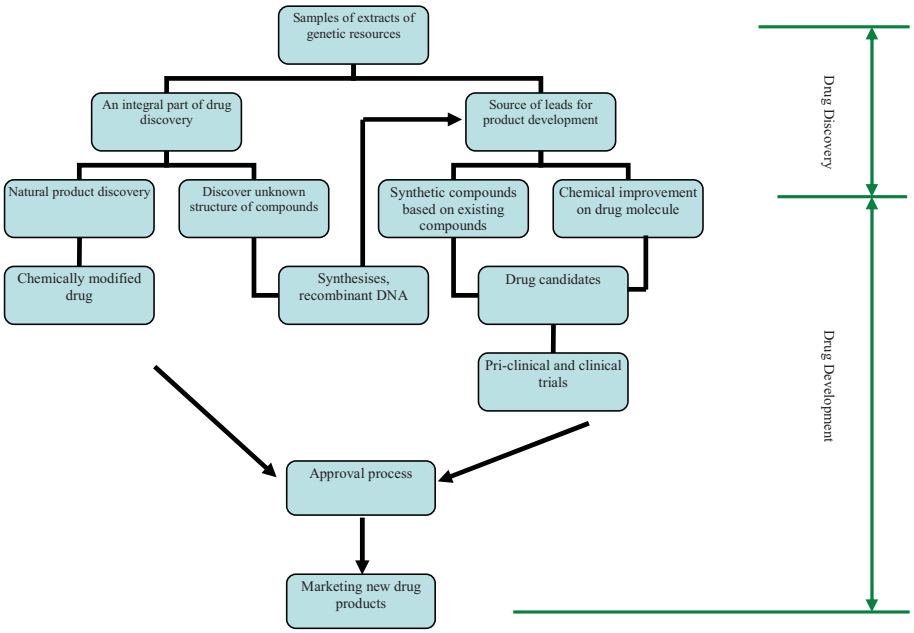

Figure 1 the contribution of natural products to pharmaceutical research

Source: Ten Kate and Laird 1999 (adapted).

3.2. Modelling the biodiversity seller's objective function

Given the condition that biological material suppliers voluntarily accept the contractual bioprospecting activities, the contract supply function for the biodiversity sellers (BS) can be formally expressed by equation (1):

$$y_{BS} = F\left(s(\underline{\theta}), L(B;\underline{\theta}), T(B;\underline{\theta})\right) \quad (1)$$

As we can see, the contract supply function is modelled as dependent (a) on the stock of genetic material available to the seller, denoted by *s*; (b) on the human efforts, denoted by *L*; and technology, denoted *T*. For the sake of simplicity, we assume that the seller does not pursue autonomous R&D activities, meaning that *T* is not a direct control variable. However, it can benefit from non-monetary sharing-benefits, such as technology transfer (e.g. funding of laboratory equipment, modifications and maintenance; funding of computer system), that may come along with the signature of the contract, and for this same reason *T* is modelled as dependent on *B,* the amount of the parties bioprospecting effort as established in the contract. Similarly, the signature of the contract can also provide non-monetary benefits by improving the quality of the human capital employed in the screening sampling process (e.g. formal training to the local Universities and access to scientific literature). Furthermore, here $\underline{\theta} \equiv (\theta_L, \theta_T)$ denotes a vector portraying a set of idiosyncratic characteristics of the seller supply, including the quality of the local labor involved in the sampling procedures, θ_L ; the degree of access to technology as well as the quality of the screened genetic material provided by the seller, θ_T . These characteristics will be embedded in the transaction specificity and reflected on the contractual seller's position. This will be then signaling the seller's bargaining power and the price of the contract. At this stage, we can model the expected profits[2] of the BS as

$$\pi_{BS} = p_B(B;\underline{\theta}) \cdot F\left(s(\underline{\theta}), L(B;\underline{\theta}), T(B;\underline{\theta})\right) - C\left(s, L, T, B\right) + \mu Roy(pat) \quad (2)$$

In first term in equation (2), pB denotes the price of the contract. As explained before, price is assumed to be dependent on the idiosyncratic characteristics of the BS. The second term captures the production and administrative costs. This term includes the costs regarding the access to the resources (e.g. when the material is not at the seller's disposal this may refer to the costs with the negotiations for authorisations with the local communities), the costs of labour and technology employed by the seller, as well as the costs of negotiating, writing and enforcing the bioprospecting contract. Finally, the last term in equation (2), denotes the royalty benefits on the basis of the expected value of a successful pharmaceutical product derived from the supplied patented compounds. The parameter μ (with $0 < \mu \leq 1$) represents the share from patent revenues that the BS will receive. Against this background, the BS maximizes its profits by choosing inter alia the amount of parties' bioprospecting effort as established in the contract, i.e. B. Formally, we have

$$\underset{B}{Max} \quad \pi_{BS} = p_B(B;\underline{\theta}) \cdot F\left(s(\underline{\theta}), L(B;\underline{\theta}), T(B;\underline{\theta})\right) - C\left(s, L, T, B\right) + \mu \cdot E[Roy(pat)] \quad (3)$$

The first order condition is:

$$\frac{\partial \pi_{BS}}{\partial B} = p_B\left[\frac{\partial F}{\partial L}\frac{\partial L}{\partial B}\theta_L + \frac{\partial F}{\partial T}\frac{\partial T}{\partial B}\theta_T\right] + y_{BS}\frac{\partial p}{\partial B}\theta - \frac{\partial C}{\partial B} = 0 \quad (4)$$

In other words, the optimal B* for the BS must satisfy equation (4). Equation (4) states that the seller is willing to write the bio-prospecting contract until the marginal benefits resulting from this action are equal to the marginal costs. According to equation (4), the marginal benefits are captured by two separate components: non-monetary benefit transfer and contract price. The first component refers to $p_B\left[\frac{\partial F}{\partial L}\frac{\partial L}{\partial B}\theta_L + \frac{\partial F}{\partial T}\frac{\partial T}{\partial B}\theta_T\right]$. As we can see, this value depends on the qualitative changes of the value of productivity that the contract can bring along with it due to the transfer of technology and education. This magnitude is dependent on the parameters θ_L and θ_T, and thus reflecting the idiosyncratic characteristics of the BS with respect to the two inputs under consideration. The second components refers to the potential effect that the idiosyncratic characteristics of the BS on the definition of the price of the contract, signaling the seller's bargaining power, $y_{BS}\frac{\partial p}{\partial B}\theta$. The magnitude of these benefits need to be compared with the marginal costs associated to parties' bioprospecting effort the negotiating, writing and enforcing of such a contract, i.e. $\frac{\partial C}{\partial B}$. Furthermore, we can highlight the following different scenarios regarding the magnitude of the two main effects of the benefit components:

(a) when $p_B\left[\frac{\partial F}{\partial L}\frac{\partial L}{\partial B}\theta_L + \frac{\partial F}{\partial T}\frac{\partial T}{\partial B}\theta_T\right]$ is larger than $y_{BS}\frac{\partial p}{\partial B}\theta$, with $y_{BS}\frac{\partial p}{\partial B}\theta \cong 0$, then we can interpret this situation as signalling that the BS strongly values the non-monetary benefits that the bioprospecting contract brings, even if the BS does not have a strong bargaining power. This situation is illustrated, for example, in the CSIR & Diversa contract (see Table 1);

(b) alternatively, when $y_{BS}\frac{\partial p}{\partial B}\theta$ is larger than $p_B\left[\frac{\partial F}{\partial L}\frac{\partial L}{\partial B}\theta_L + \frac{\partial F}{\partial T}\frac{\partial T}{\partial B}\theta_T\right]$, with $p_B\left[\frac{\partial F}{\partial L}\frac{\partial L}{\partial B}\theta_L + \frac{\partial F}{\partial T}\frac{\partial T}{\partial B}\theta_T\right] \cong 0$, then we can interpret this scenario as signalling that the BS attaches a significant value to the monetary component of the marginal revenues from the contract. This situation is illustrated, for example, in the Yellowstone & Diversa, ICBG & Bristol-Myers Squibb-Monsanto-Glaxo Wellcome and European Botanical Gardens & US Phytera contracts (see Table 1).

3.3. Modelling the biodiversity buyer's objective functions

The production function for the biodiversity buyer (BB) can be described by the following equation:

$$y_{BB} = G\left[y_{BS}(B;\underline{\sigma}), K(B;\underline{\sigma}), TI(pat(B);\underline{\sigma})\right] \tag{5}$$

in which, y_{BB} is the yield of successfully developed drugs by the pharmaceutical company, which is modelled as a function of the supplied screened genetic material, as foreseen in the contract and denoted by y_{BS}, the accumulated knowledge in the R&D process, denoted by *K*, and technological investments, denoted by *TI*. *K* has a positive effect on y_{BB} since it plays an important role in increasing the probability of successfully developing new drugs. In a similar way, *TI* positively influences the productivity of the pharmaceutical industry. It however, relies on the patentable innovations in the drug development process or the new products with respect to the writing of a bioprospecting contract. For this reason, this effect is expressed in equation (5) as *TI(pat)*. Finally, the idiosyncratic characteristics of the BB are captured by the term $\underline{\sigma}$ and can be interpreted *inter alia* in terms of the BB capability to provide R&D, market share in world market of drugs and medicines (and embedded market power). Therefore, the objective function of the BB can be modelled as follows:

$$\pi_{BB} = P_D \cdot G\left[y_{BS}(B;\underline{\sigma}), K(B;\underline{\sigma}), TI(pat(B);\underline{\sigma})\right] - C\left(y_{BS}, B, TI, pat\right) + (1-\mu)E\left[Roy(pat(B);\underline{\sigma})\right] \tag{6}$$

The first term, $P_D \cdot G\left[y_{BS}(B;\underline{\sigma}), K(B;\underline{\sigma}), TI(pat(B);\underline{\sigma})\right]$ in the equation (8) represents the total revenues of successful new drugs in the market. P_D represents the market price of drug, which is at this stage assumed to be exogenous to the BB (latter we shall relax this assumption). The second term calculates the total costs incurred by the pharmaceutical company: *C* denotes the total costs, including the costs in purchasing screened samples from the BS, administrative costs, continual investments in R&D, and the costs of patent application and renewal fees for the new drug products. Finally, $(1-\mu)E\left[Roy(pat(B);\underline{\sigma})\right]$ is the BB's share of the expected royalties. Hence, the company can maximize its net benefits through the choice of *B*, *TI*, and *pat*.

$$\underset{B,TI,pat}{Max} \quad \pi_{BB} = P_D \cdot G\left[y_{BS}(B;\underline{\sigma}), K(B;\underline{\sigma}), TI(pat(B);\underline{\sigma})\right] - C\left(y_{BS}, B, TI, pat\right) + \\ + (1-\mu)E\left[Roy(pat(B);\underline{\sigma})\right] \tag{7}$$

The three first order conditions are

$$\frac{\partial \pi_{BB}}{\partial B} = P_D\left[\frac{\partial G}{\partial y_{BS}}\frac{\partial y_{BS}}{\partial B}\sigma + \frac{\partial G}{\partial K}\frac{\partial K}{\partial B}\sigma_K + \frac{\partial G}{\partial yTI}\frac{\partial TI}{\partial pat}\frac{\partial pat}{\partial B}\sigma_{pat}\right] - \frac{\partial C}{\partial B} +$$

$$+(1-\mu)E\left[\frac{\partial Roy}{\partial pat}\frac{\partial pat}{\partial B}\sigma_{pat}\right]=0 \tag{8}$$

$$\frac{\partial \pi_{BB}}{\partial TI}=P_D\frac{\partial G}{\partial TI}-\frac{\partial C}{\partial TI}=0 \tag{9}$$

$$\frac{\partial \pi_{BB}}{\partial pat}=P_D\frac{\partial G}{\partial yTI}\frac{\partial TI}{\partial pat}\sigma_{pat}-\frac{\partial C}{\partial pat}+(1-\mu)E\left[\frac{\partial Roy}{\partial pat}\sigma_{pat}\right]=0 \tag{10}$$

Therefore, the BB optimal levels of B^*, K^*, and the optimal effort in getting a patent, pat^*, must simultaneously satisfy equations (8)-(10). Equation (8) states that the BB intends to stipulate the bioprospecting contract, if and only if, the actual marginal revenues, denoted by $P_D\left[\frac{\partial G}{\partial y_{BS}}\frac{\partial y_{BS}}{\partial B}\sigma+\frac{\partial G}{\partial K}\frac{\partial K}{\partial B}\sigma_K+\frac{\partial G}{\partial yTI}\frac{\partial TI}{\partial pat}\frac{\partial pat}{\partial B}\sigma_{pat}\right]$, plus the expected marginal revenues, denoted by $(1-\mu)E\left[\frac{\partial Roy}{\partial pat}\frac{\partial pat}{\partial B}\sigma_{pat}\right]$, arising from the selling of drugs obtained by the transformation of the screened samples, purchased in the bioprospecting contract, can fully offset the marginal costs of writing this contract, $\frac{\partial C}{\partial B}$. Equation (9) states that the optimal amount of investment is determined by the marginality condition. More interestingly, Equation (10) shows that the BB has the incentive to patent its new products, and pharmaceutical inventions, as long as its financial returns, which are expressed in terms of the value of increasing productivity, $P_D\frac{\partial G}{\partial TI}\frac{\partial TI}{\partial pat}\sigma_{pat}$, plus the additional, potential effect that patenting will bring on the expected royalty payoff, $(1-\mu)E\left[\frac{\partial Roy}{\partial pat}\frac{\partial pat}{\partial B}\sigma_{pat}\right]$, are larger than the total costs of patenting, $\frac{\partial C}{\partial pat}$. It is clear from Equation (10) that patenting has a positive impact on investments in technology, since the research discoveries and pharmaceutical innovations are protected by the legislation. The improved and patented technology, in turn, can increase the utilization potential of genetic resources and their value in reducing the time and costs of screening for pharmaceutical and other uses (Craft and Simpson 2001). Moreover, we can also consider the scenario where patenting may lead to create a monopolistic position for the BB. In this case, the BB will significantly increase its market power. This will be reflected in the possibility to set the drug market price. In formal terms, this is defined by:

$$\lambda=\frac{P_D(y_{BB},pat)-P_D(y_{BB})}{P_D(y_{BB},pat)} \tag{11}$$

With $\lambda > 0$, $P_D(y_{BB}, pat) > P_D(y_{BB})$ and $P_D(y_{BB}) \equiv P_D(y_{BB}, pat = 0)$

According to equation (11), patenting the new pharmaceutical products and innovations is responsible for the determination of a "monopolistic price overcharge", whose magnitude is captured by λ, also denoted in the literature as price mark-up. Against this background, we can re-write equation (10) as

$$\frac{\partial \pi_{BB}}{\partial pat} = P_D \frac{\partial G}{\partial yTI} \frac{\partial TI}{\partial pat} \sigma_{pat} + \frac{\partial \lambda}{\partial pat} y_{BB} - \frac{\partial C}{\partial pat} + (1-\mu) E\left[\frac{\partial Roy}{\partial pat} \sigma_{pat} \right] = 0 \quad (12)$$

Therefore, when the BB is legally allowed to patent the product, this effect can be used by the company as a tool to increase its market power, and thus earn greater profits. The magnitude of this effect is given by $\frac{\partial \lambda}{\partial pat} y_{BB}$. This constitutes an additional incentive for the private company to endorse R&D, which was not originally foreseen in equation (10).

4. DISCUSSION OF THE IMPACTS OF BIOPROSPECTING CONTRACT AND PATENTING ON WELFARE

In the previous sections we have shown that bioprospecting contracts and patenting are significant variables affecting the objective functions of the parties under consideration. The prospect of higher individual profits, and market power, can stimulate the BS and BB to endorse in bioprospecting and BB to endorse patenting. The following analysis will formally assess the total welfare impacts involved and their distribution among the stakeholders. Let us assume that the total welfare function is given by the following Samuelson-Bergson additive function:

$$W = \pi_{BS} + \pi_{BB} + v(x, y_{BB}, S)$$

$$W = p_B(B;\underline{\theta}) \cdot F(s(\underline{\theta}), L(B;\underline{\theta}), T(B;\underline{\theta})) - C_{BS}(s, L, T, B) + \mu \cdot E[Roy(pat)] +$$

$$+ P_D(y_{BB}, pat) \cdot G[y_{BS}(B;\underline{\sigma}), K(B;\underline{\sigma}), TI(pat(B);\underline{\sigma})] - C_{BB}(y_{BS}, B, TI, pat) +$$

$$+ (1-\mu) E[Roy(pat(B);\underline{\sigma})] + v(x, y_{BB}(B; pat), B)$$

with $P_D > p_B$

or,

$$= P_D\left(y_{BB}, pat\right)\cdot G\left[y_{BS}\left(B;\underline{\sigma}\right), K\left(B;\underline{\sigma}\right), TI\left(pat\left(B\right);\underline{\sigma}\right)\right] - C_{BS}\left(s, L, T, B\right) - C_{BB}\left(B, TI, pat\right) +$$

$$+ E\left[Roy\left(pat\left(B\right);\underline{\sigma}\right)\right] + v\left(x, y_{BB}\left(B; pat\right), B\right) \qquad (13)^3$$

Equation (13) shows that the welfare function is given by the aggregation of BS and BB objective functions. In addition, we also consider the consumer's utility expressed in monetary terms, denoted by *v(.)*. The latter increases with the consumption of all other goods, *x,* the consumption of pharmaceutical products, whose market is characterized by monopolistic power due to patenting. Finally, the consumer's utility is also modelled as depending on *B* and this may be interpreted as signalling consumer's motivation with respect to the writing of the bioprospecting contract in terms of its contribution to the provision of impure altruistic, and/or aesthetic and/or existence values. For example, this may reflect the consumer *additional* willingness to pay for the market drug in the scenario where he, or she, is guaranteed that the respective production process is characterized by the respect of the knowledge of local communities property rights. For this same reason, the consumer feels good when buying this product since he, or she, is also "buying" moral satisfaction or warm-glow as derived from such a "good" cause (see Andreoni 1990, Nunes and Schokkaert 2003). Alternatively, this effect may premium the producer effort to protect the degradation of local biodiversity and respective landscape, including avoiding bio-piracy[4] actions. It is important to note that the price of bioprospecting contract, or the price of screened samples, p_B, is assumed to be smaller than the price of successful developed drugs, p_D, which embeds all bio-technology values in R&D and the commercial value of the new drugs. The difference can be interpreted as added-value resulting from the efforts that the intermediary puts forward in order to improve the quality of biotic information contained in their supplied samples. As Swanson (1994) noted, information and insurance values are connected with the quality of the genetic resources.

A) The effects of the contract on social welfare:

$$dW = P_D\left[\frac{\partial G}{\partial y_{BS}}\frac{\partial y_{BS}}{\partial B}\sigma + \frac{\partial G}{\partial K}\frac{\partial K}{\partial B}\sigma_K + \frac{\partial G}{\partial yTI}\frac{\partial TI}{\partial pat}\frac{\partial pat}{\partial B}\sigma_{pat}\right]dB - \frac{\partial C_{BS}}{\partial B}dB - \frac{\partial C_{BB}}{\partial B}dB +$$

$$+ E\left[\frac{\partial Roy}{\partial pat}\frac{\partial pat}{\partial B}\sigma_{pat}\right]dB + \left(\frac{\partial v}{\partial y_{BB}}\frac{\partial y_{BB}}{\partial B} + \frac{\partial v}{\partial B}\right)dB \qquad (14)$$

Equation (14) shows that the bioprospecting contract has several welfare impacts. A close inspection of this equation shows that most of these are related to the objective function of the BB, see Equation (8). This means that, from the selected welfare perspective, all the benefits that the BS receives from the

bioprospecting contracts are balanced by the BB costs of buying screened samples. Therefore, these benefits do not appear in (14), they are simple transfers. However, this component can be of relevance from a distributional point of view. Especially, when the social planner attaches a higher welfare weight to BS, including the evaluation of the non-monetary benefit sharing effects accrued to the BS (e.g. technology transfer, internal personnel training, capacity-building, and sharing of research results and biological databases). However, this distributional welfare gain might generate additional and significant administrative costs (for instance, the costs of monitoring the contract execution and/or enforcing the contract). This might jeopardize the efficiency of the governance structure and related efficiency gains.

In particular, from Equation (14) we can distinguish the following welfare impacts:

(a) $P_D\left[\frac{\partial G}{\partial y_{BS}}\frac{\partial y_{BS}}{\partial B}\sigma + \frac{\partial G}{\partial K}\frac{\partial K}{\partial B}\sigma_K + \frac{\partial G}{\partial yTI}\frac{\partial TI}{\partial pat}\frac{\partial pat}{\partial B}\sigma_{pat}\right]$, which corresponds to the BB marginal revenues effects;

(b) $E\left[\frac{\partial Roy}{\partial pat}\frac{\partial pat}{\partial B}\sigma_{pat}\right]$, which corresponds to the expected marginal royalties revenues, that will be distributed among the BS and BB according to the μ share. The higher μ, the higher is the transfer of expected marginal royalties revenues to the BS.

In addition, we can see that the contract has two effects on the level of the consumer's utility and, thus, welfare. First, such effect refers to the impact of the bioprospecting contract on the level of supply of the drugs in the market, i.e. $\frac{\partial v}{\partial y_{BB}}\frac{\partial y_{BB}}{\partial B}$. Since the marginal utility of the consumption of the drugs is non-negative, $\frac{\partial v}{\partial y_{BB}} \geq 0$, and the marginal effect of the bioprospecting contract on the production of drugs is also non-negative, $\frac{\partial y_{BB}}{\partial B} \geq 0$, we can expect this effect to be positive. Second, $\frac{\partial v}{\partial B}$ captures the marginal impacts of the bioprospecting contract in terms of impure altruistic, aesthetic and/or existence values to the consumers. Finally, $\frac{\partial C_{BS}}{\partial B}$ and $\frac{\partial C_{BB}}{\partial B}$ shows that the contracting is a costly activity for both BS and BB, respectively, and this way affects negatively the welfare function.

To conclude, the overall effect on social welfare is unknown but most likely expected to be positive. This positive effect is strengthened by three main determinants: (1) the lower is the transaction cost; (2) the higher is the benefit of the contract in terms of the BB productivity and potential royalty revenues; and (3) the higher is the consumer valuation of the contract.

B) The effects of patenting on social welfare:

$$dW = \left[P_D \frac{\partial G}{\partial yTI} \frac{\partial TI}{\partial pat} \sigma_{pat} + \frac{\partial \lambda}{\partial pat} y_{BB} \right] dpat + E\left[\frac{\partial Roy}{\partial pat} \sigma_{pat} \right] dpat + \frac{\partial v}{\partial y_{BB}} \frac{\partial y_{BB}}{\partial pat} dpat - \frac{\partial C}{\partial pat} dpat \quad (15)$$

where we have $-\frac{\partial C}{\partial pat} < 0$. This is interpreted as a negative impact on the social welfare and indicates the relevance of the costs of patent application and renewal fees for the new drug products. In addition, patenting generates the following welfare impacts. First, the expression $P_D \frac{\partial G}{\partial yTI} \frac{\partial TI}{\partial pat} \sigma_{pat}$ refers to welfare benefits from patenting due to technological investments and respective productivity, and thus profitability, of the pharmaceutical sector. This may well signal the well-known literature effect that points out that patents creates incentives for R&D (see Heller and Eisenberg 1998; Willison and MacLeod 2002). In this context, patents do encourage research and may be essential for the success of drug development (Peeters and Van Pottelsberghe De La Potterie 2006). Second, patenting is also responsible for the creation of a monopolistic market. A patent holder achieves the monopolistic profits, by being the only producer of the products since the patent represents a legal barrier to entry. This effect is captured by $\frac{\partial \lambda}{\partial pat} y_{BB}$, which is interpreted as having a positive impact on social welfare. On the other hand, the positive effects of patenting on the BB's profits are counterbalanced by the negative impacts on consumer surplus. This effect is expressed by $\frac{\partial v}{\partial y_{BB}} \frac{\partial y_{BB}}{\partial pat}$, where the term $\frac{\partial y_{BB}}{\partial pat}$ is negative since higher prices (and thus lower quantities) due to patenting and applied by the BB monopolist will negatively affect consumer surplus[5].Finally, the patenting generates a financial revenue is terms of royalty payments, captured by $\frac{\partial Roy}{\partial pat} \sigma_{pat}$, which is interpreted as having a positive impact on social welfare. From the theoretical point of view, we can not establish a priori the overall effect (sign) of patenting on social welfare. The respective magnitude is a matter of empirical research.

5. CONCLUSIONS

The paper contains an economic analysis of bioprospecting contracts. We first reviewed a number of existing contracts worldwide in order to identify the main provisions and parties, namely biodiversity seller (e.g. local governmental and/or international research institution) and biodiversity buyer (e.g. private pharmaceutical firm). We then identified the pharmaceutical industry as a private sector involved in bioprospecting activities, representing the largest global market of genetic resource products. For this same reason, this stakeholder is identified as having an important role in formulating the current bioprospecting contracts on the

commercial use of genetic resources. Hence, we shifted our research emphasis on the pharmaceutical industry.

By clarifying the pharmaceutical research process, and the specific contractors we gained insight into the contract contents and the bioprospecting activities. These studies provide the grounds for modelling the contractors' objective functions and respective welfare impacts. All in all, our analysis provides the following results. First, modelling bioprospecting contracts has allowed us to create an original theoretical framework that explains the observed stylized facts and to study and capture the different components of the parties' objective functions. Second, comparative static analysis reveals that the selected governance structure for exchanging biodiversity has different, mixed impacts on social welfare. This is because the positive impacts delivered by bioprospecting contracts are associated with the potential discovery of a new drug product, productivity gains, non-monetary benefit sharing or transfers and royalty revenues. The negative welfare impacts of bioprospecting contracts, in turn, are due to the legal creation of a monopoly and the related well-known effect on the consumer surplus. Finally, the potential redistribution effects are limited and the enforcement of this objective may jeopardise the desirability of the contract since this action will bring a significant increase in the transaction costs. Future research should focus on studying whether bioprospecting contracts are transaction costs-minimising governance structures and on deepening and broadening empirical research in an econometrics of contracts perspective.

6. NOTES

[1] *Source suppliers* refer to the stakeholders that originally have property rights over genetic resources or indigenous knowledge. This group consists of source countries governments, local management entities and indigenous people/communities (i.g. the Kanis), some of which have the ability to grant permission for the access to, and use of, genetic resources and their derivatives, such as the national governments/organisations(i.e. Brazilian Extracta). Sources suppliers also refer to the stakeholder groups that have access to traditional knowledge, on the basis of which the private companies may directly profit or make new and improved products (i.g. CSIR South Africa). For further information, see Nunes *et al.* (2006).

[2] Generally speaking, patenting may also cover a class of genetic materials and their broad applications (Lawson 2004). It must therefore lead to a more active patenting behavior in response to the application or imitation of the patented inventions by the external collaborators and competitors. Therefore, the BS has the possibility to patent new biological components discovered during the screening process. This is not modeled because it is not the object of the formal bioprospecting contract, core of the present analysis.

[3] Since the revenue of the BS corresponds to the BB costs of buying screened samples, we can eliminate the first term by deleting the BB cost component with respect to the y_{BS}.

[4] As an example of biopiracy, we report the following case. In 1995 the U.S. Department of Agriculture and a pharmaceutical research firm received a patent on a technique to extract an anti-fungal agent from the Neem tree (*Azadirachta indica*), which grows throughout India. Indian villagers have long understood the tree's medicinal value. Although the patent had been granted on an extraction technique, the Indian press described it as a patent on the Neem tree itself; the result was widespread public outcry, which was echoed throughout the developing world. Legal action by the Indian government followed, with the patent eventually being overturned. Importantly, the pharmaceutical company involved in the Neem case argued that as traditional Indian knowledge of the properties of the Neem tree had never been published in an academic journal, such knowledge did not amount to "prior art" (*prior art* is the term used when previously existing knowledge bars a patent). In response to biopiracy threats such as this, India has been translating and publishing ancient manuscripts containing old remedies in electronic form. (see Sheva, 2006)

[5] Furthermore, since patenting is here associated to the presence of a bioprospecting contract, in order to derive the net consumer surplus one needs to take into account the positive effects in to consumers in terms of impure altruistic, aesthetic and/or existence values, as described in the previous paragraph.

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8. REFERENCES

Andreoni, J., Impure altruism and donations to public goods: a theory of warm-glow giving, Economic Journal 100, 464-477 (1990).

Artuso, A. (2002) 'Bioprospecting, benefit sharing, and biotechnological capacity building', World Development, vol. 30(8), pp. 1355-1368.

Bhat, M.G. (1999) 'On biodiversity access, intellectual property rights and conservation' Ecological Economics, vol. 29(3), pp. 391-403.

Breibart, J. (1997) 'Bioprospecting Planed For Yellowstone Park' , available at the internet site, http://www.albionmonitor.com/9709b/parkbugs.html.

Cardinal, L.B. and D.E. Hatfield (2000) 'Internal knowledge generation: The research laboratory and innovative productivity in the pharmaceutical industry', Journal of Engineering and Technology Management, vol. 17(3-4), pp. 247-271.

CBD (1992) 'Convention on Biological Diversity', available at the internet site, http://biodiv.org/doc/legal/cbd-en.pdf.

Craft, A.B. and D.R. Simpson (2001) 'The value of biodiversity in pharmaceutical research with differentiated products', Environmental and Resource Economics, vol. 18(1), pp. 1-17.

Dedeurwaerdere, T. (2005) 'From bioprospecting to reflexive governance', Ecological Economics, vol. 53(4), pp. 473-491.

Dedeurwaerdere, T., Krishna, V. and U. Pascual (2005) 'Biodiscovery and Intellectual Property Rights: A Dynamic Approach to Economic Efficiency', Department of Land Economy in its series Environmental Economy and Policy Research Working Papers, 13.2005, University of Cambridge, Cambridge, UK.

DiMasi, J.A., Hansen, R.W., Grabowski, H.G. and L. Lasagna (1991) 'Cost of innovation in the pharmaceutical industry', Journal of Health Economics, vol. 10(2), pp 107-142.

Greer, D. and B. Harvey (2004) Blue Genes: Sharing and Conserving the World's Aquatic Biodiversity, Earthscan Publications and International Development Research Center, London, UK.

Grifo, F., Newman, D., Fairfield, A.S., Bhattacharya, B. and J.T. Grupenhoff (1997) 'The origins for prescription drugs' in F. Grifo and G,. Rosenthal (Eds.), Bidiversity and Human Health, pp. 131 - 163, Island Press, Washington D.C., USA.

Heller, M.A. and R.S. Eisenberg (1998) 'Can patents deter innovation? The anticommons in biomedical research', Science, vol. 280(5364), pp. 698-701.

ICBG - International Cooperative Biodiversity Groups (1997) Report of a Special Panel of Experts on the International Cooperative Biodiversity Groups (ICBG), available at the internet site, http://www.fic.nih.gov/programs/finalreport.html.

Lawson, C. (2004) 'Patenting genetic materials' unresolved issues and promoting competition in biotechnology', Information Economics and Policy, vol. 16(1), pp. 91-112.

Merson, J. (2000) 'Bio-prospecting or bio-piracy: intellectual property rights and biodiversity in a colonial and postcolonial context', Osiris, vol. 15, pp. 282-296.

Mulholland, D.M. and E.A. Wilman, (1998) 'Bioprospecting and biodiversity contracts', Working papers in Ecological economics, Number 9806, Center for Resource and Environmental Studies, The Australian National University, Canberra, Australia.

Neto, R.B. and D. Dickson, D. (1999) '$3m deal launches major hunt for drug leads in Brazil', Nature, vol. 400, page 302.

Nunes, P.A.L.D. and J.C.J.M. van den Bergh, (2001) 'Economic valuation of biodiversity: sense or nonsense?', Ecological Economics, vol. 39, pp. 203-222.

Nunes, P.A.L.D. and E. Schokkaert (2003) “Identifying the Warm Glow Effect in Contingent Valuation”, Journal of Environmental Economics and Management, 45, pages 231-245.

Nunes, P.A.L.D., Ding, H. and I. Musu (2006) ' Is Bioprospecting Contract an Efficient Market-based Policy Instrument for Biodiversity Conservation?', paper presented at the International BIOECON Conference on Economic Analysis of Ecology and Biodiversity, 29-30 August, Kings College, Cambridge, UK.

Onaga, L. (2001) 'Cashing in on nature's pharmacy', European Molecular Biology Organization Reports, vol. 2(4), pp. 263-265.

Onofri, L. (2003a) “Contracts, Investment Incentives and Efficiency in the Restructured Electricity Market” European Journal of Law and Economics, Vol. 16, N. 1, pp. 23-38.

Onofri, L. (2003b) 'Art Sponsor Contracts: a Law and Economics Approach', in proceedings of 5th Workshop in Institutional Economics, June 2003, Department of Economics, Pompeu Fabra University, Spain.

Peeters, C. and Van Pottelsberghe De La Potterie, B. (2006) 'Innovation strategy and the patenting behavior of firms', Journal of Evolutionary Economics, vol. 16(1-2), pp. 109-135.

Rausser, G.C. and A.A. Small (2000) 'Valuing research leads: Bioprospecting and the conservation of genetic resources', Journal of Political Economy, vol. 108(1), pp. 173-206.

Rosenthal, J.P., Beck, D., Bhat, A., Biswas, J., Brady, L., Bridbord, K., Collins, S., Cragg, G., Edwards, J., Fairfield, A., Gottlieb, M., Gschwind, L.A., Hallock, Y., Hawks, R., Hegyeli, R., Johnson, G., Keusch, G.T. Lyons, E.E., Miller, R., Rodman, J., Roskoski, J. and D. Siegel-Causey (1999) 'Combining high risk science with ambitious social and economic goals', Pharmaceutical Biology, vol. 37(supplement), pp. 6-21.

Ruth, L. (2006) 'Gambling in the deep sea', European Molecular Biology Organization Reports, vol. 7, pp. 17-21.

Simpson, R.D., Sedjo, R.A. and J.W. Reid (1996) 'Valuing biodiversity for use in pharmaceutical research', Journal of Political Economy, vol. 104(1), pp. 163-185.

Standard and Poor’s Corporation (2003) Industry Survey on Healthcare: Pharmaceuticals, Report, June 26, New York, USA.

Sheva, V. (2006), The Neem Tree- a Case History of Biopiracy, The Third World Network.

Swanson, T.M. (1994) The International Regulation of Extinction, New York University Press, New York, USA.

Ten Kate, K. and S.A. Laird (1999) The Commercial Use of Biodiversity, Earthscan Publications, London, UK.

Ten Kate, K. and S.A. Laird (2000) 'Biodiversity and business: Coming to terms with the "grand bargain"', International Affairs, vol. 76(2), pp. 241-264.

Thumm, N. (2005) 'Patents for genetic inventions: a tool to promote technological advance or a limitation for upstream inventions?', Technovation, vol. 25(12), pp. 1410-1417.

Willison, D.J. and S.M. MacLeod (2002) 'Patenting of genetic material: Are the benefits to society being realized?', Can. Med. Assoc. J., vol. (167), pp. 259-262.