The stake of contract uncertainty in bioprospecting

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Abstract

To the extent that they exist, markets for genetic resources (GR) and traditional knowledge (TK) are incipient, thin and subject to a series of imperfections. While a growing body of literature address the role of valuation and property rights for such resources, much remains to be understood concerning the factors that influence concrete GR and/or TK access agreements. This paper constitutes an attempt to explain empirically bioprospecting contract performance in terms of investment uncertainty theory. Specific attention is paid to cost and price uncertainty, as represented by information acquisition through experience, and industry characteristics, respectively. Interviews and the bioprospecting literature suggest that such uncertainty distort both supply and demand of GR and TK. We apply an ordered probit model to explore how uncertainty affects the performance of bioprospecting contracts. The model is also aimed to control for investor characteristics, participation and legal framework. Preliminary results support theory by suggesting a negative uncertainty-investment link in bioprospecting projects, specifically, by causing project cancellations and distortions. This has implications for the way providers and demanders should think about access agreements and the preparation of such agreements.

1. Introduction

This paper aims to explain the uncertainty factors that influence the success of transfer agreements of GR, between southern economies and industry, typically northern pharmaceutical industry.[2] We apply the findings from the investment uncertainty literature to explore three kinds of uncertainty, namely cost uncertainty, price uncertainty and, in a more tentative fashion, legal uncertainty. International transfers of GR such as plant medicines, and associated TK provide strategic inputs for northern research and development activities (the resulting activity is

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[2] Some definitions and precautionary notes: we refer to Philippines Executive Order and Implementing Regulations for a definition of bioprospection: "the research, collection and utilisation of biological and genetic resources, for purposes of applying the knowledge derived there from for scientific and/or commercial purposes" (Laird & ten Kate, 1999). The absence of contracts to regulate such access is commonly referred to as biopiracy, although the content of that is expression in subject to debate. We count as a bioprospector any organisation that performs such activities, including: commercial or non-commercial, governmental or non-governmental (e.g. research oriented organisations that does not enrol in commercial activities but which may provide altered or unaltered GR to third parties, e.g. pharmaceutical industry, and culture collections). Project, agreement, contract and case are used synonymously throughout the paper We refer to such GR that are addressed by CBD, i.e. not human GR. Note that for reasons of data availability our dataset does not distinguish between bioprospection agreements for GR alone, and GR together with TK, respectively. "Success" is used only in its contractual sense of an agreement that is not cancelled or subject to distortions (Sykuta, 2005). In that respect the appreciation of contract outcomes is highly relative, and a success for agent X may be considered a failure for agent Y. For example several authors would suggest that any of the contracts described here are failures (Shiva, 1997, ETC, 2005). Also, we anticipate that some stakeholders may not be familiar with the association between bioprospecting and investment, e.g. scientists that are devoted to research without explicit commercial links, or communities that participate without explicit profit interest. Our approach is further discussed in section 3. Modelling framework. Also, our discussion deals with bioprospector's *access* to GR and TK. This topic is different from the very important debate about the risk that bioprospectors *exclude* the traditional covenants of such resources from using them. That analysis goes beyond the scope of this paper, including the discussion about associated failures of the international IPR regime to address such issues. Lastly, note that due to lacking data for our empirical study, in the overall discussion of this paper we do not distinguish between bioprospection agreements for GR alone, and GR together with TK, respectively. Annex 1 provides an introduction to the bioprospection topic

commonly referred to as bioprospection).[3] At the same time, such resources may constitute an important potential source of income for communities with GR and TK or governments in southern countries. Another factor is that local communities often depend on GR and TK for their cultural, spiritual but also health needs and food supply.[4] Against a historical background of free access to such resources it appears to be important to have information about the drivers and barriers to properly handled bioprospecting contracts. This is particularly important because we can assume that the same factors, which impede ABS agreements, also induce access without agreements. The current economics literature on bioprospecting is focused largely on the issue of valuation and property rights, respectively (insert refs). Given the growing theoretical literature on bioprospecting it has been suggested that there is a general lack of empirical evidence (Polsky, 2005). There is now a significant stock of access agreement to learn from, and systematized analysis may provide complementary insights into the broad range of barriers to such endeavours. This paper aim to contribute in that direction. By focusing on the role of contractual uncertainty it is envisioned that the study will provide useful new information for both advocates and critics of the current international system of access and benefit sharing of GR and associated traditional knowledge.[5]

The empirical investment literature early recognised that uncertainty plays an important role in for investment. Several empirical papers have found support for a negative uncertainty-investment link, e.g. in the decision to entry (Kalckreuth, 2000), delay (Joen, 2004) and exit investments (Nilsson & Soderholm, 2002). Uncertainty can take many forms, including technological, financial, political and organisational uncertainty. With investment we refer not only to financial contributions, but also other concepts of opportunity cost, such as time, effort and reputation, which may or may not be easily translated to monetary units.

As in any contractual relation the outcome of GR and TK activities are sensitive to uncertainty derived from information failure (Mulholland and Wilman, 2003). Firstly we will explore cost uncertainty: the bioprospection literature indicates that heterogeneity and lack of understanding of local conditions is a common problem and barrier to orderly continuation or project completion. We test how information acquisition during the course of a project affects the project outcome. Our second focus is on output uncertainty as linked to industry uncertainty: our study focuses on exploitation of GR and TK for pharmaceutical uses.[6] As described by for example Swanson and Luxmore (1996) the pharmaceutical industry is characterised by substantial product uncertainty. That is, it can take 15 years of testing before a medicine that uses GR reaches the market, if it does ever. We attribute this kind of uncertainty to price uncertainty, as it enters the bioprospectors income function. Thirdly, we aim to address legal uncertainty: while lacking information about all financial aspects of the contract is one concern, access agreements are also frequently distorted by the lack of clear and predictable legal and regulatory frameworks. On the institutional side, procedures often lack one clearly defined authority to issue the necessary permits. Internationally, these barriers have in several occasions impeded exchange of GR and TK, for both commercial and scientific use (Laird 2002).[7]

[3] Swanson (1996) explores how northern industry depends on biodiversity, in a dynamic fashion. An industry survey among biotechnology firms indicates that both the future of crop development and pharmaceutical companies crucially depend on constant supplies of in-situ germ-plasm. Specifically, the author places the analysis within an evolutionary context, in which manmade specializations of pest and stress resistant crops (or new drugs) face an uneven competition against constantly mutating wild pests and bacteria. The rapid depreciation of human made inventions necessitates continuous supply of in-situ inputs from the same competitive evolutionary context that generates the pests.

[4] One estimation is that 80 percent of the world's population depend on GR for their primary health needs (Fassil, 2003). Poor local communities are especially vulnerable, and bioprospection, if improperly handled, may have adverse effects in terms of GR and TK erosion. Meanwhile, the associated research trials and other can require up to 30 tonnes of GR as inputs for one single medicine.

[5] Typically, northern and southern research and industry organisations tend to support bioprospection, while some of the opponents come from northern and southern civil society and mass media. There are many examples of both supporters and opponents among provider communities and southern governments.

[6] This is partly a consequence of that the majority of available case studies deal with this sector. However, arguably CBD and subsequent ABS agreements has had the most significant impact on this sector.

[7] Examples are US National Cancer Institute's (NCI) two recent project withdrawals from the Philippines, and NCI's Cameroon project at the beginning of the 199Os, although our interviews indicate that the legal uncertainty to varying degree affects virtually all bioprospection contracts.

We deploy an ordered probit model to test for a negative uncertainty-investment link in bioprospecting contracts. Our results supports the theoretical prediction: cost and price uncertainty is negatively correlated with contractual success for bioprosection projects. Legal uncertainty is not significant, which we attribute to the crudeness of our proxy variable. Section 2 provides a general conceptual framework, followed by the empirical model specification in section 3. Section 4 outlines the regression model, which is tested and interpreted in section 5. Section 6 provides tentative conclusions.

2. Conceptual Framework

Investment decisions in general depend to a high degree on the price of capital, and on its expected marginal profitability (Caballero, 1991). In a traditional neo-classical framework the decision to invest (or enter into a contract) is based on a theoretical environment with full information, reversible investments (i.e. no sunk costs) and rational agents: investors are assumed to compute today's discounted value of alternative uses of the investment capital, and subsequently choose the project that render the highest outcome. The more recent investment uncertainty theory relaxes the assumptions by allowing for irreversible investments and for the option to wait. Uncertainty increases the value of waiting. For example, an investor can ameliorate uncertainty put on hold his decision in order to allow for acquiring an investment feasibility study or other information that reduce uncertainty). In bioprospection this translates to PIC and other activities to reduce information asymmetries, or disruptions during the project process, motivated by the need to enhance the information stock. Such changes may well result in adjustments of the initially agreed contract conditions. Furthermore economic theory predicts that different degrees of risk averseness, irreversibility, and competition generate different signs of the uncertainty - investment relationship. Broadly speaking, higher risk averseness and sunk costs decrease investment (Dixit & Pindyck, 1994). However, Caballero (1991) shows that the market needs to be incomplete for the sign to be negative. Indeed, for risk neutral agents the effect may be positive if the investment is relatively reversible, and if there is perfect competition. However, the case of perfect competition is clearly not the case in bioprospecting.

Also, the outcome depends on the agent's cost function, specifically on the cost relationship between entry and exit, or Bell and Campa's (1997) example, to invest or divest. That is, if increased uncertainty raises the probability for both positive and negative outcomes, and if it is less costly to divest than to invest, higher uncertainty would induce the agent to invest rather than to wait. Also the source of uncertainty is important. Individuals are prepared to take higher risks for such events about which they feel they have higher knowledge. Subsequently, a risk averse decision maker is expected to act more like risk neutral for uncertainty about which it is more familiar (e.g. organisational, political, legal, institutional). This is particularly important when discussing the impact of prior knowledge to the investment environment, such as in the case of renewed investments, but also for cost uncertainty. Regarding uncertainty on the output side, Pindyck (1988) shows that volatile and unpredictable demand affects the volume of investment negatively. Furthermore investment uncertainty theory acknowledges that several kinds of uncertainty and volatility, including policy uncertainty, may distort markets and investment patterns by giving rise to market uncertainty (Dixit and Pindyck, 1994).

3. Modelling framework

Bioprospection has been analysed from a broad set of disciplines. By applying the investment uncertainty theory to the analysis of bioprospection we hope to throw new light on the actual drivers and barriers to individual access agreements. This approach implies that we analyse the basic economics problem of economizing with scarce resources in order to meet alternative ends (e.g. effort and reputation). As such, it is not restricted to projects with an explicit profit rationale, but encompasses any underlying rationale for participation, including the furthering of scientific knowledge. It follows that the term payoff is used to reflect any such result of a bioprospecting project. The investment literature provides some empirical support for the investment uncertainty theory (Kalckreuth, 2000; Nilsson and Soderholm, 2002; Jeon, Kim & Miller, 2004; Blandon, 1999; Roberts & Weitzman, 1981). Bell and Campa (1997) highlight the importance of the investment agents' risk perception. While providers of GR and TK may be assumed to often be risk averse, due to low economic endowments, bioprospectors may well be

risk neutral. Bioprospection projects often require large sunk costs in financial commitments, time, effort and reputation. Thin markets and imperfect information means low degree of competition. This combination calls for a negative uncertainty - investment relationship. Bell & Campa (1997) emphasizes that the source of uncertainty is related to risk averseness. Agents can be assumed to gain increasing command by experience from similar investments. It is beyond the scope of this paper to discuss the relative likelihood of gaining familiarity of the kind of organisational uncertainty which is our primary focus, as compared to uncertainty of input out output prices, exchange rates and other. Also, to a certain degree the discussion is different: uncertainty such as price uncertainty is objectively measurable as volatility. The concept of organisational uncertainty is less measurable. In any case the heterogeneous nature of cross-cultural relation clearly pose a considerable uncertain context to bioprospection agreements, especially when indigenous communities are involved.

Information, and in particular lack of (precise and certain) information is at the core of bioprospection. For the purpose of this study we will take a loose definition of investment uncertainty as the basis of the analysis. Bioprospection will be analysed as an investment pursued by the bioprospector. This investment is re-evaluated along the contracting process due to that information acquisition along the way may alter the expected payoff of involvement. It follows that the investor face repeated situations in which to choose whether to continue or interrupt the contracting process, or, to wait in order to acquire more information. We will study the entire contract process, which potentially may include negotiation of the contract, via signing and implementation, until completion. However, it can also interrupt or even cancel at any stage of this process. As such we will deal with both entry and exit situations. The framework is seen as a continuous series of choices to continue, interrupt temporally, or withdraws from the bioprospecting project. As such, the setting corresponds to investment uncertainty theory's value of waiting.

We denote the output simply as value, V, as measured in monetary or other terms. $V=\Sigma R_i - \Sigma C_i (\alpha_i \beta_i \theta_i)$, where R, returns from bioprospection project, which in the case of a research organisation may be product discovery and for pharmaceutical company is financial profit, respectively. *C* is the cost incurred and can be irreversible or reversible. α_I and β_I are different choice attributes (e.g. type of counterparts) and investor characteristics (e.g. the industry with which the use of accessed GR and TK is intended), $\theta_{I\,is}$ uncertainty (e.g. local knowledge, industry specific level of uncertainty). *i* stands for individual contracts, and *E(),* expected value. The choice to contract (or not), to halt the negotiations or implementation, or to withdraw (and thereby cancel the project) is based on the value function $E(V) = f(\theta_1 \ldots \theta_n; \alpha_{1\ldots} \alpha_n; \beta_{1\ldots} \beta_n)$. The bioprospector face the choice to withdraw, *W*; interrupt temporarily, *I*, e.g. in order to acquire more information (value of waiting) or proceed without interruption, *P*. The corresponding choice values are V^W, V^I, V^P. It follows that the bioprospector will decide to proceed without interruption, if V^W > some threshold value x_3, for which $E(V^W) > E(V^I), E(V^P),$ interrupt temporarily, if V^I > some threshold value x_2, for which $E(V^I) > E(V^W), E(V^P),$ or withdraw, if V^W > some threshold value x_1, for which $E(V^W) > E(V^I), E(V^P).$

We introduce a cost uncertainty variable that addresses the role of information acquisition during the course of a project. Specifically, from the bioprospector's point of view, increased knowledge about local conditions and counterparts is a valuable commodity as it may increase project success. The reduction in uncertainty enters the bioprospector's cost function, which means it is a type of cost uncertainty. Our variable distinguishes between green field investments and project renewals (Jeon et al, 2004[8]). In a similar fashion it would be expected that during the course of a bioprospecting project the project parties of the agreement accumulate information about the project organizational setting and conditions, which stimulates future project success.[9] Increased information translates into lower value of waiting (as the information is already known).

[8] Jeon et al (2004) takes on a similar approach in their study of foreign direct investment in Korea: they argue that information about the local investment conditions plays an important role in reducing uncertainty about future payoffs. As a firm acquire a growing stock of information about the local project setting during the course of a project, it follows that when the same investor contemplates subsequent projects in the same project setting it would face less uncertainty, and have greater incentive to continue to invest.

[9] Bell & Campa (1997) indirectly found support for the idea that information acquisition stimulates investments. They estimated the drivers to investment scale in the chemicals industry in US and EU. They found that greenfield investments tend to be larger than renewed investments.

Similarly, irreversible costs give the investor more incentive to invest a marginal unit in order to increase the probability of earning a payoff that compensates for the initial investment.

The bulk of empirical investment uncertainty applications focus on macro level uncertainty (exchange rate volatility) or industry wide uncertainty (such as input and output price volatility). However the bioprospection literature emphasises the role that organisational uncertainty has on project outcomes. The investment uncertainty theoretical framework lend itself to all forms of such imperfect information which is introduces uncertainty in investment situations. The management and organisational literature has emphasised organisational uncertainty, which predicts that many endogenous interaction factors are important for project outcome, such as: lack of effective communication and of buy-in for an iterative development approach, faulty project methodology, poor requirements gathering and documentation and lack of unified tool use.[10] At the demander side, the characteristics of the bioprospectors industry contribute to structurally different levels of uncertainty. For example there is comparably more uncertainty about the final scientific and commercial success of research in the pharmaceutical industry than in other industries. For example, bioprospection in the botanical medicine sector normally addresses GR alone, not TK (as botanical medicine is already widely used and therefore not subject to patent regulation). Furthermore, such GR is normally widely accessible common property. This is largely the case also for cosmetics and personal care bioprospection, and is often argued to apply also to the agricultural sector. It follows that the provider may not have clearly defined property rights (e.g. land rights or intellectual property rights).[11]

Increased transaction costs was the argument used by several large pharmaceutical corporations that closed bioprospection operations during the 1990s.[12] Specifically, those demanders argued that CBD and associated PIC and ABS guidelines had increased their transaction costs to a shadow price level that made alternative technologies more attractive (e.g. combinatorial chemistry).[13] However, it is key to the problem to recognise that their transaction costs not only depended on new provisions for benefit sharing, but to a high degree to the financial and other cost of contract negotiations.

As described, at the macro level there is clearly a case for addressing the role of policy uncertainty. The legal framework and its enforcing institutions are at the core of the bioprospection debate. From an investment point of view, the CBD guidelines about assuring local participation in bioprospection projects has a parallel to FDI regulation that sets requirements for minimum allowed local ownership. However, in our model CBD will be analysed in terms of legal uncertainty. Such regulation inherently generates increased other uncertainty and transaction costs for investors. In fact, the need to negotiate with source communities is perceived as a highly unpredictable and resource demanding element. Furthermore, detailed regulations may motivate more involvement by source court governments. As host countries of GR and TK tend to be developing countries their bureaucracies are less efficient and may even generate other kinds of uncertainties. To sum up these additional elements may outweigh the perceived benefits of lower legal uncertainty. Ideally the variable would reflect the characteristics of the legal and institutional framework. Our variables for CBD legislation are included as a first attempt to test empirically for the effect of changes in legal and policy environment.

4. Data and Variables

A database of 190 bioprospection cases was constructed based on secondary information, such as case studies of individual bioprospecting cases, and interviews with international experts.[14] The

[10] This field has been less attended by economists and there is a subsequent gap in economics empirical evidence.
[11] Lack of clearly defined property rights has contributed to over harvesting and has resulted in that many GR have been driven to being at risk of extinction.
[12] In fact, corporations such as Merck were major bioprospectors, with annual quantity of quantity and diversity of GR strains that outperformed by the ones of cultural collections.
[13] In spite of that the benefits of such substitute technologies have proven to be exaggerated, these pharmaceutical corporations have not returned to biorprospection. Nevertheless several of them continue to acquire GR from intermediaries such as contracted collecting firms or cultural collections.
[14] The case studies are principally written by academic and semi-governmental research institutions, and their content is backed up by interviews, books and mass media articles.

database includes cases from different countries and which access GR and TK for different user purposes. Due to difficulty to obtain data, further analysis is performed on a subset of 52 observations from 21 developing countries in Africa, Asia, Latin America and Oceania. We included bioprospection project that initiated in the 1990-2003 period.[15] [16]

Contractual outcomes can be viewed as a result of a continuous, unobserved index that represents how favourable the contract setting is. That is, from the point of view of how it affects the probability of success. Each contractual outcome corresponds to a specific range of such contract setting index, where higher ratings correspond to a more favourable range of contract setting. We view the contractual outcome as a qualitative ordinal variable, for which the ordered probit model is specifically designed. Assume that the unobserved continuous measure, contract setting ($`y$), is a linear function of a set of explanatory variables x, with parameter vector β, and an error term ε. μ is the threshold value that define the ranges of the contract setting index:

$$`y=\beta`x+\varepsilon$$

As usual, $`y$ is unobserved. The observed component is the contractual outcome, i.e. cancellation, interruption (without cancellation) and continuation (without interruption) in the 1990-2003 period:

$y=Cancellation$ *if* $`y \leq \mu_1$,

$y=Disruption$ *if* $\mu_1 < `y \leq \mu_2$,

$y=Continuation$ *if* $\mu_2 \leq `y$

Estimation proceeds by maximum likelihood, because of the asymptotic properties of ML estimators: consistency, normal distribution and efficiency (Green, 2002).

Annex 2 summarises the variables that are used in the ordered probit regression. The project is defined from the start of project negotiations until the end of the project. The dependent variable *Outcome* represents project outcome, and is classified as (0) cancelled, (1) interrupted (for example for the purpose of re-negotiation), or (2) continued (without interruption). As the standard case from the investment uncertainty literature the investor bases his choice on maximized expected payoff.[17] The principal variables used to control for uncertainty are: firstly, the dummy variable *Renewal* is introduced to reflect the value of local knowledge, and secondly, *Dem_end* and *Dem_RnD*. The latter two can be analysed together and represent industry of the bioprospector. *Renewal* represents project renewals (as opposed to greenfield investments) and is expected to be positively related to project success. Our price uncertainty dummy variables are *Dem_end* and *Dem_RnD*. Both are GR demanders that are dedicated to the pharmaceutical

[15] A few notes representativity and potential bias: firstly, lack of data is a frequent constraint in econometrics of contracting. Sample sizes are commonly small due to the cost of data collection, and due to proprietary attributes of contract information (Sykuta, 2005). This is further emphasised by the sensitive political nature of bioprospecting agreements, and, due to the relatively recent surge of such contracts. The cases in the dataset represent only a portion of the total number of biorprospecting agreements. However, there is no particular reason to assume that they are not fairly representative. Secondly, one potential concern would be that case studies are biased towards successful cases, as such information is more easily accessible. However, table 1 indicates balanced case outcomes in the dependent variable. Thirdly, as showed in Table 1 some of the dummy variables have rather few observations for one of the categories. This implies that, for example, the results of the *Renewal* variable should be analysed carefully.

[16] The time period is chosen to maximise the number of cases. That is, bioprospection started to receive broader attention in the beginning of the 1990s, and we did not find sufficient information about earlier cases.

[17] The case studies upon which the dataset is based include both finalised and ongoing projects (at the time when the case study was written). This could affect the comparability of the cases because an ongoing project is less likely to have faced distortions, simply because it is compared to a project that was recently initiated at the time when the case study was written. As older cases are more likely to have received more complete scrutiny in case studies and mass media (which was our back up source of information), we performed sensitivity analysis to find out if more recent projects performed better. This was not the case, but the project outcomes are well distributed throughout the time period of our dataset. We also took the measure to exclude all projects initiated later than 2003.

products. However, *Dem_end* represents such pharmaceutical organisations that commercialise products to the end market (although they may also enrol in research and development (R&D) activities), while *Dem_RnD* does not. We hypotheses that commercially oriented bioprospectors brings with them attributes that increases uncertainty, and therefore contract failures. To control for the inherent uncertainty in the pharmaceutical industry, the dataset includes a minor set of bioprospector from other sectors.[18] By analysing *Dem_end and Dem_RnD* together we control for if the attributes of this third group affects the model differently.

In order to control for the legal framework and institutions that are aimed to enforce it, the dummy variables *CBD_Full* and *CBD_w* are introduced. The variables control for if the case was initiated before or after CBD came into force globally (i.e. 1993), and before or after that the source country ratified CBD at the national level (anywhere between 1993 and 2003, if at all), respectively. It should be kept in mind that the legal framework for controlling bioprospection is very heterogeneous between the source countries, and the CBD variable is only a crude approximation. Additionally, note that the variables have inherently low variability as only 21 countries are represented in the dataset. However we acknowledge that country variables may hold important information about the variability in the model (Bell and Campa, 1997[19]), and, the important role that the legal framework has for bioprospecting cases motivate us to include even such a crude approximate variable. We hypothesise in a tentative fashion that the CBD variables are negatively correlated with the outcome.[20] The cases, which initiated before CBD came into force (and consequently before country ratification) constitute a control group.[21]

To measure the effect of uncertainty on contract outcome it is necessary to control for other factors at the level of the contract and the investment country. The dummy variable *Coun_gov* controls for if the source country Government participates in the bioprospection agreement. This participation variable may indeed affect the project outcome in different ways. It could be anticipated that participation decreases uncertainties about the country setting, including legislative and institutional issues. At the same time it may increase uncertainty linked to bureaucracy, or just increase organisational complexity as such.[22] Therefore the outcome is ambiguous, even when controlling for other variables, such as country capacity level (our proxy GDP per capita) in general. The dummy variables *Dem_US* and *Dem_non* represent cases in which the demander is only a US organization, and cases in which the demander is a Non-US, non-source country organization, respectively. The variables are included to control for if the origin of the genetic resource demander is influential. As non of the cases in our dataset have both a US and a source country demander, the remaining possibility is controlled for, namely that the demander is a source country organization only. The bioprospection literature and interviews does not give information about the expected sign of the variables but it is included as it is perceived that it may account for some of the variability in the model.[23] *Dem_Pub* and *Dem_PP*

[18] Those cases are bioprospecting for botanical medicine. In order to increase the comparability of the cases we included only such agreements for which the provider has some kind of property. That is, instead of including cases of botanical medicine, in which the BS arrangement is a mere per hour payment for bulk supply of GR, without TK, we aimed to included such cases in with the BS agreement also account for payments for the use of the provider communities image etc. in product marketing.

[19] Barbier (2004) also suggest the use of composite models, although not explicitly the mix of micro and macro variables.

[20] After all, the fact that bioprospectors did not acknowledge PIC and ABS issues prior to CBD signals that it is the regulatory pressure that drives CBD compliance, not the demander's project rationale *per se*.

[21] The variable is time dependent and may be highly correlated with the maturity of direct and indirect source country stakeholders (e.g. source country provider organisations and communities, mass media, civil society, respectively). However, "CBD_ctry" helps to control for that effect. Namely, while CBD_w represents one year, 1993, CBD_ctry relates to different years in different countries. Therefore, CBD_w may be related to the maturity of international watchdogs (as they can be argued to be relatively more influenced by the likewise international CBD_w), but to less extent the maturity of national mass media and civil society.

[22] For example, for FDI in general, local participation (e.g. joint ventures) may be associated with higher risk.

[23] For example, one could hypothise that local demander institutions should face an informational advantage about legal and intuitional frameworks, as well as the cultural setting. However the only such case for which we have more detailed information is the Indian Kani case, which first phase was cancelled and the second face distortions. Another potential hypothesis would be that US demanders are subject to less regulatory pressure from their home country (as US has not ratified CBD) and thus should apply less degree of PIC and

are dummy variable that represent those demanders that are publicly owned, and private-public partnerships, respectively. The former is entirely composed by projects conducted by the US National Cancer Institute (NCI), and the latter by the US International Cooperative Biodivesrity Group projects (ICBG). They are analyzed jointly to control for the effect of Degree of public ownership of genetic resource demander, and for the third category of entirely private demanders (e.g. Shaman Pharmaceuticals, Diversa). Note that academic institutions have been classified as private. This has two reasons: firstly, it is often difficult to separate private and public academic institutions, and secondly, what we wish to analyze is to what extent public organisations are under higher pressure to comply with CBD. Resulting PIC and BS agreements reduces uncertainty and increases success rate. But can produce organisational complexity. We hypothise that public demanders are more likely to adhere to PIC and ABS measures than private organisations. That is because the former group may be more visible to both source and demander home country watchdogs. It would follow that public organisations face more distortions and cancellations than others. On the other hand, in the case of our dataset the variable is represented by NCI projects. Subsequently it is correlated with the experience of the demander, and potentially with the project size (NCI has pursued bioprospection activities since the 1960s, in over 60 countries). However we do not expect to be able to draw clear conclusions from this variable.

The macro variable *GDP_cap* stands for yearly GDP per capita adjusted for purchasing power parity. It is included to incorporate in the model the capacity level of the source country. Increased capacity may induce more "distortions" and "cancellations". Also, governments in poorer countries tend to have fewer resources to set aside for implementing and enforcing regulation of bioprospection. Siebenhauer (2005) surveyed international CBD negotiators and found that African countries in general commonly raise concerns over their limited financial and institutional capacity to deal with bioprospection. At another level, governmental and other institutional capacity in a broader sense tend to increase with GDP (ref). For example, countries in which the national civil society movement [24] has higher capabilities are expected to interact more frequently in order to highlight contracts that they consider unfair. Risk averseness and incomplete markets, both which are expected to increase by lower country incomes, increase the probability that uncertainty negatively affects investment. The above factors appear to outweigh the potential impact of that risk averseness increases with lower income. It could be argued that poor countries, their communities or governments, would be more sensitive to risk and therefore have less incentive to invest. In our model that would translate in more contract failures. However, they may also be more susceptible to external pressure from bioprospectors, and, if the project does not entail much risk for them, they may even have higher incentive to enter and honour agreements.

The bioprospection literature highlights that the institutional setting and property rights structure (for land with GR, or for TK) at the community level frequently cause distortions of projects, for example, through competing claims to take part of ABS agreements. One reason is that people understand rights differently (Strathern, **XXX** and Kalione, **XXX**) Due to the difficulty in define a proper indicator that accounts for such factors, we use a crude proxy, PopGrRur, to represents rural population growth at the country level. We hypothise that the variable puts pressure on local institutions and property rights regimes, thereby affecting project outcomes in a negative way. However, as for *GDP_cap* we apply the precautionary note that we do not put too much hope in generating significant outcomes.

Table 1: Descriptive statistics for the ordered probit model estimation

Variable	Units	Mean	Std. Dev.	Min	Max
outcome	Dummy	1.090909	.7998316	0	2
Uncertainty variables					

BS in their projects. Following the reasoning of our legislative framework variables, this would translate into potentially less exposure to source country legal frameworks and institutions, and subsequently higher success rate. However, as the US data is biased by NCI and ICBG cases, both which adopt fairly detailed internal ABS regulations, this hypothesis is not considered to be valid.

[24] For a further discussion, refer to Berlin & Berlin (2003), Descola (2003), Hayden (2003) and Green (2004).

renewal	Dummy	.1818182	.3892495	0	1
dem_end	Dummy	.3461538	.4803845	0	1
dem_rnd	Dummy	.5192308	.5045046	0	1
dem_oth	Dummy	.1346154	.3446423	0	1
cbd_full	Dummy	.7818182	.4168182	0	1
cbd_w	Dummy	.1090909	.3146266	0	1
cbd_non	Dummy	.1090909	.3146266	0	1
Control variables					
coun_gov	Dummy	.6727273	.4735424	0	1
dem_us	Dummy	.6727273	.4735424	0	1
dem_non	Dummy	.1818182	.3892495	0	1
dem_sour	Dummy	.1454545	.355808	0	1
dem_pub	Dummy	.1090909	.3146266	0	1
dem_pp	Dummy	.2545455	.4396203	0	1
dem_pri	Dummy	.6363636	.4854794	0	1
popgrru	USD	.2052097	1.084362	-2.055711	2.999439
gdp_cap	Yearly % growth	6792	6307.219	740	36000

5. Results

As shown in table 2, both of the more important uncertainty variables support the negative uncertainty-investment relationship hypothesis. Firstly, our variable for price uncertainty (*Renewal*) show the expected sign and is significant. This would suggest that project renewals perform better in contractual terms than new projects, and that the value of information acquisition appear to be so relevant that it ought to be acknowledged that the value of waiting in bioprospecting projects is important. Theory suggests that higher degree of irreversibility of the project further increases the value of waiting, which may but not has to be the case in larger and longer-term projects. Given the tentative status of the model we should not take this result as a given. Secondly, the variables for industry uncertainty indicate that the uncertainty attributes of commercially oriented pharmaceutical projects have a more negative impact on project outcome than is the case for purely research oriented pharmaceutical bioprospectioin (*Dem_end* and *Dem_RnD*, which are translated to price uncertainty). We compare the variables jointly and thus derive the conclusion that the lower uncertainty associated with non-pharmaceutical projects (represented by that variable *Dem_RnD* takes the value "0") results in fewer distortions and cancellations than in the case of pharmaceutical projects.

Table 2: Results of ordered probit regression

Outcome	Coef.
renewal	.9832979 (.4769505)
dem_end	-1.336041 (.6905778)
dem_rnd	-1.028368 (.6231267)
cbd_full	-.8685194 (.6653488)
cbd_w	1.537667 (1.143518)
coun_gov	.6232614 (.4656192)
dem_us	1.123738 (.6598148)
dem_non	1.241041 (.6540008)
dem_pub	-1.301301 (.7262345)
dem_pp	-1.006326 (.6462651)
Popgrru	.2971761 (.2467442)
gdp_cap	-.0000638 (.0000374)

** Significant at the 5% level: * significant at the 10% level
Standard errors are in parenthesis

Non of the macro level variables *Cbd_full, Cbd_w, or PopRrRu* were significant. This is likely to depend on their high level of aggregation which fails to include such information that is relevant at the case level (for example rural poverty is highly heterogeneously distributed which implies that the variable fails to provide the adequate linkage to the maturity of local institutional and property rights setting). In the case of the legal variable we have already noticed the difficulty in depicting in a appropriate way the quality characteristics of such complex and heterogeneous issues such as regulatory framework and implementation mechanisms. Also, there is low

variability in the data since macro variables for only 21 countries are set to represent 52 cases. The variable for government participation is not significant (*Coun_gov*). Furthermore, both D*em_us* and *Dem_non* are significant, but with unexpected sign. The sign and scale of the coefficients would imply that; projects in which the demander is a US institution experience fewer contract cancellations and distortions, followed by projects in which the demander is neither from the US nor from the source country. The lowest performance is to be seen when the demander is from the source country alone (which indeed confirms the experience of the Kani case). *Dem_pub* is significant and with expected sign, implying that the publicly owned NCI projects face more distortions and cancellations than others. *Dem_pp* is not significant so we cannot draw conclusions about the third case, which is projects in which the project demander comes from the source country.

Our hypothesis about country income level is supported, as the *Gdp_cap* show the expected sign and is significant. This would suggest that the higher institutional capacity associated with higher income developing countries provide a more challenging setting for bioprospecting demanders. On the one hand increased income translates into a broader set of alternative activities to invest in. That is, the opportunity cost of participating in bioprospecting activities (neither by no means should we underestimate the considerable investment that a bioprospection project imply for a rural community, not to mention cultural and spiritual issues) may be high as compared to other investments. On the other hand, as rural communities and government institutions, they are likely to be playing at a more level playing field with bioprospector demanders. Also, civil society and mass media watch dogs become more alert. From the point of view of the bioprospector, this is weighted against the positive factor, which is that counterparts are more capable to provide adequate services, including scientific and academic collaborator institutions. This is likely to explain why bioprospecting contracts are still common in higher income developing countries such as Brazil, the Philippines and Mexico. As a first test of robustness of the results we regressed the same data with an ordered logit model. None of the variables changed significance level.[25]

6. Conclusions

In this paper we have analysed empirically how contract uncertainty and other variables affect the outcomes of bioprospecting agreements. Preliminary results support theory by a negative uncertainty-outcome relationship. This refers both to our variable for information acquisition during the coarse of a project (a form of cost uncertainty), and for the variable that represents industry related uncertainty of the demander. This information may leverage the decision basis for existing and prospective GR and TK providers and demanders: if project renewals are more successful, and if this is due to the information acquisition process, then that would suggest a high value of waiting (to acquire information). This conclusion may then be brought backwards in the project process so that also new projects consider the value of investing more in project preparations, including PIC, in order to filter out unpromising projects, and to create a more solid basis for the projects, which are more likely to succeed. As for the higher uncertainty in commercially oriented projects: pharmaceutically oriented bioprospecting projects are clearly more risky than others. However, this is also acknowledged in relatively higher BS arrangement for such contracts. To sum up: in order to decrease information asymmetries and exaggerated expectations (a potential source of disruptions and cancellations), GR and TK providers should be aware of the risks of involvement and weigh them towards the potential benefits that may derived from successful drugs, in order to decide whether to enter an agreement or not. Demanders should also address thoroughly such risks in the PIC activities preceding the signing of bioprospecting contracts. It is the CBD framework that drives the applications in the field of PIC and ABS, and it is widely recognised that barriers to compliance are driving demanders to access GR and TK without taking the appropriate PIC and ABS measures. Therefore, from our findings it would appear to be relevant for policy makers and other stakeholder alike to recognise fully the importance of ameliorating contractual uncertainty. Our variable for legal uncertainty was not significant. Consequently, a suggestion for future research is that it would be desirable to enhance the data for the legal uncertainty variable in order to better explore the role of legal-institutional setting.

[25] Alternative model specifications will be tested and further sensitivity analysis and tests applied.

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Annex 1: The context of bioprospection

The failure of the market mechanism to serve as a vehicle for ABS has many reasons: the lack of clear property rights; the systemic nature of GR and TK impedes any attempts to break them down in discrete units: the failure of present IPR regimes to address the most adequate management of such resources (e.g. its definition of innovation excludes most traditional contributions to GR development and conservation, and of TK production) (Swanson and Goschl, 1999). Dedeurwaerdere (2004) develops the idea and, with a reference to new institutional economics and evolutionary economics, suggests that the problem lies within the institutions as such: the misallocation of PR and resulting monopolisation of information is a consequence of structural social economic factors and basic power structures. Another factor is that the problem relates to the vertical market structure, i.e. the production chain, not the horizontal market structure of competing buyers (for which Coase's solution is applicable). The solution, as Swanson shows, is public intervention (Swanson and Goschl, 1999). To address access and benefit sharing (ABS) of GR and associated TK the Convention on Biodiversity (CBD) entered into force in 1993. The CBD establishes that GR and TK are property of the source country, and makes explicit provisions for the special link between TK, biodiversity and local and indigenous communities. Furthermore CBD documents refer to that Free Prior Informed Consent (FPIC) is to be obtained from the holders of GR and TK before bioprospection activities take place, and, that the demander of GR and TK need to ensure that the provider receives equitable benefit sharing. However the ambitious language of CBD is not reflected in corresponding clear guidelines on how to implement it in the terrain. As a result the more specified, but voluntary, Bonn guidelines emerged. CBD is in legal terms are binding for all member countries. However, it finally rests upon the member countries to implement regulation that enacts CBD. The present legal situation provides a highly uncertain legal framework for bioprospection. At the national level, recent amendments and new laws in several source countries consider FPIC and ABS to varying degree, from the strict and detailed regulations of Samoa (where the government charges fixed fees to grant bioprospection permits and require additional PIC and BS arrangements in the case that communities participates) to more vague or partial recognition in the broad majority of countries. Much of the debate concerns either the degree of government control over access endeavours, or the degree of centralization of GR and TK information. The first is exemplified by Philippine's previously centralized permit process, versus Mexico's approach of leaving much control to the holders of land with GR. Concerning GR and TK information India has chosen to publish GR use practices - such as traditional medicinal recipes - on the internet. While this strategy limits illegal patenting, it may also deprive the TK holder or country of the possibility to seek own intellectual property protection.[26] The 1990s saw several high profile cases of ABS contracts.

The high demand and subsequent value of some GR and TK has suggested that bioprospection can even be an instrument for large scale biodiversity conservation, that is, by providing land holders with the economic incentives to conserve biodiversity rich land. However Pearce (**XXX**) and Simpson (**XXX**) suggest that the number of species with commercial value is not high enough. An industry survey reported that one quarter of prescription drugs contain active ingredients from plants, but that they were derived from only 40 species (Olsen, Swanson and Luxmoore, 1997). Rausser and Small (2000) argues that bioprospection under certain conditions can finance biodiversity conservation. Moreover, its value may not be sufficient to compensate landholders, and communities' income needs are often too urgent to allow for the both uncertain and longer-term benefits expected from research and development processes. Swanson (1995a) specifies that total GR value is composed by the land holders user value of land and, from the viewpoint of demanders, portfolio value, quasi option value and exploration value. As showed in the literature on deforestation, poverty and high population growth are critical factors in the opportunity cost of land. It follows that compensation to the community needs to be at least the marginal benefit of land conversion. Pascual, Dedeurwaerdere & Krishna (2005) analyses the provider side of bioprospection by performing a contingent valuation analysis on the provider community that is enrolled in the highprofile bioprospecting case Kani, in India. Among other, they find that the community members do indeed assign a for them important economic value on their resources.

[26] Commonly discussed measures include patents and trade secrets.

Annex 2: Details of the variables included in regression analysis

Variable	Variable description	Effect on Outcome
Dependent variable		
Outcome	Contract has been cancelled, distorted but not cancelled, not distorted (and not cancelled)	
Uncertainty variables		
Renewal	The agreement constitutes a renewal/not	(+) diminished uncertainty through local knowledge etc.
Dem_end	Pharmaceutical institution: end market (can include R&D)/not	(-) commercial agreements subject to more uncertainty regarding benefit sharing, etc.
Dem_RnD	Pharmaceutical institution: R&D exclude end market)/not	
Dem_non	Non pharmaceutical institution/not	
CBD_Full	World ratification, and entering into force in the country/not	(-) CBD legislation tend to be imperfectly implemented.
CBD_w	World ratification, but not entered into force in the country/not	
CBD_non	No world ratification, and not entered into force in the country/not	
Control variables		
Coun_gov	Government participates/not	Ambiguous
Dem_US	US organisation only/not	Ambiguous
Dem_non	Non-US, non-source country organisation/not	
Dem_oth	Source country organisation only/not	
Dem_Pub	Public (e.g. National Cancer Institute)/not	(-) more exposure to CBD
Dem_PP	Public and private (e.g. ICBG)/not	
Dem_Priv	Private (e.g. Diversa, Shaman)/not	
GDP_cap	Yearly GDP per capita adjusted for Purchasing Power Parity	(-) increasing capacity level and alternative investment opportunities for providers
PopGrRur	Rural population growth	(-) poor institutions and property rights regime