Essays on Resources and Institutions

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Declaration of Authorship

I, *Mare Sarr*, confirm that the work presented in this thesis *"Essays on Resources and Institutions"* is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signature:______________________

Date:_________________________

A Faat N'diaye Ken Bougoul et A Mame Awa N'diaye.

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Abstract

This thesis consists of four essays covering two sets of issues linking resources to institutions.

Chapter 1 provides a summary of the thesis.

Chapter 2 provides a general overview of the resource curse literature, emphasising the role of institutions, the nature of the political regimes in resource-rich countries and the link with civil conflicts.

Chapter 3 examines the implications of liberal lending practices of international credit markets to dictators during resource booms. We show that the combination of institutional weaknesses such as unaccountable leadership and unsound lending may give autocrats perverse incentives to loot and destabilise their countries, which impedes economic growth.

Chapter 4 investigates what motivates some dictators in resource-rich countries to invest in productivity enhancing public goods while others deliberately choose predatory or repressive policies. We find that the ruler is more likely invest in public goods when the productivity of the non-resource sector is high, and when he is relatively ineffective in controlling the country's resources.

Chapter 5 presents an overview of the literature on intellectual property rights focusing on the problems raised by sequential innovations for the design of patents and the role of legal institutions in resolving disputes.

Chapter 6 examines the nature of the North–South divide in the bioscience industries as a hold-up problem caused by the lack of coordination between North and South property rights systems. We develop a model of bargaining in a sequential R&D framework that demonstrates the mechanism by which underinvestment in maintaining biodiversity and inefficient flow of information occurs.

Chapter 7 assumes that the coordination problem is resolved and investigates the number and placement of the property rights to provide incentives for efficient investment in information generation. We show that the existence of a property right in the genetic resources is necessary for the South to share in the rents from the R&D sector. When traditional knowledge is the South's private information, it is not necessary to establish a separate property right in it to appropriate its return.

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Chapter 1

Overview of the Thesis

This thesis consists of four essays covering two sets of issues linking resources to institutions. The first part of the thesis is concerned with the political dimension of the so-called curse of natural resources, i.e. the inverse relationship between resource abundance and economic growth across countries. The second part examines the North/South divide over the issue of intellectual property rights in the life sciences industries (pharmaceutical and biotechnology).

Part I: Political Dimension of the Resource Curse

Part 1 of the thesis is comprised of three chapters investigating the political dimension of the curse of natural resources. In particular we explore the conditions under which dictators ruling resource-rich countries have incentives to undertake productive investment.

Chapter 2: Resource curse and Institutions: Literature Overview Chapter 2 provides an overview of the resource curse literature, highlighting its evolution as well as the controversy and disagreement among researchers. We also link the economic literature and political science literature by specifically pointing to the connection between resource abundance and political regimes—in particular dictatorship (Ross, 2001)—and civil conflict (Collier and Hoeffler, 1998 and 2004).

This chapter starts by highlighting the influential work by Sachs and Warner (1995) in uncovering the persistent negative statistical relationship between natural resource exports and economic growth measured as per capita GDP. In its early days, the resource curse puzzle received considerable support based on case studies (Auty, 1994) as well as on statistical analysis—see Gylfason (2001) on the role of education and human capital, or Atkinson and Hamilton (2003) on the unsustainable development path chosen by many resource-rich countries. However, various authors have cast doubt on the validity of Sachs and Warner's findings. First, the relevance of natural resource exports as a measure of resource abundance rather than a measure of resource dependence is questioned, along with the endogeneity of this measure. Second, the resource curse literature does not explain the heterogeneity among resource-rich countries very well, i.e. why some countries perform badly while others have been highly successful. Third, the development of the literature on "endogenous institutions" points to an indirect effect of resources on growth through institutions, rather than a direct effect as documented by the early literature.

This chapter goes on to discuss the two other commonly accepted manifestations of the resource curse. First, we examine the link between resources and dictatorships (Ross, 2001) and the presumption that the quality of a dictator may determine whether or not a country will suffer from the resource curse. Second, we discuss the link between resources and civil conflicts (civil wars). In an influential paper, Collier and Hoeffler (2004) argue that resource wealth enhances the likelihood of a civil war because of the greed (rather than grievance) of the rebels. This result, however, is challenged on the basis of its lack of robustness. (Fearon, 2005) Other critiques like Brunnschweiler and Bulte (2008b) question the validity of the causal link established by Collier and Hoeffler and find that once endogeneity is controlled for, the probability of the onset of a civil war decreases with a truly exogenous measure of resource abundance.

The literature on the curse has various facets and tries to pull together insights from both economics and political science. Despite significant progress (an emerging consensus on the role of institutional quality is gaining momentum), the empirical literature of the resource curse provides many contradicting results and many issues remain unsettled.

Chapter 3: On the Looting of Countries: International Lending, Political Instability and Economic Growth Comparing the relative performance of Indonesia and Mexico—two resource-rich countries—Usui (1997) points to a striking regularity in international lending patterns: the fact that resource booms tend to attract international inflow of capital in the form of lax lending and borrowing. In fact, international lending patterns have followed resource booms and busts remarkably closely over the 30-year period between 1970 to 2000 (see Figure 3.6). Manzano and Rigobon (2001) argue that the explanation of the resource curse puzzle can be traced back to this very phenomenon which, according to them, has caused debt overhang and subsequently led to the resource curse.

Following the idea of "resource boom-based lending", this chapter investigates how inflows of unsound lending can induce the wrong incentives when resource-rich countries are led by unaccountable and self-interested leaders. We develop a dynamic discrete choice model of a self-interested and unchecked ruler making decisions regarding the development of a resource-rich country. Resource wealth serves as collateral and facilitates the acquisition of loans. The ruler makes the recursive choice of either staying in power to live off the productivity of the country while facing the risk of being ousted, or looting the country's riches by liquefying the natural assets through external lending. We assume that the risk incurred by staying is reduced by investing in capital or investing in security (military, police, etc.). We show that unstructured lending from international credit markets to a resource-rich dictator can enhance his ability to liquefy assets, and create incentives to loot the country's wealth. Second, we find that an enhanced likelihood of looting reduces tenures (greater political instability), increases indebtedness, reduces investment, and diminishes growth. These predictions are tested using a treatment effects model where instability proxied by leadership turnover is the treatment equation and per capita GDP growth is the outcome equation. We find strong empirical evidence that instability caused by unsound lending to unchecked rulers of resource-rich countries may result in slow economic growth. This result is robust to a number of changes.

Chapter 4: Resources, Conflict and Development – Public Good Provision in Resource-Rich Economies Many scholars find it intriguing that some leaders apparently deliberately choose sub-optimal predatory policies when they could choose developmental policies that yield higher returns, if only out of sheer self-interest. (Robinson, 2001) However, when a resource abundant country is led by a self-interested autocrat and when the mere existence of natural resources increases the threat of a conflict (Collier and Hoeffler, 1998; 2004), then the question might be rather why would such a ruler implement pro-development policies—namely public good provision: provision of health, education, infrastructure—instead of predatory or repressive policies? Often, the very public good supplied by a dictator becomes the instrument of his demise.

We develop a Stackelberg game between a ruler and the population of a resource-rich country, to analyse the ruler's decision to provide a public good in the context of a contest over the resource wealth. The ruler's actions are first, to invest or not in a public good and second, to choose a level of repression in response to the population's decision to fight. The population chooses the allocation of its time between working in the non-resource sector and fighting to appropriate natural resource rents. We find that the ruler's policy choice depends critically on the extent of the resource wealth; on the productivity of the non-resource sector; and finally on the ruler's relative effectiveness to control the resources. In particular, this dictator is likely to invest in public goods when the non-resource sector is productive enough to raise the population's opportunity cost of fighting. On the other hand, he is less likely to invest in public goods to buy the peace when he is relatively effective in contesting the resources. Depending on these parameters, different policy choices are made, resulting in different public good decisions. We present empirical evidence consistent with the predictions of the model.

Our contributions in this first part of the thesis are twofold: first, we contribute to a better understanding of the resource curse by providing *conditional theories* that help explain why some resource-rich countries are successful while others are not. Second, we test empirically the proposed theories to assess their relevance. Such attempts are still very rare in the resource curse literature and we hope that our contributions will demonstrate the value of such exercise.

Part II: The North–South Sequential Innovation Problem

In the second part of the thesis, we examine the North–South divide over intellectual property rights (IPR) within the framework of sequential investment in informational goods.

Chapter 5: Intellectual Property Rights & Sequential Innovation: Literature Overview

This chapter provides a overview of the intellectual property rights literature in industrial organisation, with an application to the North–South relationship. Intellectual property rights refer to legal protection conferred to individuals over their creation. An intellectual property rights system is an incentive mechanism that provides inventors with temporary exclusive ownership rights so that they engage in innovative and creative works. There are various forms of intellectual property rights: patents, copyrights, trade secrets, trademarks, etc. Among them, patents are the strongest and most robust form. They are particularly used to protect innovations in the pharmaceutical sector.

In the course of this review, we discuss in detail the rationale of the IPR system and the requirements for patentability as well as the policy questions regarding the optimal design of patents—a much debated issue by economists. We look at these issues both for stand-alone innovations and cumulative and sequential innovations (i.e. when an invention draws directly from a previous one to make further development). Cumulative innovations are, however, our main focus. The important finding made by Green and Scotchmer (1995) is that when innovation is cumulative, the patent life should be longer than with stand-alone innovations, and the scope of the patent should be broad enough to prevent minor improvements to compete with the original innovation. Such a policy is necessary to provide the first innovator enough of an incentive to invest since, without his investment, no follow-on innovation is possible. This literature, therefore, clearly points to the protection of the first innovation. This prescription is at odds with the practice in the life science industries where a single patent right is placed at the level of the second innovation.

The North–South bilateral relationship is presented within the industrial organisation (I/O) framework of a vertical research and development (R&D) industry where the North—downstream—and the South—upstream—are at each end of the industry. The South generates information originating from natural capital through investment in traditional human capital (traditional knowledge or TK)[1] and land use for the preservation of biological diversity. The North uses this information as an input in the R&D process to bring new drugs to the market. The summary of the I/O literature on successive R&D makes clear that the issues relating to patent rights and claims in these industries are important to the determination of efficient flow of information across the R&D process as well as the division of the rents. When individual entities interact in the creation of related information and innovations, it is the willingness of states to recognise these contributions and of courts to enforce these rights that determines the shares that each innovator receives.

Admittedly, as a statutory right, an IPR has little value if it is not enforced by courts in case of infringement. We discuss how courts resolve disputes regarding patent cases and highlight the remedies at their disposal to do so—injunctions and damages—as well as their effects on efficiency and distribution.

[1] In this thesis, traditional knowledge (TK) refers to the accumulated stock of human capital and knowledge over the centuries about the properties of medicinal plants.

Chapter 6: North–South Hold-up Problem in Sequential R&D In this chapter, we provide an analysis of the nature of the problem faced by the North and the South in terms of a hold-up problem. It is often argued that the creation of property rights in the primary information generated by the South—genetic resource-based information and associated traditional knowledge—is necessary to solve the incentive problem. However, this solution to the property rights failure overlooks another crucial problem, i.e. a property right is a domestic statutory right that does not span the boundaries of the jurisdiction conferring it: there is no such thing as an 'international property right'. Given the nature of the information generated by the South (naturally-occurring information and traditional knowledge), they are likely to be considered as mere discoveries or non-novel knowledge and as such are not amenable to intellectual property rights as defined by the North. Therefore, for the rights conferred in the South to deserve protection and compensation, there is a need for coordination between the legal systems from both regions.

The hold-up problem reflects the inability of the North and the South to coordinate their legal systems in order to promote global cooperation for access to genetic resources on a more equitable basis. We develop a model of North-South bargaining in a sequential R&D framework to shed light on the mechanism by which underinvestment in maintaining genetic diversity and an inefficient flow of information in bioprospecting occurs. Our main focus in this chapter is the incentive for efficient investment in land use to preserve biodiversity. This investment is a necessary condition for useful genetic resources to be found and traditional knowledge to be developed. We show that when the property right in genetic resources conferred in the South is not enforceable *ex ante* across jurisdictions (in the North), a hold-up problem may arise and lead to underinvestment in genetic diversity. We also find that under certain conditions, a liability rule imposed *ex post* by courts in the North can resolve the hold-up problem. In other words, under specific conditions, when the North is ordered to pay damages to the South for infringing its rights, *ex post* enforcement of property rights across jurisdictions helps circumvent the hold up problem and may encourage socially optimal investments. This happens if courts can make the South the residual claimant of the surplus created by its investment. Thus, legal institutions play an essential role by establishing the rules that give the South proper incentive to undertake optimal investment. However, as we will see, these conditions are not general so that sub-optimal investment in maintaining diversity is the most likely outcome. This chapter highlights the role that legal institutions may play in shaping the incentives to invest.

Chapter 7: Economics of Traditional Knowledge as Private Information This chapter assumes that governments in North and South are able to coordinate their legal systems and recognise the property rights conferred in the other region. Once the contributions from the South are protected in the North, the question then becomes which contributions should be protected by intellectual property rights. That is, we are interested in determining the number and placement of these rights to achieve efficiency. The South provides two different informational goods that are often bundled together in the literature: genetic information and traditional knowledge. To investigate this question, we formalise traditional knowledge as the South's private information on the most promising and useful genetic resources for R&D purposes. We show that in the absence of traditional knowledge, the protection of genetic resources determines the starting point for negotiations by providing the South with an outside option that is to be reckoned with. Contracting between the primary and secondary stages of R&D requires a starting point, and this starting point depends upon the South's outside option. We demonstrate that whatever the distribution of the bargaining power, contracting yields an efficient outcome. When the North also relies on traditional knowledge—assumed to be the South's private information—in addition to the genetic resources, the division of the benefits may improve in favour of the South when the outside option is significantly affected by the private information. We show that when the genetic resources are protected, it is not necessary to assign a separate property right to traditional knowledge for the South to appropriate the rents derived from the quality of its information.

The second part of the thesis makes two contributions. First, we provide a framework that formally explains the mechanism of underinvestment in biodiversity and inefficient exchange of genetic resources in the life sciences industries as a more general hold-up problem in sequential R&D between North and South. Second, we provide a formal economic definition for traditional knowledge as the South's private information and we establish that TK may act as a trade secret and therefore does not require a separate property right for the South to appropriate its benefits so long as the associated genetic resources duly protected.

Part I

Political Dimension of the Resource Curse

Chapter 2

Resource Curse and Institutions: Literature Overview

"...natural resource endowments would enable developing countries to make the transition from underdevelopment to industrial 'take off'..." (Rostow)

"We are in part to blame, but this is the curse of being born with a copper spoon in our mouths." (K. Kaunda, President of Zambia)

2.1 The Resource Curse: Evidence, Manifestation and Critics

2.1.1 What is the Resource Curse? Empirical Evidence

Until the eighties, a general view among economists and political scientists was that a large endowment of natural resources has a positive impact on a country's development prospects. As the geographer Ginsburg put it, "the possession of a sizable and diversified natural resource base is a major advantage to any country embarking on a period of rapid economic growth." Yet, over the past forty years, casual observation and statistical studies indicate that natural resources often fail to deliver the expected economic benefits. On the contrary, resource wealth seems to impede the economic performance of many countries. In a series of highly influential of papers, Sachs and Warner (1995, 2001) find that there exists a strong and negative relationship between the average per capita GDP growth (1970–1989) in a cross-section of countries and resource abundance in 1971 measured by the GDP share of primary export—agriculture, minerals, and fuels. A standard deviation increase in the share of primary export (on average 13.5 percent of GDP) results in a reduction of about 1 percent per year in economic growth. This negative relationship does not disappear even after controlling for the main determinants of growth—institutional features, trade policy, investment, terms of trade, etc. It also remains robust to a wide range of alternative measures of primary resource wealth (ratio of mineral production in GDP, ratio of primary export in total export, land area per per person) and model specifications (Barro and Sala-i-Martin, 1995; DeLong and Summers, 1991; Mankiw, et al, 1992; King and Levine, 1993; Knack and Keefer, 1995).

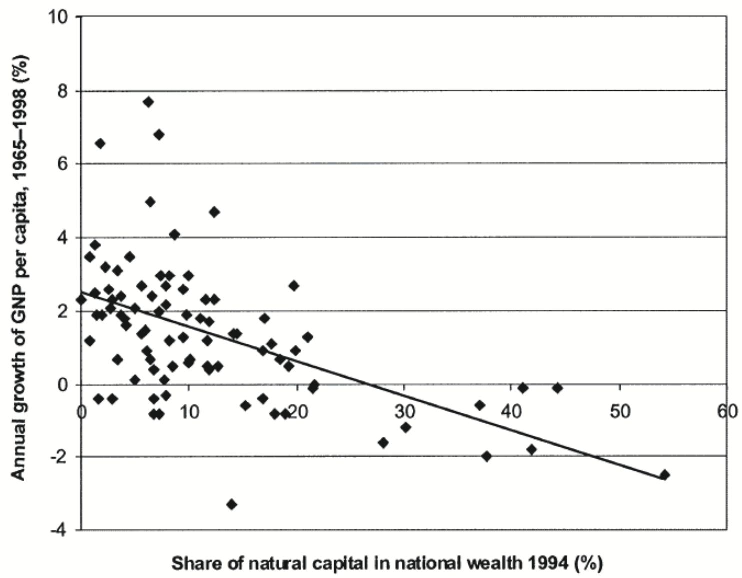


Figure 2.1: Economic Growth and Natural Capital (Source Gylfason 2001)

Sachs and Warner's statistical analysis confirms the findings made in earlier case studies documenting the apparent paradox that the resource boom in the seventies and early eighties did little to improve the growth prospects of primary commodity exporters (Gelb, 1986; Gelb & Associates, 1988; and Auty (1993; 1994)). On the contrary, the resource windfall appears to have resulted in a "curse"[1] for many countries, although it "is not an iron law, [but] rather it is a strong recurrent tendency" (Auty, 1994). Number of cross-country studies following Sachs and Warner have found evidence of the resource curse—Gylfason et al. (1999), Gylfason (2001), Auty (2001), Leite & Weidmann (2002), Sala-i-Martin & Subramanian (2003), Isham et al. (2005), Atkinson & Hamilton (2003), Bulte et al. (2005). For the moment, we will discuss here

[1]Auty 1993 is probably the first who used this term.

two different perspective to the resource curse.

Atkinson & Hamilton (2003) show that the curse may be a manifestation of government's failure to manage natural resources in a sustainable manner. They argue that by consuming large resource revenues instead of investing them in productive projects for the future, many resource countries have implemented short-sighted policies that resulted in low or even negative rates of genuine saving—i.e. net saving adjusted for resource depletion. Those low rates of genuine saving imply an unsustainable development path with low or even declining welfare, which translates into slow economic growth.

Gylfason (2001) in contrast, emphasises the role of human capital. He finds empirical evidence that one transmission mechanism of the curse may be the neglect of investment in education by resource-rich countries. Resource wealth is negatively associated with education expenditure, average years of schooling for girls, or gross secondary-school enrolment, and seems to crowd out human capital, thereby impeding economic development.

Under free disposal, these seemingly robust findings constitute a puzzle to economists. More resources provide more options to a country and therefore should make it better off or at least as well off. If it was not the case, the possibility of leaving the resources in the ground is always an option. It is also a puzzle in light of economic history. Countries such as the United States, Canada or Australia heavily relied on their large resource endowment and primary commodity exports at earlier stages of their development. For instance, in the nineteenth century the US became the richest country, and yet commodity exports constituted more than two thirds of all US exports (Bairoch, 1993, p. 194–196). For these countries, resources proved to be a blessing, lifting them among the richest nations in the world. So, the crucial question is what accounts for the apparent poor economic performance of rich countries since the seventies?

To the extent that GDP growth is an imperfect measure of economic well-being, one may question its suitability as an indicator of economic development and welfare. Davis (1995) compares indicators of well-being—life expectancy, infant mortality, access to sanitation, human development index[2], etc.—for mineral and non-mineral exporters and finds no evidence that mineral exporters perform worse. This question is taken forward by Bulte et al. (2005)

[2]Human development index or HDI was developed by the United Nations Development Programme as "a measure of people's ability to live a long and healthy life, to communicate and to participate in the life of the community and to have sufficient resources to obtain a decent living" (UNDP, 1993, p. 104). It combines normalised measures of life expectancy, literacy, educational attainment, and GDP per capita for countries worldwide.

who, in a cross-country analysis, explore whether resource intensity is associated with economic underdevelopment and low welfare? They find that resource wealth is negatively related to development indicators when resources are *point source* as opposed to when they are *diffuse*. The former are geographically clustered and easy to control by the elite in power—e.g. minerals and fuels—whereas the latter are geographically spread and difficult to control by governments—e.g. agriculture.

Various hypotheses have been suggested to explain the resource curse puzzle. Economists have focused on the Dutch disease and rent seeking, pointing to the direct effect resources may have on economic growth. Then, with the development of the endogenous institutions literature, explanations have emphasised the indirect effect of resources through institutional quality.

2.1.2 Traditional Explanations of the Curse

Structuralist Economists' view. The first explanations linking resource exports and economic growth and development were suggested in the fifties by structuralist economists Hans Singer (1950) and Raul Prebisch (1950). The Prebisch-Singer hypothesis posits that the long term decline in terms of trade for primary commodity exporters—mainly developing countries—constitute a handicap to the growth prospects and development of resource dependent countries. Explanations based on fluctuations of commodity prices, or lack of linkages between the resource sector and the rest of the economy (Hirschman, 1958) have also been advanced. Although the existence of the decline in commodity prices has received some support (Brohman, 1996), the structuralist explanations are nowadays regarded with skepticism. There is evidence that commodity prices that have declined the most were exported either by developed countries or successful developing countries. (Rosser 2006) According to Ross (1999), these explanations have not stood the test of closer empirical scrutiny (Behrman, 1987; Cuddington, 1992; Fosu, 1996), although they are relevant for certain resources.

The Dutch Disease. The Dutch disease theory, initially developed in the eighties (Neary and van Wijnbergen, 1986), sought to explain the disappointing economic performance of resource-rich countries such as the Netherlands following the discovery of natural gas in the North Sea in the 1970s. The theory postulates that the rapid growth of primary exports will cause the resource sector (non-traded sector) to crowd out the traded sector (manufacturing sector) inducing its shrinkage. The reason is as follows: a surge in resource exports often leads to an increase in spending in the non-traded sector, which raises prices in that sector. The equilibrium in the labour market and the non-traded goods market is restored through the appreciation of the real exchange rate, which in turn may hurt manufacturing exports and eventually result in the contraction of the manufacturing sector altogether ("spending effect"). In addition to that, high wages in the resource sector will attract workers away from the traded sector depressing the manufacturing sector even more ("resource pull effect"). However, income growth is negatively affected only if the effect of the contraction of the manufacturing sector outweighs the positive growth effect in the resource sector. Matsuyama (1992) and Sachs and Warner (1995) make such assumption, arguing that only the manufacturing sector can induce a learning-by-doing process and productivity. Indeed, if the manufacturing sector is the main engine for growth as opposed to the resource sector, resource dependent countries are bound to suffer from the curse due to the shrinkage of the very sector that drives economic growth. However, Stijns (2001) challenges this view pointing out that the development process of nineteenth century Britain, Germany and the US demonstrates that this assumption may not be founded. How could we otherwise explain that some countries—Norway, Botswana, Malaysia, Chili—have escaped the "curse"? Besides, even in countries that notoriously suffer from the curse, little evidence of the Dutch Disease has been found. (Leite and Weidmann, 2002; Sala-i-Martin and Subramanian, 2003) Overall, the Dutch disease explanation does not seem able to explain the curse of natural resources.

The Rent-Seeking Behaviour. The third explanation is rent seeking behaviour. Lane and Tornell (1996) have argued that resource-rich countries are prone to extreme forms of rent seeking behaviour where corrupt officials, and interest groups engage in wasteful activities and compete to capture resource rents. Tornell and Lane (1999) maintain that the existence of easily appropriable resource rents make countries prone to corruption especially when vested interests are not limited by strong legal and institutional barriers. In the absence of strong institutions, the formal and productive sector becomes subject to predatory behaviour of powerful groups in society. As a consequence, entrepreneurs shy away from the formal sector and move to the informal sector which provides relatively lower returns on investment but offers security from unwarranted predation. The situation is aggravated during periods of resource boom and leads to slow economic growth because the 'voracity effect' outweighs the windfall gains.

Baland and Francois (2000) suggest a different but complementary perspective to rent seeking behaviour. They argue that rent seeking arises because of the misallocation of human resources. Under some conditions, easily appropriable resource rents may lure the talented agents of the economy into rent seeking, away from productive activities and entrepreneurship. This situation leads to a loss of human capital (or talent), which in turn adversely affects economic performance.

A widely accepted explanation is that a windfall coming from a terms-of-trade improvement or a discovery of natural resource deposits can lead to a 'feeding frenzy' in which competing factions fight for natural resource rents and end up inefficiently exhausting the public good (Lane and Tornell, 1996).

Despite the merit of these explanations and the interesting directions they point to for understanding the resource curse, their failure to account for the divergent economic outcomes experienced among resource-rich countries constitutes a major shortcoming. For instance, while the Democratic Republic of Congo's (ex-Zaire) growth performance over the past thirty five years has been terrible, Botswana's record has been a has been an outstanding one. (Acemoglu et al., 2002) A satisfactory theory must account for the variation in economic performance among resource-rich countries. There is a need for a *conditional* theory to understand the resource curse. (Dunning, 2005) The growing literature of endogenous institutions has provided a new impetus to such investigation.

2.1.3 The Role of Institutions

A fast growing literature developed in the past decade has put much emphasis on the importance of institutions in determining the large difference in economic performance among countries. It aims to address the question of "Why do some countries produce so much more output that others?" (Hall and Jones, 1999) Several influential papers—Sokoloff and Engerman (2000), Hall and Jones (1999), Acemoglu, Johnson and Robinson (2001), and Rodrik, Subramanian and Trebbi (2004)—have suggested that differences in institutional quality may cause the differences observed in economic performance (be it in income levels or in income growth). A major contribution of this literature is in endogenising institutions in order to identify its effect on economic performance. Institutions are likely to be endogenous because while they may determine economic performance, it is also true that rich countries may have better institutions because they can afford them. (Acemoglu Johnson and Robinson, 2001)

Lessons from the "Endogenous Institutions" Literature To address the possible endogeneity of institutions, Acemoglu, Johnson and Robinson (AJR, 2001), in an influential paper, adopt a historical perspective. They use the mortality rate of European settlers—proxied by the soldiers, bishops and sailors mortality—during the colonial era as a source of exogenous variation in institutions. The idea is that the feasibility of settlement based on the settlers mortality rate shaped the type and quality of institutions implemented in the European colonies. AJR argue that in places where settlers faced a high mortality rate extractive economies, aiming mainly at natural resource exploitation, were implemented. That led to particularly bad institutions based on rent-seeking, and the absence of checks and balances. Congo under Belgian domination is a good example. On the other hand, in colonies suitable for settlement (low mortality rate), the European colonisers tended to implement institutions close to those in Europe as far as private property rights, and check and balances against expropriation are concerned. Those institutions were conducive to foster economic growth as in the US, Canada, and Australia. Finally, the institutions implemented by the European settlers have persisted even after the independence of the former colonies according to AJR. They find strong empirical evidence that institutions have a large effect on economic performance. Furthermore, once institutions are controlled for, geographic characteristic such as distance to the equator (used by Hall and Jones, 1999) or the Africa dummy are no longer significant. This suggests that poor performance in African countries and more broadly in other area may not be due to geographic or cultural factors but mainly to a bad sets of institutions. The recent work by Rodrik et al. (2004) confirms this finding and suggests the "primacy of institutions over geography".

Sokoloff and Engerman (2000) also underline the historical determinants of institutions by linking institutions to factor endowment, inequality and long term development. Their basic idea is that certain types of natural resources (such as crops in large plantations) favour institutional arrangements that exacerbate inequality and impede development. They argue that extractive colonies in Latin America based on plantation crops (sugar, coffee) were established in places where physical conditions (climate and soil) were suitable for plantation agriculture (benefiting from returns to scale) and where cheap labour was locally available or could be imported (Native Indians and slaves of African descent). Once in place, institutions based on unequal distribution of power and income persisted and reproduced inequality over time. In contrast, development in North America was based on different factor endowments: the soil and climate were less suitable for plantations, and labourers are from European descent with fairly high and similar human capital. These different factor endowments favoured the development of small household farming and created a society with a relatively more equal distribution of wealth and power. This greater equality affected how policies and institutions were designed in American society. The main hypothesis is that colonies with diffuse resources developed favourable institutions, conducive to long-term growth, whereas large inequalities were exacerbated in colonies endowed with soil, climate and cheap labour conducive to plantation agriculture, which eventually was a hindrance to economic development.

The findings made by this literature have shaped the evolution of the resource curse literature in an interesting manner. There is now a growing consensus about the role of institutions in determining whether a resource-rich country will experience a curse or a blessing. The economic performance of a resource-rich country is now traced back to the quality of its institutions. Countries with good institutions might be the ones that turn resource wealth into a blessing whereas countries with poor institutions are likely to fail.

Institutions and the Resource Curse The development of the literature on institutions underlined above has helped renew the theory of the resource curse and provides the basis for a conditional theory able to understand the various paths experienced by resource-rich countries. In this respect, Mehlum, Moene and Torvik (2006) made an important contribution to the literature. They develop a model of rent-seeking which accommodates multiple equilibria—like Baland and Francois (2000) and unlike earlier models by Tornell and Lane (1999)—to explain both the existence of a curse or a blessing. They model a country in which entrepreneurs can allocate their talent between a rent-seeking activity ("grabbing" resource rents) and a productive activity ("production"). The choice between these two activities depends on the quality of institutions, i.e. whether the institutions are grabber friendly (grabbing and production are then competing activities) or producer friendly (grabbing and production are then complementary). They show that a production equilibrium emerges when institutional quality is high whereas a grabber equilibrium emerges when institutional quality is low. Furthermore, higher natural resources correspond to a blessing in the former equilibrium, and to a curse in the latter. Interacting resource wealth with institutional quality using Sachs and Warner data, they find empirical support to their theory. However the major shortcoming of this paper is that institutions are taken as given. A more fruitful endeavour is to endogenise institutions.

Leite and Weidmann (2002) are probably the first authors to point to the role of resources in shaping institutions. They argue that natural resource abundance is a major determinant of a country's level of corruption. Endogenising corruption, they find *no direct* negative effect of natural resource wealth on growth but an *indirect* effect running through corruption. Like Leite and Weidmann (2002), Sala-i-Martin and Subramanian (2003) test the hypothesis that the negative effect of the resource curse operates through corruption and institutional quality. Their focus is on Nigeria as a special case of a country suffering the curse. They make three interesting findings. First aggregate resource wealth has little effect on growth once endogenous institutional quality is controlled for. In other words, the curse operates indirectly through the institutional channel: natural resources deteriorate institutional quality—via corruption and weak rule of law—which in turn has a negative impact on growth. Secondly, point source resources—oil and mineral—are mostly detrimental to institutional quality as opposed to diffuse resources—not easily appropriated such as food, agriculture. Thirdly, the negative impact of natural resources on institutional quality—and presumably on corruption—is non linear and increases with resource abundance.

Isham et al. (2005) confirm some of these conclusions, using a different approach. Based on Sokoloff and Engerman's (2000) idea of "entrenched inequality" linking institutions to factor endowments, inequality and long term development, they argue that export composition affects growth through institutions. That is, the composition of natural resource exports is key to understand the differences in growth performance among resource countries. They find that "point source" resources—resources that are geographically clustered and easily controlled by the state, i.e. oil and minerals— and crops from plantations—coffee and cocoa—do have a negative effect on the quality of institutions unlike diffuse resources. The poor quality of institutions in turn impedes economic growth. Using an instrumental variable strategy where various institutional indicators (rule of law, political instability, government effectiveness, control of corruption, regulatory framework and property rights and rule-based governance) are instrumented using the share of English and European speakers, latitude and predicted trade share, they find strong evidence (in the cross section of countries) in support of their hypothesis. These results are confirmed by Bulte et al. (2005) using development indicators instead of growth rates. They find that 1) that intensity in point resources tends to undermine institutional quality; and 2) after controlling for institutional quality, resource intensity (whether point source or diffuse) has no direct effect on development indicators.

2.1.4 The Resource curse, a Red Herring?

Despite the support described in the previous sections, Sachs and Warner's puzzling result has also generated many critics that all revolve around the issue of the endogeneity of the variable chosen as a proxy for resource abundance. These critics can be classified into three categories: first, the robustness to a change in econometrics methods (fixed effects versus cross-section), second the inadequacy of the choice of resource dependence (ratio of primary exports over GDP) as a measure of resource abundance, and third the issue of reverse causality.

Resources and Debt Overhang. Manzano and Rigobon (2001) question the robustness of the results to a panel data with fixed effects. They show that the negative effect of the primary exports variable disappears when a panel data analysis with fixed effects is used instead of a cross-section. This suggests that resource abundance may be correlated with unobserved characteristics captured by the fixed effects. This endogeneity problem results in biased estimates so that Sachs and Warner's results may not be reliable. Furthermore, they demonstrate that even within a cross-section analysis, the negative relationship between resource and growth rates disappears once countries' external indebtedness (Debt/GNP ratio in 1981) is controlled for. They suggest that the debt overhang experienced by many resource-rich countries in the eighties may be the cause of what appears to be a puzzle. The argument goes as follows: with the "boom" in resource prices in the seventies (oil, coal, copper, iron ore, etc.), high prices acted as an implicit collateral for the loan contracted by resource-rich countries from international commercial banks. However, when commodity prices collapsed during the eighties, international credit became scarce and the payment of the debt turned out to be problematic. The situation deteriorated even more with the rise in the interest rates and the dollar. To complete the picture, structural adjustment policies were carried out to re-establish macroeconomic balances harming further growth prospects. Manzano and Rigobon's intuition is based on the observation that international lending patterns have followed resource booms and busts. Chapter 3 will suggest a theoretical model backed by empirical evidence based on the observation of "resource boom-based borrowing". (Usui, 1997)

Resource Abundance or Resource Dependence? Second, the use of primary exports as an appropriate measure of resource abundance is questioned. According to Stijns (2001), and Norman (2004) natural resource reserves (physical stocks) constitute a better indicator of resource abundance than resource exports favoured by Sachs and Warner. Indeed, the reserves capture the actual endowment whereas the flow of export is a choice variable measuring in fact resource dependence. However, the data on measured reserves of fuels and minerals back to 1970 is scarce. In addition, measured reserves may cause some concern because they partly reflect the "technological and geological expertise, costs, financial and government structures and the product price" (Norman, 2004), inducing an endogeneity problem. This type of endogeneity, however, is likely to be less acute than the one generated by the use of a choice variable (resource export) as a right hand side variable. Using physical reserves as a measure of resource abundance, Stijns finds no evidence of the curse. He conjectures that natural resources may affect growth through both positive and negative channels, and not in the deterministic manner assumed by Sachs and Warner (1995). Nevertheless, Norman in turn challenges the results found by Stijns.

Reverse Causality. The third and most refined critique comes from Brunnschweiler and Bulte (2008a). They cast doubt on the validity of the commonly accepted causal link that resource abundance undermines institutions, which in turn impede growth. Like Stijns (2001) and Norman (2004), they question the relevance of the primary export share of GDP (resource dependence indicator) used by Sachs and Warner (1995) and the subsequent literature, as a measure of resource abundance. Instrumenting resource dependence and institutional quality, and controlling for the stock of natural capital as their exogenous measure of resource abundance, they show that: 1) resource dependence is determined by institutional quality; and 2) endogenous resource dependence has no explanatory power in the growth equation after controlling for resource abundance (stock of natural capital). Rather, resource abundance is positively associated with economic growth. Contrary to the general consensus in this literature, their conclusions imply that bad institutions lead to resource dependence but resource dependence has no effect on growth, while resource abundance is a blessing rather than a curse. Arezki and van der Ploeg (2007) find similar results also controlling for endogeneity.

It seems as if the fate of the resource curse is sealed and one may wonder if there is a curse after all. This question is even more relevant as Rodriguez and Sachs (1999) but also Bravo-Ortega and de Gregorio (2005) find a positive correlation between resources and income levels. This finding, however, is challenged by Arezki and van der Ploeg (2007) who suggest that even though economic growth *was not negatively* related to resources, income levels *are negatively* associated with resources. As Brunnschweiler and Bulte (2008a) put it the resource curse is a red herring!

Despite the mixed results produced by the empirical economic literature on the causal relation between resource abundance and economic growth, it is fair to recognise that the economic performance of many resource-rich countries has been disappointing; that they are often led by autocratic regimes (Ross, 1999 and 2001) and prone to civil conflict (Collier and Hoeffler, 1998 and 2004). In the next sections we present a brief overview of the literature linking resources to dictatorship on the one hand, and the literature linking resources with conflicts on the other hand. These issues will relate directly to chapter 3 and chapter 4 where we explore the political dimension of the resource curse, in particular how the policy choices made by autocrats will impact upon economic outcome.

2.2 Resources, Leaders & Policy Choice

Typology of dictators. Wintrobe (1990) develops a simple economic theory of dictatorship that sheds light on some important aspects of how political scientists and political economists model autocratic regimes. He describes the behaviour of a "tinpot dictator" and a "totalitarian dictator" who are facing some uncertainty about their tenure. The former is only interested in remaining in power to enjoy "palaces, Mercedes-Benz, Swiss banks accounts" while the latter primarily aims at maximising his power over the population. For our purpose, dictators in resource-rich countries are more likely to belong to the "tinpot" category. The dictator is a self-interested agent who only cares about his own benefit. In maximising his utility, he can use two instruments or policies to increase his power: he can invest in loyalty to ensure the support of interest groups through patronage; or invest in repression to prevent the occurrence of a viable opposition that potentially would overthrow them. These features (or similar features) are common to most models of dictatorship in political economy.

Objective of dictators. Because the dictator pursues his self interest, one would expect his objective to conflict with the population's objective. McGuire and Olson (1996) contend that when an autocrat has an "encompassing interest" in the country he rules (and enjoys a secure tenure) he will stop behaving as a bandit leader stealing from the people through extortionary taxes and will act as a ruler whose interest is best served by taking care of his subjects' interests. In order to increase the share of revenue he can tax (in a reasonable manner), the autocrat will be provide productivity enhancing public goods and security so that the population can increase its productive capability. Thus, when the autocrat values the future and has long term horizon (e.g. when the probability of survival is high), an "invisible hand" makes his interest consistent with the interest of society in general.

The discussion above makes clear that dictators use three major instruments or policies to reach their objective. First the dictator may undertake developmental policies that encourage productive capacity, and promote investment and growth. (Acemoglu et al., 2003; McGuire and Olson, 1996). Second he may carry out predatory policies: wasteful policies that hamper investment and economic development: expropriatory taxation, investment in white elephants[3], bribery, patronage. (Robinson and Torvik, 2006; Lane and Tornell, 1999) Third, he may resort to repressive policies to keep the population quiet and thwart any willingness to change the political *status quo.*

Rentier states and repressive states. The political science literature addresses the question of the curse by exploring the link between resource abundance and political regimes. One of the most popular ideas in this regard is the notion of "rentier states" (Ross, 2001). The hypothesis of the rentier state was developed by Middle-East experts to analyse the political economy of petro-states, and in particular, their lack of democracy. Rentier states refer to states that receive "substantial rents from foreign individuals, concerns or governments" (Mahdavi, 1970). According to Beblawi (1987) these rents are paid by foreign actors and accrue directly to the state and "only a few [citizens] are engaged in the generation of this rent, the majority being only involved in the distribution or utilization of it." The origin and magnitude of the windfall—e.g. large oil rent—make it easier for authoritarian regimes in oil-rich countries to consolidate their power and escape public scrutiny through a policy of low taxation, and spending on patronage. (Ross, 2001; Lam and Wantchekon, 2003) The assumption here is that citizens will demand more accountability if they pay taxes. In addition to this, large rents enable autocrats to invest heavily in security and defence to ensure the stability of their regimes and thwart political

[3]Often, resource-rich dictators devotes vast amount of financial resources in inappropriate or wasteful investment projects that yield very low returns (Robinson and Torvik, 2005).

opposition through repression if necessary. (Ross, 2001; and Jensen and Wantchekon, 2004)

Testing this theory, Ross (2001) sheds light on the relation between resources and democracy. He finds strong evidence of a negative correlation between oil and mineral wealth and democratic regimes. His results are consistent both with the rentier state hypothesis and the repression effect. Thus, another manifestation of the natural resource curse is that resources may hinder democracy. However, this negative effect tends to fade away the richer the oil-rich country is (e.g. US and Norway).

This finding is potentially important. As a result, economic outcomes might also differ in a significant manner. Before we analyse the effect of dictators' policy decisions on the economic outcome of resource-rich countries in chapter 3 and chapter 4, we provide here a basic introduction to the theory and evidence of dictatorships and economic outcomes.

Dictators, Policy choices and Economic Performance Since resources hinder democracy, it is tempting to attribute the curse to the fact that autocracies may have a poorer growth record than democracies. Given dictators are generally not accountable to voters, their policy choices may differ from democratically elected leaders who regularly face poll verdict. However, Przeworski and Limongi (1993) show that the correlation between political regime and economic performance is mixed at best. There is a presumption, that given unaccountability, the quality of the autocrats may be determinant.[4] In this regard, Jones and Olken (2005) provide some interesting insight. Their research explores whether leaders do have an impact on their countries' economic performance. In particular they "investigate whether changes in national leaders are systematically associated with changes in growth". However, changes in leadership are most often likely to be non-random, e.g. they may be caused by economic outcomes. To circumvent the selection problem, Jones and Olken focus on leaders who died in office either by natural causes or by accidents using a sample on leaders transition for 130 countries over the period 1945-2000. Their identifying assumption is that the timing of the leaders death is unrelated to underlying economic conditions, i.e. death has to be random. They make two important findings. First leaders do matter in determining economic performance: they find that a standard deviation increase in leader quality—average growth in the years before the leader's death—increases growth rates by at least 1.5 percentage points per year, which is a very large effect. Secondly, autocratic leaders have a significant impact on growth while democratic leaders do not.

[4] Compare for example the outcome achieved by the leaders in Botswana to Mobutu in Zaire.

These results suggest how important the quality of autocrats—for this matter the quality of their policy choices—in shaping the performance of national economies. Using a theoretical model, Overland et al. (2005) also show how policy decisions in dictatorships may affect economic growth. In particular, they analyse the consequences of a dictator's investment on growth given an insecure tenure. The insecurity of tenure decreases with capital accumulation. The dictator is self-interested and seeks to maximise his life time utility by appropriating a rent from the nation's wealth. They show that the dictator will plunder the economy when the initial capital is low enough while he will follow a growth path when initial conditions are favourable. In event of high initial conditions, the economy grows faster than under the social planner, which allows the dictator to buy off peace to ensure a secure and stable tenure. This theory is reminiscent of McGuire and Olson's (1996) "encompassing" autocrat.

This paper has interesting features that will be used in chapter 3, namely the assumption that capital stock stabilises the dictator's tenure. In fact, many authors assume that the policy choices endogenously affect the dictator's survival probability. However, there is no agreement on how a particular policy affects this probability. The literature can be divided between those like Overland et al. (2005) who believe that the quality of the economic policy will extend the status quo because the dictator can bribe the population and keep it quiet. This assumption relies on the empirical evidence that violent conflicts generally occur during recession periods. For example, it has been found that coups are more likely during periods of recessions (Fair, 1978) and less likely during periods of high growth (Londregan and Poole, 1990). A different view is that a developmental policy is a potentially risky endeavour for the current elite because of what Acemoglu and Robinson (2002) call the *replacement effect*. That is, good policies in a non-democratic regime may lead the elite to lose its political power and its economic rent. Therefore the elite becomes reluctant to diversify the economy because pro-development policies would favour competing groups that are willing to take its place. Similarly, in Robinson (2001) it is assumed that a developmental policy (i.e. investment in public good) decreases the probability of remaining in power. So long as the cost of predation is not too high, the elite may intentionally choose inefficient and predatory policies to ensure its survival. This occurs when the ruler/elite fears for its tenure.

2.3 Linking Resources and Civil Conflicts

The strand of the literature linking resources to civil conflict is fairly new and combines contributions from both economics and political science. The economists' perspective fits into the rational choice paradigm—Collier and Hoeffler (1998, 2004); Robinson (2001), Caselli (2006)—which explains conflicts as the non-cooperative behaviour of agents (e.g. elite/ruler versus rebels) who compete for the same prize. In this approach, the presence of easily appropriable natural resources has a destabilising effect in that it raises the stakes of "grabbing" power and remaining in power. (Acemoglu and Robinson, 2002; and Robinson, 2001) This situation is likely to exacerbate power contest and violent conflicts. As a consequence, the elite in autocratic regimes has a strong incentive to adopt repressive policies when its dominant position is under threat. As Caselli (2006) illustrates, the appropriation of large oil rent is almost surely the root cause of the continuing power struggle and political instability experienced by Nigeria over the past forty years. Nigeria has experienced not less than eight successful coups (and countless failed coups) and a civil war because seizing power gives an implicit property right on the resources and therefore guarantees large personal gains to the ruler and his supporters. Hence, natural resources can trigger conflicts and even civil wars (Collier and Hoeffler, 1998 and 2004).

However, little is known about the causal link between resources and conflicts. In a series of highly influential and controversial papers, Collier and Hoeffler (1998 and 2004) attempt to uncover the determinants of the onset of civil war. They compare the relative merit of two competing explanations of the onset of civil wars. One is the grievance hypothesis which is popular among political scientists. The second explanation is the greed hypothesis, consistent with economic theory of conflicts (Grossman, 1991; Hirschleifer, 1995). The former says in essence that civil conflict arises once the grievance of some sections of society (ethnic, religious, or social discrimination or inequality) is sufficiently acute. The explanation based on greed motives asserts that rebels engage in rebellion to reap personal gains and not to end injustices or to pursue ideological goals. In this perspective rebels are no different from organised criminals or rational predators. Analysing 79 civil wars over the period 1960–1999, Collier and Hoeffler (2004) find little support for the grievance hypothesis while the greed story fairs pretty well. Their results suggest that resource dependence measured as the ratio of primary commodity over GDP (which includes fuels, mineral and agricultural products) increases the likelihood of a civil war non-monotonically. The relationship peaks at 33% and becomes negative indicating that extreme resource dependence deters civil war. These findings have spurred intense debates and many political scientists challenge the validity of the relationship between resource exports and conflict. Using a different data source, Elbadawi and Sambanis (2002) conclude that the evidence supporting Collier and Hoeffler's conclusion is mixed, while Fearon and Laitin (2003) find no ground for these conclusions and contend that: "neither the share of primary commodity exports in GDP nor its square are remotely significant". However, they do find that the presence of oil (oil dummy) is associated with the onset of conflict, which is consistent with De Soysa (2002).

Ross (2004) contends that the relationship between resource dependence and violent conflict stated by Collier and Hoeffler does not withstand closer empirical inspection because of its very general form. Research has shown that both the type of resource and the type of conflict are determinant. In this respect, there seems to three robust regularities. First, oil and other non-fuel minerals are associated with the onset of civil war, especially secessionist conflicts (Ross, 2006; Lujala et al., 2005; Fearon, 2005). Resource-rich regions might want to separate from the rest of the economy to control the resource rents and enjoy the benefits of foreign investment. In addition to this greed motive, grievances also may play a role. With respect to non-secessionist wars, the effect is not so clear, as resource rents may encourage rebels to attempt and grab part of the riches, but also enables the government to defend itself against any insurgency (de Soysa and Neumayer, 2007). The second regularity is that so-called "lootable" resources—gemstones, drugs and timber—lengthen the duration of conflict. (Snyder and Bhavani, 2005) These resources allow the weaker party to raise funds so that they are able to prolong the duration of a war. (De Soysa and Neumayer, 2007) Third, agricultural goods and other "diffuse resources" are associated with neither the onset nor the duration of violent conflict.

Finally, the conclusions drawn by Collier and Hoeffler can be misleading and erroneous if the onset of a civil war and resource dependence are endogenous. Similar observations have been made by De Soysa (2002), Dunning (2005), Lujala (2005), Lujala et al. (2005), Ross (2006), and Murshed and Tadjoeddin (2007). There may be reverse causality in the sense that a civil war might deter foreign investment and destroy local industries and thus makes the economy even more dependent on the resource sector whose share becomes disproportionately important. Brunnschweiler and Bulte (2008b) explore this route to sort out the direction of causality between resources and conflict. Controlling for endogeneity they find that resource dependence no longer determines the onset of civil war. In addition, they find a significant negative relationship between resource abundance (measured by the stock of natural resources) and the onset of civil war.

Bibliography

[1] Acemoglu, D., and J. A. Robinson (2001): A Theory of Political Transitions, *American Economic Review*, 91: 938–963.

[2] Acemoglu, D., and J. A. Robinson (2002): Economic Backwardness in Political Perspective, *NBER Working Paper 8831*.

[3] Acemoglu, D., S. Johnson, and J. A. Robinson (2003): An African Success Story: Botswana, In D. Rodrik (Ed): *Search of Prosperity: Analytical Narrative on Economic Growth*, Princeton University Press.

[4] Acemoglu, D., J. A. Robinson, and T. Verdier (2004): Kleptocracy and Divide-and-Rule: A Model of Personal Rule, *Journal of the European Economic Association*, 31: 162–192.

[5] Arezki, R. and F. van der Ploeg (2007): Can the Natural Resource Curse Be Turned Into a Blessing? The Role of Trade Policies and Institutions, *IMF Working Paper* No. 07/55.

[6] Atkinson, G. and K. Hamilton (2003): Savings, Growth and the Resource Curse Hypothesis. *World Development*, 31: 1793–1807.

[7] Auty, R.M. (1990): *Resource-based Industrialisation: Sowing the Oil in Eight Developing Countries*, New York: Oxford University Press.

[8] Auty, R.M. (1993): *Sustaining Development in Mineral Economies: The Resource Curse Thesis*, Routledge, London.

[9] Auty, R.M. (1994): Industrial Policy Reform in Six Newly Industrializing Countries: the Resource Curse Thesis, *World Development*, 22(1): 11–26.

[10] Bairoch, P. (1993): *Mythes et Paradoxes de l'Histoire Economique*, La Découverte.

[11] Baland, J.M. and P. Francois (2000): Rent-seeking and Resource Booms, *Journal of Development Economics*, 61(2): 527–542.

[12] Barro, R. and X. Sala-i-Martin (1995): *Economic Growth*, New York: McGraw Hill, Inc.

[13] Barro, R. J. and A. Subramanian (2003): Addressing the Natural Resources Curse: An Illustration from Nigeria, *NBER Working Paper*.

[14] Beblawi, H. (1987): The Rentier State, In G. Luciani, G. Salamé and H. Beblawi (Eds): *Nation, State and Integration in the Arab World*, New York: Croom Helm.

[15] Behrman, J.R. (1987): Commodity Price Instability and Economic Goal Attainment in Developing Countries, *World Development*, 15(5): 559–573.

[16] Bravo-Ortega, C. and J. de Gregorio (2005): The Relative Richness of the Poor? Natural Resources, Human Capital, and Economic Growth, *World Bank Policy Research Working Paper 3484*.

[17] Brohman, J. (1996): *Popular Development: Rethinking the Theory and Practice of Development*, Blackwell, Oxford.

[18] Brunnschweiler, C. N. & E. Bulte (2008a): The Resource Curse Revisited and Revised: A Tale of Paradoxes and Red Herrings, *Journal of Environmental Economics and Management*, 55(3): 248–264.

[19] Brunnschweiler, C. N. & E. Bulte (2008b): Natural Resources and Violent Conflict: Resource Abundance, Dependence and the Onset of Civil Wars. *Economics Working Paper Series* 08/78, ETH Zurich.

[20] Bulte, E., R. Damania and R. Deacon (2005): Resource Intensity, Institutions and Development, World Development 33: 1029–1044

[21] Bulte, E. and R. Damania (2008): Resources for Sale: Corruption, Democracy and the Natural Resource Curse. *The B.E. Journal of Economic Analysis & Policy*, 8(1): Article 5.

[22] Caselli, F. (2006): Power Struggles and the Natural Resource Curse. *Working Paper*.

[23] Collier, P. and A. Hoeffler (1998): On Economic Causes of Civil War, *Oxford Economics Papers*, 50(4): 563–573.

[24] Collier, P. and A. Hoeffler (2004): Greed and Grievance in Civil War, *Oxford Economic Papers*, 56(4): 563–595

[25] Cuddington, J.T. (1992): Long Run Trends in 26 Primary Commodity Prices, *Journal of Development Economics*, 39: 207–227.

[26] Davis, G. A. (1995): Learning to Love the Dutch Disease: Evidence from Mineral Economies, *World Development*, 23(10): 1765–1779.

[27] De Soysa, I. (2002): Paradise is a Bazaar? Greed, Creed and Governance in Civil War 1989- 1990, *Journal of Peace Research*, 39: 395–416.

[28] De Soysa, I. and E. Neumayer (2007): Resource Wealth and the Risk of Civil War Onset: Results from a New Dataset of Natural Resource Rents, 1970-1999, *Conflict Management and Peace Science*, 24(3): 201–218.

[29] DeLong, J.B. and L. Summers (1991): Equipment Investment and Economic Growth, *Quarterly Journal of Economics*, 106(2): 455–502.

[30] Dunning, T. (2005): Resource Dependence, Economic Performance and Political Stability, *Journal of Conflict Resolution*, 49(4): 451–482.

[31] Elbadawi, I. and N. Sambanis (2002): How Much War Will We See? Estimating the Prevalence of Civil War in 161 Countries, 1960-1999, *Journal of Conflict Resolution*, 46(3): 307–334.

[32] Fair, R.C. (1978): The effect of Economic Events on Votes for President, *Review of Economics and Statistics*, 60(2): 159–173.

[33] Fearon, J. D. (2005): Primary Commodity Exports and Civil War, *Journal of Conflict Resolution*, 49(4): 483–507.

[34] Fearon, J. D. and D. Laitin (2003): Ethnicity, Insurgency, and Civil War, *American Political Science Review*, 97: 75–90.

[35] Fosu, A. (1996): Primary Exports and Economic Growth in Developing Countries, *World Economy*, 19: 465–475.

[36] Galetovic, A. and R. Sanhueza (2000): Citizens, Autocrats and Plotters: A Model and New Evidence of Coup d'Etat, *Economics and Politics*, 12: 183–204.

[37] Gelb, A.H. (1986): Adjustment to Windfall Gains, In Neary, J.P. and Van Wijnbergen, S. (Eds). *Natural Resources and the Macroeconomy*, Basil Blackwell, Oxford.

[38] Gelb, A.H. and Associates (1988): *Windfall Gains: Blessing or Curse?*, New York: Oxford University Press.

[39] Grossman, H. (1991): A General Equilibrium Model of Insurrections, *American Economic Review*, 81: 912–921.

[40] Gylfason, T. (2001): Natural Resources, Education, and Economic Development, *European Economic Review*, 45: 847–859.

[41] Gylfason, T., T. Herbertsson and G. Zoega (1999): A Mixed Blessing: Natural Resources and Economic Growth, *Macroeconomic Dynamics*, 3: 204– 25.

[42] Hirschleifer, J. (1995): Anarchy and its Breakdown, *Journal of Political Economy*, 103: 26–52.

[43] Hirschman, A.O. (1958): *The Strategy of Economic Development*, New Haven CT: Yale University Press.

[44] Isham, J., M. Woolcock, L. Pritchett and G. Busby (2005): The Varieties of Resource Experience: Natural Resource Export Structures Affect the Political Economy of Economic Growth. *World Bank Economic Review*, 19: 141–174.

[45] Jensen, N. and L. Wantchekon (2004): Resource Wealth and Political Regimes in Africa, *Comparative Political Studies*, 37: 816–841.

[46] Jones, B. and B. Olken (2005): Do Leaders Matter? National Leadership and Growth since World War II, *Quarterly Journal of Economics*, 120: 835–864.

[47] King, R.G. and R. Levine (1993): Finance and Growth: Schumpeter Might be Right, *Quarterly Journal of Economics*, 108(3): 717–737.

[48] KNACK, S. AND P. KEEFER (1995): Institutions and Economic Performance: Cross-country Tests using Alternative Institutional Measures, *Economics and Politics*, 7(3): 207–227.

[49] LAM, R. AND L. WANTCHEKON (2003): Political Dutch Disease, *NYU Working Paper*.

[50] LANE, P. AND A. TORNELL (1996): Power, Growth and the Voracity Effect, *Journal of Economic Growth*, 1(2): 213–241.

[51] LEITE, C. & J. WEIDMANN (2002): Does mother nature corrupt? Natural resources, corruption and economic growth. Chapter 7 in Abed, G. & S. Gupta (eds.): *Governance, Corruption, and Economic Performance*, Washington DC: International Monetary Fund, 159–196.

[52] LONDREGAN, J.B. AND K.T. POOLE (1990): Poverty, The Coup Trap and the Seizure of Executive Power, *World Politics* 42: 151–183.

[53] LUJALA, P. (2005): The Spoils of Nature: Armed Civil Conflict and Rebel Access to Natural Resources, Department of Economics, Norwegian University of Science and Technology, *Working Paper*.

[54] LUJALA, P., N. P. GLEDITSCH AND E. GILMORE (2005): A Diamond Curse? Civil War and a Lootable Resource, *Journal of Conflict Resolution*, 49: 538–562.

[55] LUTZ, M. (1994): The Effects of Volatility in the Terms of Trade on Output Growth: New Evidence, *World Development*, 22: 1959–1975.

[56] MAHDAVI, H. (1970): The Patterns and Problems of Economic Development in Rentier States : The Case of Iran, In M.A. Cook (Ed.) *Studies in the Economic History of the Middle East*, Oxford University Press: London.

[57] MANKIW, N.G., D ROMER, AND D.N. WEIL (1992): A Contribution to the Empirics of Economic Growth, *Quarterly Journal of Economics*, 107(2): 407–437.

[58] MANZANO, O. AND R. RIGOBON, R. (2001): Resource Curse or Debt Overhang? *NBER Working Paper* No 8390, Cambridge MA.

[59] MATSUYAMA, K. (1992): Agricultural Productivity, Comparative Advantage and Economic Growth, *Journal of Economic Theory*, 58: 317–334.

[60] McGuire, M. and M. Olson (1996): The Economics of Autocracy and Majority Rule, *Journal of Economic Literature*, 34: 72–96.

[61] Mehlum, H., K. Moene and R. Torvik (2006): Institutions and the Resource Curse, *Economic Journal*, 116(508): 1–20.

[62] Murshed, M. and Z. Tadjoeddin (2007): Reappraising the Greed and Grievance Explanations for Violent Internal Conflict. *MICROCON Research Working Paper 2*, Brighton: MICROCON.

[63] Neary, J.P. and S. van Wijnbergen (1986): *Natural Resources and the Macroeconomy*, MIT Press, Cambridge, MA.

[64] Norman, C.S. (2005): Rule of Law and the Resource Curse: Abundance versus Intensity, Dept. of Economics, *University of California at Santa Barbara, Discussion Paper.*

[65] Olsson, O. and H.C. Fors (2004): Congo: The Prize of Predation, *Journal of Peace Research*, 41(3): 321–336.

[66] Overland, J., K. L. Simons, and M. Spagat (2005): Political Instability and Growth in Dictatorships. *Public Choice*, 25: 445–470.

[67] Papyrakis E. and R. Gerlagh (2004): The Resource Curse Hypothesis and Its Transmission Channels, *Journal of Comparative Economics*, 32(1): 181–193.

[68] Prebisch, R. (1950): *The Economic Development of Latin America and its Principal Problems*, New York: United Nations.

[69] Przeworski, A. and F. Limongi (1993): Political Regimes and Economic Growth, *Journal of Economic Perspectives*, 7: 51–69.

[70] Robinson, J.A. (2001): When is a State Predatory? *Working Paper.*

[71] Robinson, J.A. and R. Torvik (2005): White Elephants, *Journal of Public Economics*, 89(2-3): 197–210.

[72] Robinson, J.A. and R. Torvik (2006): A Political Economy Theory of the Soft Budget Constraint. *NBER Working Paper* 12133.

[73] Robinson, J.A., R. Torvik and T. Verdier (2006): Political Foundations of the Resource Curse, *Journal of Development Economics*, 79(2): 447–468.

[74] Rodriguez, F. and J. Sachs (1999): Why Do Resource-Abundant Economies Grow More Slowly? *Journal of Economic Growth*, 4(3): 277–303.

[75] Ross, M. (1999): The Political Economy of the Resource Curse, *World Politics*, 51: 297–322.

[76] Ross, M. (2001): Does Oil Hinder Democracy?, *World Politics*, 53: 325–361.

[77] Ross, M. (2004): What Do We Know about Natural Resources and Civil War?, *Journal of Peace Research*, 41: 337–356.

[78] Ross M. (2006): A Closer Look at Oil, Diamonds, and Civil War, *Annual Review of Political Science*, 9: 265–300

[79] Rosser, A. (2006): The Political Economy of the Resource Curse: a Literature Survey, *IDS Working Paper 268.*

[80] Sachs, J. and A. Warner (1995): Natural Resource Abundance and Economic Growth. *NBER Working Paper 5398*, Cambridge: MA.

[81] Sachs, J. and. A. Warner (2001): The Curse of Natural Resources, *European Economic Review*, 45: 827–838.

[82] Sala-i-Martin, X. and A. Subramanian (2003): Addressing the Natural Resource Curse: an Illustration from Nigeria. *NBER Working Paper 9804*, Cambridge: MA.

[83] Sandbu, M. (2006): Natural Wealth Accounts: A Proposal for Alleviating the Natural Resource Curse, *World Development*, 34(7): 1153–1170.

[84] Singer, H. (1950): The Distribution of Trade Between Investing and Borrowing Countries, *American Economic Review*, 40: 473–485.

[85] Snyder, R. and R. Bhavnani (2005): Diamonds, Blood, and Taxes: A Revenue-centered framework for Explaining Political Order, *Journal of Conflict Resolution*, 49 (4): 563–597.

[86] Sokoloff, K. and Engerman, S. (2000): Institutions, Factor Endowments and Paths of Development in the New World, *Journal of Economic Perspectives*, 14(3): 217–232.

[87] STIJNS, J. (2002): Natural Resource Abundance and Economic Growth Revisited. *University of California at Berkeley, Department of Economics*, *Mimeo.*

[88] TORNELL, A. AND P. LANE (1999): The Voracity Effect, *American Economic Review*, 89: 22–46.

[89] TORVIK, R. (2002): Natural resources, Rent Seeking and Welfare, *Journal of Development Economics*, 67(2): 455–470.

[90] UNITED NATIONS DEVELOPMENT PROGRAMME (1993): *Human Development Report 1993*, New York: Oxford University Press.

[91] VAN WIJNBERGEN, S. (1984): The Dutch Disease: a Disease after all?, *Economic Journal*, 94: 41– 55.

[92] WINTROBE, R. (1990): The Tinpot and the Totalitarian: An Economic Theory of Dictatorship, *American Political Science Review*, 84: 849–872.

Chapter 3

On the Looting of Nations: International Lending, Political Instability and Economic Growth[1]

"Countries don't go out of business.... The infrastructure doesn't go away, the productivity of the people doesn't go away, the natural resources don't go away. And so their assets always exceed their liabilities, which is the technical reason for bankruptcy. And that's very different from a company." Walter Wriston (Citicorp Chairman, 1970-1984)

3.1 Introduction

An extensive literature documents that resource wealth appears to be a curse rather than a blessing for many countries. There are at least three different explanations for this so-called resource curse. Resource wealth is seen to be associated with (i) slow growth (Sachs and Warner 1995), (ii) domestic conflict and political instability (Collier and Hoeffler, 2004), and with (iii) autocratic regimes and poor institutions (Ross 2001; Isham et al., 2004). Traditionally, analysts attempted to explain these phenomena with mono-disciplinary models and perspectives. For example, economists advanced Dutch disease models and rent seeking to analyze slow growth, and political scientists employed "rentier-state" models and "weak state" arguments to explain institutional failure and conflict. Increasingly, the inter-relations between the three dimensions of the curse are recognized, and the search is on for unified models that capture the various salient features in one coherent framework.

[1]This chapter is a joint work with Erwin Bulte of Wageningen University, Chris Meissner of University California Davis, and Tim Swanson at University College London.

This paper contributes to that ambitious objective, and aims to pull together the political and economic domain insofar as this is relevant for the relationship between resource wealth and underdevelopment. It starts from the premise that many resource-rich countries hold these resources as national assets (rather than under systems of private property rights). This presents a situation where the ruling party or person taking political control finds itself immediately endowed with substantial resource wealth. Where unchecked, these rulers are often afforded the option of looting their country's riches, rather than investing in the development of the nation. For example, the disastrous economic and political performance of countries such as Nigeria or the Democratic Republic of Congo (DRC) can be easily traced to the predatory behavior of their autocratic regimes. A long list of this sort of resource-inspired looting-type behaviour is cited by Jayachandran and Kremer (2006). But resources do not have to be a curse. There are of course countries where the leaders implement sound development policies from a base of resource-richness. After contrasting the diverging trajectories of countries such as Botswana, DRC, and Indonesia, Dunning (2005) stresses the need for *conditional* theories of the resource curse. The main challenge is to unravel the conditions under which resource wealth results in development, and those conditions conducive to looting.

We develop the argument here that there is a specific set of institutional failures that combine to present the opportunity for looting: a) relatively undeveloped democratic institutions (an absence of checks on the current ruler); b) nationally held resource rights (centralised economies); and c) relatively unstructured lending (unconditional conferment of liquidity). We are not the first to point to the importance of institutions in the explanation of the curse. There is plenty of evidence suggesting that institutional quality is one of the main drivers of economic development in general (Acemoglu et al. 2001, Rodrik et al., 2004), and it has been argued that the fates of resource-rich economies in particular are influenced by the quality of their institutions (Robinson et al., 2006; Mehlum et al., 2005). Our point is more subtle. We demonstrate here that it can be a particular sort of interaction between domestic institutional weaknesses (centralised governance and unchecked autocratic decision making) and international institutional weaknesses (unstructured lending conditions) that might explain looting behaviour and contributes to a better understanding of the resource curse.

The international capital market plays a crucial role in our story. We wish to examine in particular how and why excessive resource-based lending by external financial institutions can induce default, departure and debt in developing countries. This sort of moral hazard in the financial markets leading to excessive lending to sovereigns has been previously noted. (Bulow, 2002) We also are not the first to highlight the roles of international loans and debts in reduced growth. Manzano and Rigobon (2001) find that the resource curse vanishes when controlling for indebtedness. Their argument is that large credit offered on resource-based collateral in periods of commodity boom resulted in substantial debt overhang when commodity prices fell in the 1980's.[2] The importance of these findings is reinforced by the observation that 12 of the world's most mineral-dependent countries and six of the world most oil-dependent countries are currently classified as highly indebted poor countries (Weinthal and Luong, 2006).[3]

We agree with this analysis, and develop ours to elaborate and expound upon the mechanisms by which resource-based lending goes bad. The most fundamental cause in our story is moral hazard: the international financial institutions perceive no downside risk to lending on the basis of resource-based collateral. This is because lenders see little reason to exercise restraint in lending to resource-rich states, since the resources remain behind even when the regime changes (see the quote above). (Bulow, 2002) This means that lenders have little reason to be concerned about the incentives their loans generate. According to Raffer and Singer (2001 p. 161), the policy of "liberal lending by commercial banks opened a bonanza for corrupt regimes. After amassing huge debts and filling their pockets, military juntas (...) simply handed power and the debt problem over to civilians." We demonstrate in our model precisely how such unstructured lending generates the incentives for the combined events of debt and departure, instability and indebtedness.

To analyse the multi-faceted relations between indebtedness, political stability and growth, we develop a model of a resource-rich economy governed by a self-interested ruler with unchecked property rights in national resources who cares only about his own consumption. The crucial and discrete choice made by the ruler is whether to stay and invest, or to exit and loot. In spirit,

[2]In the 1970s and early 1980s international banks (such as Citicorp and Chase Manhattan) lent vast amounts of money to developing nations based on their natural resources endowment, virtually irrespective of their ability to repay such debts (Sampson, 1982). It is now seen that the boom in resource prices in the 1970s increased the value of *in situ* resources, aiding the ability of resource-rich economies to attract foreign loans and run up debts. The absence of productive investment by these resource-rich nations meant that there was significant indebtedness with little demonstratively positive impact upon growth.

[3]Usui (1997) provides a case study on two oil-rich countries Indonesia and Mexico, that supports this argument. He finds that both Indonesia (in 1975) and Mexico (in 1978-1982) became attractive customers in the credit market, and took advantage of the drastic improvement of the borrowing capacity during the periods of the boom of their resource sector. This unsound lending and borrowing - also called "boom based borrowing capacity"— resulted in the Pertamina crisis in 1975 in Indonesia and to Mexico's debt crisis in 1982.

the model is close to Overland et al. (2005) who explore what determines a dictator to initiate growth or "plunder his country" when he faces a potentially insecure tenure. However, our model differs because our focus is on the role of financial markets in liquefying sunk capital, especially in regard to natural resources. To the extent that external finance facilitates the conversion of sunk capital into liquid capital—enabling the leader to make immediate access to wealth that usually requires time and investment—it affects the tradeoff between staying (re-investing in the economy and consuming by maintaining control) or looting (taking the extant liquidity and exiting). This combination of resource wealth and excessive external lending gives rise to endogenous political instability, lack of investment and indebtedness.

Our story is closely related to the literature on "odious debt". (Jayachandran and Kremer, 2006) Odious debt results when lending to autocrats results in little for the country concerned other than debt. We demonstrate how resource-based lending generates this result. Our story is also related to the literature on efficient contracts for sovereign lending. (Bulow, 2002; Kletzer and Wright, 2005) We argue that resource-based lending is the antithesis of efficient sovereign loan contracting, and we demonstrate how odious debts result from such unstructured lending. Our point here is that the indebtedness and poor performance of these resource-rich economies is as much a result of the poor contracting by the financial sector as it is the unchecked power and poor institutions within the debtor regimes. It takes negligence or malfeasance by both the parties to make a bad contract. These bad contracts, together with the weak institutions in the resource-rich nations, create the environment within which non-investment, instability, and debt are generated—hence the resource curse.

Our main results are as follows. We first demonstrate in a simple model how a dictator taking control of a nation's resources might decide between three distinctly different paths: (1) immediate looting of the country's resource wealth; (2) transitory investment in the country's capital base to build up additional liquidity for looting in the medium term; or (3) long term investment in the economy (and possibly in shared consumption or political repression) in an attempt to secure tenure and to consume from the economy. Second, we demonstrate the main factors affecting the dictator's choice between these various paths, being: a) the level of external finance available for liquefying resource wealth; b) the indebtedness of the economy; and finally c) the productivity of investments within the economy. After the modelling of the dictator's problem, we provide simulations of the optimal path for such an economy which, under specific conditions (low productivity and high liquidity), is one of recurrent looting—resulting in political instability, low growth and substantial indebtedness. We demonstrate that the same dictator (with lower liquidity or higher security) will pursue a path of optimal investment and high growth—acting more as an owner and less as a looter of the economy. Finally, we provide empirical evidence that corroborates the predictions from our theoretical framework. We find that the combination of resource wealth and lending in autocratic states are correlated with instability, which in turn is negatively associated with economic growth. This finding suggests that the model points to a channel through which the resource curse may arise.

The paper is organized as follows. In section 3.2, we present the stylized growth model of a resource-rich nation with an unchecked ruler who has access to foreign lending. In section 3.3, we simulate the resource-relevant choices of such an autocrat, and demonstrate the economic outcomes for the nation over a significant range of parameters. In section 3.4, we initiate our empirical analysis of resource-rich states, outlining our empirical strategy and introducing our data. In section 3.5, we present regression results - looking at the relationship in these states between: a) resources and lending; and b) political instability and economic growth. Section 3.6 concludes.

3.2 The model

We develop a model in which we investigate the effects of natural resource abundance, poor governance and unsound lending on political stability and ultimately on economic performance. Poor governance is present in the form of an unchecked ruler with implicit property rights in the resources of the state. We are interested in how such an autocrat will elect to achieve a payout on these property rights and, in particular, the impact of lending market imperfections upon the dictator's choice between staying and looting. Staying involves the dictator's commitment to acquiring a return through holding power and investing in the economy. Looting involves electing a short term "hit and run" strategy of maximum loan, minimal investment, and immediate departure. Before we examine the model, we will first define the primary actors existing within the framework.

Autocratic Resource-Rich States. The states concerned hold their fixed natural resource stocks directly as sovereign assets; there are no intermediate entities (corporations, individuals) holding rights in these resources. Once in power, the leader of the state has the unchecked authority to mine the resources or to enter into contracts on behalf of the state in regard to the natural resource assets. These natural resources are sunk assets, but are assumed to be capable of providing a constant stream of revenues into the indefinite future.

Consider such an autocratic resource-rich state, a small open economy producing output y_t according to the function $y_t = f(k_t) + \phi Z$, where f is a strictly increasing, strictly concave, continuously differentiable function of capital k_t and ϕZ is the flow of resource rents deriving from the state's sunk resource wealth Z. We will assume here that the flow of rents from resources remains constant throughout the program, while the productivity of the economy may be enhanced by means of investment in capital. The capital stock k_t evolves according to the transition equation $k_{t+1} = (1-\delta)k_t + i_t$, where i_t and δ represent the current gross investment and the depreciation rate. Because of the natural resource endowment, this country qualifies for loans l_t from international commercial banks at the beginning of each period so that it faces the following budget constraint: $c_t + i_t + rd_t = y_t + l_t$, where r is the interest rate paid on accumulated debt, d_t. The country's stock of debt evolves according to the following transition equation:

$$d_{t+1} = d_t + l_t$$

The interest on the debt must be paid each period for the banks to accept lending in the next period. So, the cost of servicing the debt rd_t is incurred each period that the state is not in default.

External financial institutions. Foreign financial institutions make liquidity available to the resource-rich states in recognition of the expected future flows of value from the resource base. These institutions (primarily the commercial banking sector) recognise the authority of rulers of autocratic resource-rich states to enter into contracts on behalf of the states in regard to these resources, and any contracts entered into by a ruler continue as obligations of that state beyond the individual tenure of that ruler. The commercial banking sector offers liquidity to the current leader contingent upon the state not currently being in default. The amount of liquidity is constrained by an aggregate debt ceiling proportionate to the total resources available.

We are assuming here that international lenders are relying primarily on the anticipated flows from natural resource stocks as implicit collateral for their loans. Natural resources (more specifically the so-called "point source" resources such as oil and minerals) differ from other forms of capital such as physical infrastructure, hospitals, schools or factories in that they can be more readily liquefied by means of bank lending. We capture this notion by assuming that the liquidity parameter θ_z for the natural resource is larger than for other forms of capital, θ_k, i.e. $\theta_z > \theta_k \geq 0$.

Banks recognise that adverse selection can result from price-based lending and so limit lending levels instead. (Stiglitz and Weiss, 1981) Credit rationing here is limited by both the immediate and aggregate flows from the resource base available for repayment. (Bulow and Rogoff, 1989) This means that, so long as the state is not in default (i.e. prior debt is serviced), the lenders are willing to provide a maximum loan amount in any given period in proportion to the total amount of longer term resources available. The first point indicates that there is a certain proportion of resource-based capital and physical capital that is liquefiable in any given period, i.e. $\theta_z Z + \theta_k k_t$ ($l_t \leq \theta_z Z + \theta_k k_t$). The second point captures the idea of a credit ceiling. (Eaton and Gersovitz, 1981) We assume that the aggregate debt level is limited to the amount serviceable by the present value of the stream of liquidity derivable from all natural resources.

$$d_{t+1} \leq \frac{(1+r)}{r} \left(\theta_z Z + \theta_k k_t\right) \tag{3.1}$$

The Dictator. The ruler of the state concerned is a dictator in that he has unchecked power over the resource wealth and other assets of the state for the duration of his tenure. His problem is to determine how best to appropriate maximum utility from his period of tenure over these resources. These resources are sunk, in that there is only a fixed proportion of the resources realisable in any given period of his tenure. These flows may then be consumed immediately or invested in the productive capacity of the economy which makes them available for future consumption. The ruler can affect the length of his tenure by means of investments in societal betterment (shared consumption) but there remains uncertainty in each period concerning whether the regime will end at that time. With international lending, the ruler has the option of liquefying some additional proportion of the state's resource wealth in any given period, at the cost of an increase in the state's debt at the beginning of the next period.

The Dictator's Problem. These three assumptions are sufficient for establishing the structure of our autocrat's choice problem, which is built upon the premise that the ruler is pursuing his own agenda after assuming control of the state. (Acemoglu et al., 2004) We assume that the self-interested dictator is faced with the problem of maximising his own life-time utility largely by means of making the decision concerning his optimal length of tenure.

$$\begin{aligned} V(k_t, d_t, \varepsilon_t) \quad &= \quad \max_{\chi_t \in \{stay, loot\}} E_t \left[\sum_{j=0}^{\infty} \beta^j U(k_{t+j}, d_{t+j}, \varepsilon_{t+j}, \chi_{t+j}) \right] \\ & \quad\quad \text{s.t. } \chi_t \geq \chi_{t-1} \end{aligned} \tag{3.2}$$

where χ_t is the dictator's binary choice between staying ($\chi_t = 0$) and looting ($\chi_t = 1$); and ε_t is an unobservable state variable for the analyst.[4] Time is discrete and the dictator faces an infinite time horizon.

In each period, the incumbent dictator decides whether to stay in power or to loot the country and leave immediately. His choice resembles that of the manager of a firm who is strategically choosing the point in time of the liquidation of a limited liability corporation. (Mason and Swanson, 1996) The basic decision comes down to whether to abscond with maximum liquidity today, or whether to stay and invest in tenure and productivity in order acquire a return from holding control over the productive capacities of the enterprise in the future.

Here we model the problem recursively. If the dictator decides to stay, he captures part of the benefits from production, and then faces the decision regarding looting again in the next period. By staying, the dictator faces the possibility that he will be ousted, and lose everything along with his loss of control. The decision whether to stay one more period or to loot is a recursive discrete choice problem described by the following equation:

$$V(k_t, d_t, \varepsilon_t) = \max_{\chi_t \in \{stay, loot\}} [v^{\chi}(k_t, d_t) + \varepsilon_t(\chi_t)] \tag{3.3}$$

This equation relies on the assumption of additive separability (AS) of the utility function between observed and unobserved state variables. We will also assume that 1) ε_t follows an extreme value distribution; and 2) ε_{t+1} and ε_t are independent conditional on the observed

[4] The state variables k_t and d_t are observable unlike ε_t.

state variables k_t and d_t. These assumptions follow Rust (1987 and 1994) and greatly simplify this complex problem.

The Decision to Retain Control. Given a decision to stay and maintain control, the dictator will choose current period consumption c_t, capital level k_{t+1}, debt level d_{t+1} and repression level s_t to secure his rule. He enjoys an instantaneous utility $u(c_t)$ where $u > 0$, $u' > 0$ and $u'' < 0$, and expected stream of future utilities should he remain in power. He decides the investment level in productive capital each period by choosing k_{t+1} according to the following law of motion:

$$k_{t+1} = f(k_t) + \phi Z + (1 - \delta)k_t - c_t - rd_t + l_t - cost(s_t) \tag{3.4}$$

where s_t measures the repression level chosen by the dictator (e.g. expenditures on secret services, police and army) and $cost(s_t)$ are the associated costs.

Within each period t, the dictator experiences the realisation of a discrete random variable $\xi_t = \{0, 1\}$, where $\xi_t = 1$ indicates that the dictator is toppled, and $\xi_t = 0$ indicates that the dictator remains in power. We assume that the realisation of the shock depends both on the choice of next period's capital stock and repression level. This specification captures the idea that both consumption-sharing and military-spending are strategies for maintaining control over the economy. Let $\rho(k_{t+1}, s_t) = \rho(\xi_t = 1 \mid k_{t+1}, s_t)$ denote the probability of the dictator being deposed next period given he was in power this period; $\rho(k_{t+1}, s_t)$ is assumed to be strictly decreasing and strictly convex in both arguments—see Overland et al. (2005) for a similar idea. That is, increased k_{t+1} and s_t decrease the probability of being toppled at a decreasing rate. The idea here is that the dictator may invest in repression to secure his tenure and may also attempt to buy off peace by sharing some of the output with the population (k_{t+1}). This dilemma has also been analyzed by Azam (1995).

The recursive problem faced by the dictator does not depend on time *per se*, so that the programme is written as:

$$v^{stay}(k,d) = \max_{c,k',d',s \in \Gamma(k,d)} \big(1-\rho(k',s)\big)\big[u(c)+\beta E_{\varepsilon'} V(k',d')\big] \tag{3.5}$$

$$\text{s.t. } \Gamma(k,d) = \begin{cases} k' = f(k) + \phi Z + (1-\delta)k - c - (1+r)d + d' - cost(s) \\ d' = d + l \\ d' \leq \dfrac{(1+r)}{r}\left(\theta_z Z + \theta_k k\right) \\ l \leq \theta_z Z + \theta_k k \\ c \geq 0; \\ k \geq 0;\ d \geq 0 \\ k(0) = k_0;\ d(0) = d_0 \end{cases} \tag{3.6}$$

where β is the discount factor, and k', d' and ε' represent next period's state variables.

The Decision to Loot. The dictator also has the choice to loot the economy's riches and exit. Conditional on looting, the dictator leaves with the maximum loan amount he can contract and the share of non-sunk capital $w_0 = \theta_z Z + \theta_k k$ representing the current value of the liquefied natural and physical capital assets. It is assumed that the dictator absconds with this maximum amount of liquidity, without making any effort at retaining power, paying debts or investing in the economy. On departure, he invests the looted sum to live off a constant flow of consumption c^{loot}. The value of looting is then given by:

$$v^{loot}(k,d) = \frac{u(c^{loot})}{1-\beta} \quad \text{where } c^{loot} = \frac{rw_0}{1+r} = \frac{r}{1+r}\left(\theta_z Z + \theta_k k\right) \tag{3.7}$$

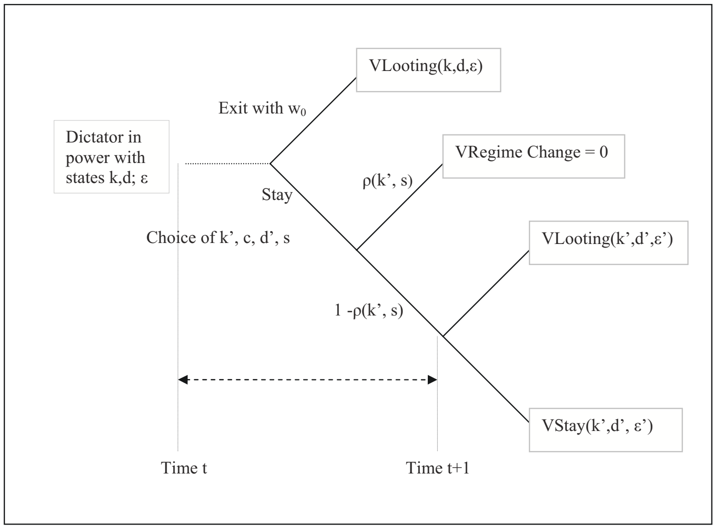


Figure 3.1: Dictator's Decision Tree

Results. Obviously the dictator compares the payoffs from the two distinct options and chooses the strategy with the highest payoff. Hence, the optimal solution solves:

$$\chi^*(k,d,\varepsilon) = argmax\ \left[v^{stay}(k,d) + \varepsilon(0),\ v^{loot}(k,d) + \varepsilon(1)\right] \tag{3.8}$$

where the value of staying $v^{stay}(k,d)$ and the value of looting $v^{loot}(k,d)$ are defined above. This amounts to an optimal stopping problem, where the decision to loot is an absorbing state.

As mentioned, if the decision is to loot, the optimal choice for the dictator is to set the level of loan at its maximum, invest nothing in the retention of tenure, and to depart immediately in pursuit of a lifetime of consumption (from looted lending). Given the decision to stay, however, the dictator's optimal choice for the next period's capital k', consumption c^{stay} and next period's debt d' is given by the following first order conditions:

$$\begin{aligned}\left(1-\rho(k',s)\right)u'(c^{stay}) \quad &= \quad \beta\left(1-\rho(k',s)\right)\left[\left(1-\rho(k'',s')\right)\left(f'(k')+(1-\delta)\right)u'(c'^{stay})Pr(\chi=0|k',d')\right. \\ &+ \quad \left.\frac{r\theta_k}{1+r}\frac{u'(c'^{loot})}{1-\beta}Pr(\chi=1|k',d')\right] - \frac{\partial\rho}{\partial k'}\left(u(c^{stay})+\beta EV(k',d')\right)\end{aligned} \tag{3.9}$$

$$u'(c^{stay}) = \beta\left(1-\rho(k'',s')\right)(1+r)\,u'(c'^{stay})Pr(\chi=0|k',d') \tag{3.10}$$

$$\left(1-\rho(k',s)\right) cost'(s)\,u'(c^{stay}) = -\frac{\partial\rho}{\partial s}\left(u(c^{stay})+\beta EV(k',d')\right) \tag{3.11}$$

Equation (3.9) says that the dictator faces a trade-off when increasing capital stock: decreased consumption today versus an increased probability of remaining in power next period together with increased consumption tomorrow if power is retained or increased liquidity from capital in case of exit. The next condition (3.10) conveys the idea that the dictator chooses d' in order to balance increased consumption today against decreased consumption tomorrow due to debt servicing (if he stays the following period). Finally, equation (3.11) reflects the fact that by choosing s the dictator will trade-off the utility loss from expending resources on retaining power against the benefit from an enhanced security of tenure. These conditions are sufficient to allow us to establish the basic comparative statics of the dictator's choice.

Proposition 1: *Define $\Delta V(k,d) \equiv v^{stay}(k,d) - v^{loot}(k,d)$ to be the net gain from staying relative to looting in any given period. For any given pair (k,d), the dictator's optimal choice is to stay if $\Delta V(k,d) > 0$ and to loot if $\Delta V(k,d) < 0$.*

The value function $V(k,d)$ is increasing in k, Z, θ_z and θ_k, and is decreasing in d.

The gain from staying ΔV is decreasing in d, θ_z and θ_k, and non-monotonic with respect to k and Z .

These results are derived formally in Appendix A.1. The intuition for most of the findings is straightforward. Affording higher liquidity to the dictator (increasing parameters θ_z and θ_k) increases the opportunity cost of retaining power. The level of indebtedness reduces the relative returns to staying, since payment (by the dictator) is not required after looting. Increased security of tenure (reduced hazards) increases the relative returns to staying.

The non-monotonicity of ΔV with respect to k is determined by the relative productivity of capital versus the returns from liquefying capital.[5] If the marginal product of capital (discounted

[5] We have established in the proof in the appendix that:
$$\frac{\partial\Delta V(k,d)}{\partial k} = \left(1-\rho(k',s)\right)\left(f'(k)+(1-\delta)\right)u'(c^{stay}) - \frac{r\theta_k}{1+r}\frac{u'(c^{loot})}{1-\beta}$$

by the probability of preventing a coup) is greater than marginal liquidity of capital (in utility terms), i.e. $\left(1-\rho(k', s)\right)\left(f'(k)+(1-\delta)\right)u'(c^{stay}) > \frac{r\theta_k}{1+r}\frac{u'(c^{loot})}{1-\beta}$, then the relative gain of staying increases with the level of capital. If not, then the relative gain of staying decreases with k.

The reason for the non-monotonicity of ΔV with respect to Z depends on the relative impact of resources on production (terms 1 of equation (3.21) in Appendix A.1) and on the liquidity of resources provided by the banks (term 2 of equation (3.21)). If the return to liquidity is higher, then the gains from staying decrease, giving the the dictator more incentives to loot. On the other hand if the return of resources in the productive activities is relatively high, then the dictator has an incentive to stay.

As indicated in Proposition 1, the sign of ΔV , that is whether v^{stay} is above or below v^{loot}, depends on many of the parameters in the model (debt, liquidity, security). We wish to focus here on how the level of resource-based liquidity afforded to the dictator (θ_z) affects the autocrat's incentives to loot or to stay and invest in the economy. We commence by defining the critical values of collateral-based liquidity (θ_z) in terms of their impacts upon the dictator's incentives.

Definition:

1) For a given θ_k, define $\overline{\theta}_z : v^{loot}(\overline{\theta}_z) = \dfrac{ru(\overline{\theta}_z Z + \theta_k k)}{(1+r)(1-\beta)}$, represented by the line tangent to v^{stay} at k^* in Figure 3.2 such that $f'(k^*) + (1-\delta) = \dfrac{r\theta_k u'(\overline{\theta}_z Z + \theta_k k)}{(1+r)(1-\beta)}$ and $v^{loot}(k^*, d) = v^{stay}(k^*, d)$.

2) For a given θ_k, define $\underline{\theta}_z : v^{loot}(\underline{\theta}_z) = \dfrac{ru(\underline{\theta}_z Z + \theta_k k)}{(1+r)(1-\beta)}$, represented by the line parallel to $v^{loot}(\overline{\theta}_z)$ in Figure 3.2 such that $v^{loot}(k=0, d; \underline{\theta}_z) = v^{stay}(k=0, d)$, with $\underline{\theta}_z < \overline{\theta}_z$.

Note that $v^{loot}(\overline{\theta}_z)$ is the line passing the point at which the marginal product of capital and the marginal liquidity of capital are equal for a given θ_k. Also, $v^{loot}(\underline{\theta}_z)$ is parallel to $v^{loot}(\overline{\theta}_z)$ and passes through the minimum of v^{stay} at $k=0$. In effect, the v^{loot} iso-cline shifts upwards with increasing θ_z and the critical values define where it lies in relation to the v^{stay} curve. This definition allows us to state our main result.

Proposition 2: Value of looting as a function of liquidity

1) If $v^{loot}(\theta_z) > v^{loot}(\overline{\theta}_z)$ for a given d and θ_k, then the dictator always loots irrespective of the level of k.

2) *If $v^{loot}(\underline{\theta}_z) < v^{loot}(\theta_z) < v^{loot}(\overline{\theta}_z)$ for a given d and θ_k, there are two capital levels $\tilde{k}_1$ and $\tilde{k}_2$ (with $\tilde{k}_1 < \tilde{k}_2$) such that the dictator stays for any $k \in (\tilde{k}_1, \tilde{k}_2)$ and loots otherwise.*

3) If $v^{loot}(\theta_z) < v^{loot}(\underline{\theta}_z)$ for a given d and θ_k, then there exists a unique $\tilde{k}_3$ such that $v^{stay}(\tilde{k}_3, d) = v^{loot}(\tilde{k}_3, d)$. The dictator loots for any capital level above $\tilde{k}_3$ and stays otherwise.

Proof: see Appendix A.2.

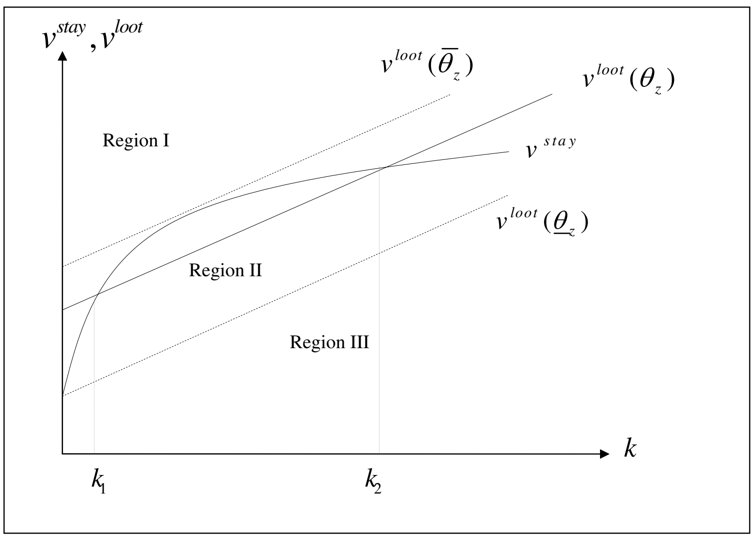


Figure 3.2: Looting and Staying Regions as function of θ_z

In Figure 3.2 we illustrate the results stated in Proposition 2. For a given set of parameters (debt level, security of tenure), the level of resource-based liquidity will determine the incentives of the dictator to stay and invest, or to loot the economy.[6] Specifically, the level of resource-based liquidity afforded must be such that the dictator finds itself in the region where the v^{stay} curve lies above the v^{loot} curve in order to have any incentives to stay and invest in the economy; otherwise, the optimal choice is to take any proffered liquidity and "to loot" the economy. Our

[6] Of course, the other parameters also play a role. Reductions in the values for the parameters for debt (d) and security of tenure (λ) increases the value of staying (shifts the v^{stay} curve upwards). We investigate this further in the simulations in section 3.3.

main result is that increased liquidity will unambiguously increase the prospects for political instability and looting in a given state. That is, increases in the value of the parameter for resource-based liquidity (θ_z) raises the value of looting (shifts the v^{loot} curve upwards).[7]

If the two curves potentially intersect, then the two values $\overline{\theta}_z$ and $\underline{\theta}_z$ separate the space into three regions: 1) Region I, for values of θ_z located above $\overline{\theta}_z$ where looting is always optimal; 2) Region II for values of θ_z between $\overline{\theta}_z$ and $\underline{\theta}_z$ where staying and investing is optimal within a specified (intermediate) range of capital levels; and 3) Region III for values of θ_z below $\underline{\theta}_z$ where looting is optimal only for the highest values of k. This interaction between liquidity, capital and the incentives for looting provides the structure of the dynamics of the incentive system, and is investigated in the simulations in section 3.3.

The fundamental trade-off from the perspective of the dictator concerns the amounts currently appropriable from the economy (via liquidity and looting) and the amounts potentially producible (via investment and security of tenure). Any new dictator must turn down proffered liquidity in order to decide to stay and invest in the economy. This points to the fact that almost any resource-rich country can be rendered politically unstable by affording sufficient levels of liquidity. This has been demonstrated by others, in their demonstration of the nature of self-enforcing sovereign debt contracts. (Bulow and Rogoff, 1989; Kletzer and Wright, 2005) In all of these models of enforceable sovereign loan agreements, excess liquidity in any given period is sufficient to generate the choice of default. Our model is a counter-part to those, illustrating how an inefficient sovereign debt contract is capable of inducing political instability and default, and what is "excessive" liquidity in the context of a resource-rich but autocratic state.

3.3 Simulation of the model – Liquidity and the Looting Economy

The previous section demonstrated how the offer of resource-based liquidity provides an incentive system for the dictator, determining whether he will choose to loot, or invest in, the economy. The results of Proposition 2 indicate that the incentives are dependent upon the level of capital stock available within the economy (k), since this will determine both the expected productivity

[7] It is of course possible that, for particular parameter values, the two curves do not intersect anywhere in (v, k) space. This would be the case if either debt levels or security levels were so extreme as to render financial contracting unimportant. In this instance we term the issue of financial contracting non-critical, and we leave this case aside. Examples of such states might be the highly indebted states of sub-Saharan Africa or the extremely secure states of Arabia.

of additional increments to the capital stock as well as the capital for liquidation. For this reason, the system of incentives for looting may evolve along a particular development path, given a particular level of proffered liquidity. In particular, an economy commencing within Region II (in Figure 3.2) will initially commence with incentives for investment, but may evolve into a situation where the incentives are for looting. In these circumstances the time of departure is endogenous, and a function of both liquidity and capital stock within the economy.

In this section we simulate the evolution of such an economy, given both low liquidity and high liquidity, to illustrate how a dictator will choose its date of departure by reference to the evolving system of incentives to loot. Initially the dictator will perceive high returns to initial investments in capital, and so stay and invest, but as successive increments to the capital stock reduce returns, the relative returns to looting may come to dominate.

Specification of the Model. To illustrate the dynamics of a resource-rich economy with optional liquidity-based looting, we simulate the model using the following functional forms: utility is specified as a CES function $u(c) = \dfrac{c^{1-\sigma}}{1-\sigma}$, and the probability of losing power is an exponential function of the form $\rho(k') = \exp(-\lambda k')$, where λ represents the dictator's effectiveness in preventing his demise. The production function takes the form $f(k) = Y_s - \dfrac{Y_s}{1+k}$, where $f' < 0$ and $f'' < 0$. In the limit, output will tend to Y_s. The value of staying and looting are then given by:[8]

$$v^{stay}(k,d) = \max_{c,k',d' \in \Gamma(k,d)} \ \left(1-\exp(-\lambda k')\right) \left[\frac{c^{1-\sigma}}{1-\sigma} + \beta E_{\varepsilon'} V(k',d')\right] \tag{3.12}$$

$$\text{s.t. } \Gamma(k,d) = \begin{cases} k' = f(k) + \phi Z + (1-\delta)k - c - (1+r)d + d' \\ d' = d + l \\ d' \leq \dfrac{(1+r)}{r}\left(\theta_z Z + \theta_k k\right) \\ l \leq \theta_z Z + \theta_k k \\ c \geq 0; \\ k \geq 0;\ d \geq 0 \\ k(0) = k_0;\ d(0) = d_0 \end{cases} \tag{3.13}$$

[8]For the sake of simplicity, we omit the role of repression s in the simulation. An analysis of the effect of repression on a dictator's incentives to invest is performed in the next chapter.

$$v^{loot}(k,d) = \frac{u(c^{loot})}{1-\beta} \quad \text{where } c^{loot} = \frac{r}{1+r}\left(\theta_z Z + \theta_k k\right) \tag{3.14}$$

Parametrisation of the Model. The following parameters are established as baselines, and will remain constant throughout all of the simulations: $\beta = 0.95$; $\sigma = 0.9$; $\delta = 0.1$; $r = 0.12$.

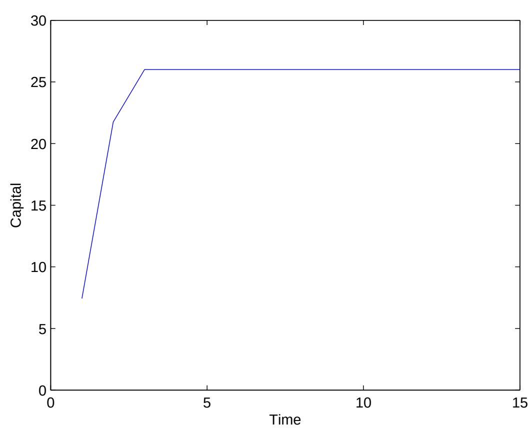
Simulation of Growth. In Figure 3.3 and Figure 3.4 we illustrate the impact of incentives for looting generated by first low liquidity and then high liquidity in resource-based lending. Figure 3.3 demonstrates how, for low enough values of θ_z, the incentives for investment inhere. Here the dictator views the productivity of the economy as his primary asset. Debt is exercised to its limit, but the dictator uses it for investment and in-place consumption. The regime does not change and capital levels reach the steady state optimum. In effect, the autocrat is acting as "owner" of the entire economy, and lending simply serves its purpose as a mechanism for shifting consumption across time. However, when θ_z is high enough (doubled to 0.4 Z as in Figure 3.4), the dictator uses debt to pursue a "hit and run" strategy with regard to the economy. He accumulates capital to a point, but then loots as much of the capital and liquidity as is possible. This decision to loot is based on the dictator's comparison of the relative returns to further capital investments versus liquidity-based looting, which flip the incentives for the autocrat in the third period. This change in incentives for the dictator makes a big difference for the economy concerned. A comparison of the two simulations reveals that capital in the looted economy moves to levels approximately 25% below that which occurs under the investment scenario (comparing Figure 3.3 and Figure 3.4 at period $t3$).

More importantly, the dynamics of the simulations reveal that the second economy never recovers from this initial looting. The fact that the new dictator (in $t4$) takes over an economy with higher debt levels means that the value of staying commences at a much reduced level. Looting becomes the optimal choice for this economy from then on. A series of incoming autocrats immediately loot the country's riches until debt reaches the ceiling, at which point banks are no longer willing to provide further liquidity. (see Figure 3.4 in periods $t4 - t14$) This economy is now caught in a "debt trap" of political instability and low growth, with its origins in the level of resource-based liquidity proffered to the incoming autocrats.

These simulations demonstrate that an incoming autocrat may act as an "owner" or as a "thief" in regard to the economy, depending upon the level of liquidity on offer. Low levels of liquidity maintain the incentives to stay and to invest as the owner of the economy. The returns from control are secured by staying on the scene, maintaining control and securing the flow of returns from earlier investments. On the other hand, high levels of liquidity act as a prize to the winner of the contest for control, and create incentives for an ongoing system of hit and runs. The returns from control in this case are secured simply by winning the contest for control of the economy—then the banks pay the prize and the contest winner exits the stage. This may be illustrated by comparing the incentives of a relatively secure dictator (low hazard of displacement) in Figure 3.3 with those inhering under the conditions of an insecure ruler (high hazard rate) in Figure 3.5. What is the impact of "security of tenure" on the incentive system facing the dictator?[9] If the dictator is able to secure his tenure (relatively high λ in Figure 3.3) then he has incentives to stay and invest in productive capital as "owner". By contrast, if he is unable to secure his tenure (low λ in Figure 3.5), then the incentives are to loot. Since insecurity and lending have the same impact on incentives, it is apparent that both have the capacity to turn an owner-ruler into a thief.

Case of low liquidity

$\beta = 0.95$; $\sigma = 0.9$; $r = 0.12$; $\delta = 0.1$; $\theta_z = 0.2$; $\theta_k = 0.1$; $\lambda = 0.15$; $\phi = 0.1$; $NR = 5$; $Y_s = 13$; $d_{max} = 37$



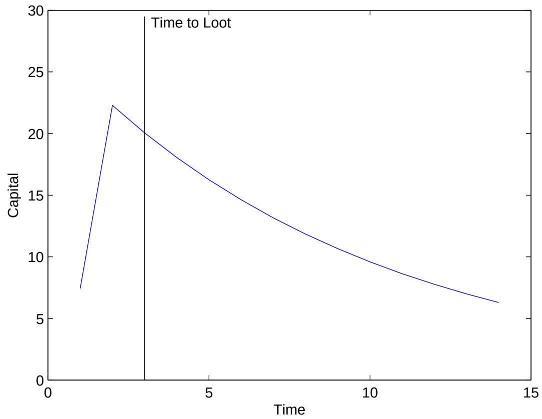
Period	Capital	Output	Debt	Consumption	Number Regimes
t1	7.4	11.5	1.5	0.7	1
t2	21.8	12.4	6.0	9.8	1
t3	26.0	12.5	10.6	13.1	1
t4	26.0	12.5	15.1	12.6	1
t5	26.0	12.5	19.6	12.1	1
t6	26.0	12.5	24.2	11.5	1
t7	26.0	12.5	28.7	11.0	1
t8	26.0	12.5	33.2	10.2	1
t9	26.0	12.5	37.0	6.0	1
t10	26.0	12.5	37.0	6.0	1
t11	26.0	12.5	37.0	6.0	1
t12	26.0	12.5	37.0	6.0	1
t13	26.0	12.5	37.0	6.0	1
t14	26.0	12.5	37.0	6.0	1
t15	26.0	12.5	37.0	6.0	1

Figure 3.3: Optimal capital over time with low θ_z

[9] Comparing Figures 3.3 and 3.5 demonstrates the point of McGuire & Olson (1996). Their argument is that when an autocrat is secure about his tenure, he will stop behaving as a bandit leader and instead act as a ruler whose interest is aligned with the people's. When the probability of survival is high and the autocrat values the future, an "invisible hand" makes his interest consistent with the interests of society at large.

Case of high liquidity

$\beta = 0.95$; $\sigma = 0.9$; $r = 0.12$; $\delta = 0.1$; $\theta_z = 0.4$; $\theta_k = 0.1$; $\lambda = 0.15$; $\phi = 0.1$; $NR = 5$; $Y_s = 13$; $d_{max} = 47$

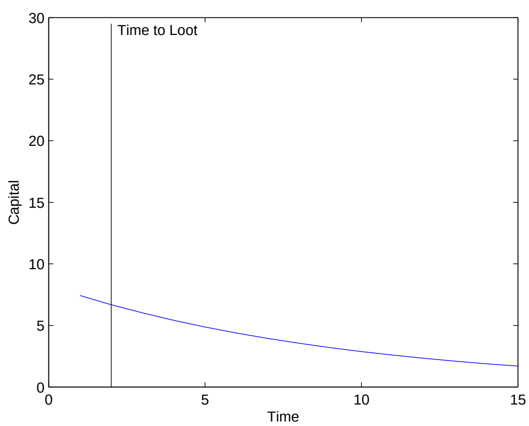


Period	Capital	Output	Debt	Consumption	VLoot	Number Regimes
t1	7.4	11.5	1.9	1.1		1
t2	22.3	12.4	7.7	11.1		1
t3	20.1	12.4	11.7		183.8	1
t4	18.1	12.3	15.7		182.8	2
t5	16.2	12.2	19.7		182.0	3
t6	14.6	12.2	23.7		181.1	4
t7	13.2	12.1	26.7		180.3	5
t8	11.8	12.0	29.7		179.6	6
t9	10.7	11.9	32.7		178.9	7
t10	9.6	11.8	35.7		178.3	8
t11	8.6	11.7	38.7		177.7	9
t12	7.8	11.5	41.7		177.2	10
t13	7.0	11.4	44.7		176.7	11
t14	6.3	11.2	47		176.2	12

Figure 3.4: Optimal capital over time with high θ_z

Case of high hazard

$\beta = 0.95$; $\sigma = 0.9$; $r = 0.12$; $\delta = 0.1$; $\theta_z = 0.2$; $\theta_k = 0.1$; $\lambda = 0.13$; $\phi = 0.1$; $NR = 5$; $Y_s = 13$; $d_{max} = 37$



Period	Capital	Output	Debt	Consumption	ConsoLoot	VLoot	Number Regimes
t1	7.4	11.5	1.5	0.71			1
t2	6.7	11.3	3.5		0.18	168.37	1
t3	6.0	11.1	5.5		0.17	167.68	2
t4	5.4	11.0	7.5		0.17	167.04	3
t5	4.9	10.8	9.5		0.16	166.44	4
t6	4.4	10.6	10.5		0.15	165.89	5
t7	3.9	10.4	11.5		0.15	165.38	6
t8	3.6	10.1	12.5		0.15	164.90	7
t9	3.2	9.9	13.5		0.14	164.47	8
t10	2.9	9.6	14.5		0.14	164.06	9
t11	2.6	9.4	15.5		0.13	163.69	10
t12	2.3	9.1	16.5		0.13	163.35	11
t13	2.1	8.8	17.5		0.13	163.04	12
t14	1.9	8.5	18.5		0.13	162.76	13
t15	1.7	8.2	19.5		0.13	162.50	14

Figure 3.5: Optimal Capital over time with High Hazard (low λ)

These simulations translate our basic model of autocratic choice into empirically observable outcomes regarding lending, political instability, and economic growth. We have demonstrated that excessive resource-based lending may be seen to induce political instability and result in poorly performing economies. We turn now to an empirical examination of these claims.

3.4 Empirical Model and Data

The key prediction of our model is that lending combined with resources contributes to looting and political instability and this in turn results in reduced economic growth.

Our model suggests that the following claims might be supported, which we intend to explore here:

Claim 1) Lending based upon natural resource wealth will result in higher political instability. Looting will increase when resource-richness is combined with high levels of liquidity. This instability will in turn adversely affect economic growth in the autocratic resource-rich state.

Claim 2) Lending-induced political instability will depend upon the level of the nation's production. Looting should be reduced with income but, beyond some threshold, larger incomes should result in a greater incidence of looting.

Our primary objective in this section is to test these claims in regard to country-level data on lending, political and economic performance. We specify the econometric model as follows:

$$\Delta log(GDPcap)_{it} = \alpha_0 + \alpha_1 Turnover_{it} + \alpha_2 X_{1it} + \varepsilon_{it} \tag{3.15}$$

$$\begin{aligned} Turnover_{it} &= \begin{cases} 1 & \text{if } Turnover^*_{it} > 0 \\ 0 & \text{otherwise} \end{cases} \\ Turnover^*_{it} &= \beta_0 + \beta_1 Resources_{it} + \beta_2 Lending_{it} + \beta_3 Resources_{it} * Lending_{it} \\ &+ \beta_4 log(GDPcap)_{it} + \beta_5 log(GDPcap)^2_{it} + \beta_6 X_{2it} + \eta_{it} \end{aligned} \tag{3.16}$$

Following the literature on instability and growth (Ozler and Tabellini, 1991 and Alesina et al., 1996), political instability is defined as "the propensity to observe government changes, be it constitutional or unconstitutional".[10] Consistent with model predictions, political instability

[10] The main difficulty in estimating the structural model developed in section 3.2 is that looting decisions as modelled in this paper are virtually unobservable to the analyst. For example, the occurrence of a leader's turnover may be a poor approximation for the looting decision as turnover often takes place for reasons independent of leaders' decision to leave power. Given the lack of data for our dependent variable to perform a structural estimation, we opt for a more modest approach, and test the predictions of the model using reduced form estimations.

(or turnover) is determined by resource rents, lending and their interaction. The interaction between these two variables is particularly important because it substantiates the impact of credit markets lending practices on political instability in resource-rich countries. The model also predicts political instability for low and high levels of capital in Region II. We test this prediction by including per capita GDP and its square in the specification of the turnover equation. Finally, in the vector X_2, we include numerous controls to circumvent omitted variables bias. Our specifications also control for ethnic fractionalization (an exogenous source of political instability), institutional features (proxied by the proportion of the population speaking a European language at birth as suggested by Hall and Jones, 1999), regional dummies and time dummies to account for macroeconomic effects that impact all countries in a given year.

Following the growth literature, the growth equation incorporates lagged GDP per capita to control for convergence (Islam, 1995), a proxy for human capital accumulation (number of years of schooling), population growth, investment as a percentage of GDP, the inflation rate, trade openness. In addition to these variables, vector X_1 includes numerous controls to circumvent omitted variables bias. Our specifications control among others for institutional features, regional dummies or country dummies, and time dummies. The standard growth equation is augmented with leadership turnover as a measure of instability.[11] We are interested in the indirect effect of resources and lending on growth due to political instability, that is:

$$\frac{\partial E(\Delta log(GDPcap)_{it}|Lending_{it})}{\partial Lending_{it}} = \alpha_1 \frac{\partial Pr(Turnover = 1|Lending_{it})}{\partial Lending_{it}} \tag{3.17}$$

We estimate equations (3.15) and (3.16) jointly by Full Information Maximum Likelihood (FIML) using a treatment regression approach. This allows for correlation between the error terms which are assumed to be joint normally distributed. The treatment (turnover regression) and outcome (growth equation) are estimated jointly by maximizing the bivariate normal likelihood function. This is a fully efficient estimation method which takes account of the possibility that omitted forces drive both growth and turnover by incorporating a correlation between the error terms in the treatment and outcome equations into the model. Identification in this

[11]To check for robustness, we will use later the occurrence of a coup, and the turnover of veto players as alternative measures of instability.

framework may come from the non-linear functional form and in principle does not require an exclusion restriction assumption. However, identification by functional form may be particularly weak (Arellano, 2006). To improve the identification of the model, we impose an exclusion restriction. In particular we assume that ethnic fractionalization affects the probability of turnover but is excluded from the growth equation. The prior is that higher ethnic fractionalization may lead to more instability. This is consistent with Easterly and Levine (1997) who argue that ethnic diversity may affect economic growth through political instability.

Our data set runs from 1970 to 2000 and contains 61 countries that have been led by an authoritarian regime at some point since 1970 (see Table 3.1).[12] We are mainly constrained by the availability of data on external finance. The sample excludes six Arab Gulf countries (Bahrain, Kuwait, Iraq, Qatar, Saudi Arabia, United Arab Emirates) due to lack of data on lending. It also excludes Western countries and the former Soviet bloc. We use the variable polity2 from Polity IV dataset to indicate whether a regime is authoritarian. For any given year, a country with a polity2 score below 0 is considered authoritarian.

As our first dependent variable, we use the turnover of political leadership as the measure of political instability. This information comes from Bueno de Mesquita, et al. (2003). Complementary data is available from Archigos, a database of political leaders developed by Gleditsch and Chiozza (2006, version July 2006). Archigos is particularly comprehensive and detailed so that we relied on it whenever there was a discrepancy with Bueno de Mesquita et al. Our second dependent variable measures the growth of PPP-adjusted real GDP per capita and comes from the Penn World Tables 6.2 (PWT 6.2, 2006).

As independent variables, data on resources and inflows of lending are of particular interest. Our measure of resource wealth is the resource rent provided by K. Hamilton and G. Ruta from the World Bank. It includes mineral, coal, oil and gas rent and spans the period 1970 to 2000. It is measured as the product of the quantity of resources extracted and the difference between the resource price and the unit cost of extraction. Lending (i.e., disbursements) by private creditors comes from the World Bank Global Development Finance (GDF, 2006). The main limitation of this dataset is that the major Gulf countries are not available. We take real PPP-adjusted

[12]For robustness check, we also use a set of 9 countries that have always been democratic since 1970.

real GDP (and real GDP per capita) from PWT 6.2 (2006).

A casual look at the data confirms some basic findings highlighted in the literature. Figure 3.6 shows the evolution of average lending and resource rents between 1970 and 2000. The lending curve mirrors the resource rents curve. This supports earlier claims that international financial markets lend money during commodity “booms” and restrict liquidity during “busts”. The evolution of these two indicators until the early eighties is clearly indicative of the “boom-based borrowing capacity” highlighted by Usui (1997), and Manzano and Rigobon (2001).

Finally, we proxy for institutional quality with the fraction of people speaking a European language at birth introduced by Hall and Jones (1999).

3.5 Estimation Results

This section reports our estimation results and analyses the determinants of political instability and growth using full information maximum likelihood estimation. Our basic specifications are reported in columns (1) and (2) of Table 3.2. Panel A represents growth equation (3.15) and Panel B presents the results from turnover equation (3.16). In column (2) of the growth equation, we control for country fixed effects. Note that in both specifications, the treatment equations (turnover equations) control only for regional dummies because fixed effects probit would produce inconsistent estimates.

Two main findings are apparent from our basic specifications. First, in Panel B columns (1)-(2), the treatment equations show that the interaction term of resources and lending is associated with a higher likelihood of turnover and its coefficient is highly significant. This result indicates that greater lending to resource-rich countries is associated with higher political instability. This finding is consistent with the prediction of the theoretical model that dictators of resource-rich countries with easy access to external capital may choose to loot rather than invest, which leads to increased instability. Besides, the fact that the coefficient of resource rents (main effect) is significantly negative suggests that resources *per se* are not to blame for political instability.

Our second finding is that political instability is detrimental to growth consistent with Alesina et al. (1996) – see columns (1) and (2) in Panel A. The effect of political instability on growth is particularly large, negative and it is statistically significant. In investigating the effect of instability on growth, we are typically interested in the indirect effect of lending on growth through instability. This indirect effect is the product of the coefficient of instability in the growth equation (α_1) with the partial effect of lending on the probability of turnover. For expositional purposes, we choose to vary lending by one standard deviation from its mean (respectively $\overline{L}$ and $\overline{L} + StdDev$). All the other variables are set at their mean level. However, the value of the resource rent, ethnic diversity, per capita GDP are those of Nigeria – a country with a high resource base. Equation (3.17) is then re-written as:

$$E(\Delta log(GDPcap)_{it}|\overline{L} + StdDev) - E(\Delta log(GDPcap)_{it}|\overline{L})$$
$$= \alpha_1 \left(Pr(Turnover = 1|\overline{L} + StdDev) - Pr(Turnover = 1|\overline{L})\right)$$

We find in Table 3.3 that the effect of a one standard deviation increase in lending results in a decrease in economic growth by 0.68 and 0.82 percentage point for specifications (1) and (2).

Together these two main results provide a strong evidence to support our theory. Lending to resource-rich dictators raises the chance of political instability, leading to low growth.

The effect of the other explanatory variables will now be analysed. We find that the per capita income tends to reduce instability (it has a negative and significant effect both in columns (1) and (2)), while its square is positively correlated with instability. This suggests that beyond a certain level per capita GDP induces more instability. Finally, ethnic fractionalization is positively correlated with instability as expected.

We now turn to the effect of the control variables on growth. Investment is the main determinant of growth once fixed effects are controlled for. A rise in the investment rate by 1 percentage point causes growth to increase by 0.10 and 0.18 percentage point. The inflation rate is also an important predictor for growth: it is negative and significant although its magnitude is fairly small. However, the effect of trade on growth is surprisingly negative.[13] This may be due to the fact that in our sample African countries, which experience the lowest growth performance, have also the highest GDP share of trade.

Finally, a Wald test rejects the null hypothesis that the error term of the instability equation is uncorrelated with the error term of the growth equation. For example, in our basic specifica-

[13] Evidence on the relationship between trade and growth is generally mixed (cf. Yanikaya, 2003; and Edwards, 1998). According to Rodrik and Rodriguez (2000), the only systematic relationship is "that countries reduce their trade barriers as they get richer."

tions, we obtain $\chi^2(1) = 73.79$ without fixed effects in column (1) and $\chi^2(1) = 78.64$ with fixed effects in columns (2). This implies that the joint estimation of the treatment and outcome equations is required to generate unbiased estimates.

We now perform several checks to ensure the robustness of our findings. First, there is a potential endogeneity bias for our main explanatory variables—lending and resource rent since both variables may be determined by political instability. We instrument them and their interaction with commodity price indices, US interest rates proxied by yields on 10 years bond, and the interaction of these variables. These variables are correlated with the endogenous explanatory variables and are assumed to affect political instability only via those variables and not directly. We will use a control function approach which enables us to test directly the exogeneity of these variables in the political instability equation. The control function consists in a two-step procedure. In the first step, we estimate the residuals of the reduced-form equation for resources, lending and their interaction on the excluded instruments and the other covariates. The second step is the estimation of the political instability equation with the reduced-form residuals included as additional explanatory variables. The joint significance of the coefficients of the residuals in the second stage equation will be indicative of endogeneity. (Smith and Blundell, 1986)

In the first stage, we perform a heteroskedasticity-robust exogeneity test and find that the set of instruments used for lending, resources and their interaction is jointly significant in all three reduced form equations. Then, in the second stage we test the joint significance of the residuals derived in the first stage (see Table 3.4). The residuals are jointly insignificant as we obtain $\chi^2(3) = 1.98$ with $p < 0.58$. This finding shows that we cannot reject the null hypothesis that these variables are exogenous.

As a second robustness check, we analyse the subsample of countries that have continuously been democratic since 1970 (see columns (3)-(4) of Table 3.2). We find that the marginal effect of lending, although positive, is not statistically significant. This suggests that the adverse relationship between lending and political instability is not present in democracies. There is however, a strong negative association between growth and leaders' turnover. A careful analysis of the data reveals that this is mostly due to the fact that in democracies, bad economic performance tend to be sanctioned during elections by the dismissal of the leader.

The third robustness check consists in using two alternative measures of political instability. In particular, we construct a dummy variable which indicates the propensity for a coup to occur.[14] The basic data comes from the *Cross-National Time-Series Data Archive* (Banks, 2001). We also use the turnover of all the veto players introduced by Beck et al. (*Database of Political Institutions*, 2004 update).[15] The results are presented in Table 3.5 and are consistent with our earlier findings using turnover.

3.6 Conclusion

This paper attempts to unravel a mechanism through which the much-discussed resource curse operates. Our main contribution is to show how credit market imperfections impact upon the choices of dictators in resource-rich countries, which in turn leads to instability and slow growth. In our model, a dictator makes a choice between staying and looting. Looting is facilitated when international banks are willing to turn natural capital into loans. The incentives for staying, on the other hand, result from the opportunity for taking advantage of the country's potential productivity while remaining in power. Key to the choice made by the dictator is his ability to prevent his own removal by political events such as coups or revolutions.

Our model suggests that the dictator will be fundamentally influenced in this choice by the level of lending afforded by external banking institutions. The opportunity cost to staying and investing in the economy increases directly with any increase in the liquidity being afforded. The importance of restricting short term liquidity to aid the enforceability of loan agreements has been long-noted (Bulow and Rogoff, 1989) as has been the tendency of banks to ignore such advice. (Bulow, 2002) The problem is argued to be one of moral hazard in the financial markets, where banks fail to internalise the risks of default because of the belief that sovereign debts will ultimately be "worked out" and particularly those with large amounts of natural

[14] Coups d'etat and revolutions are defined in Banks (2001) as follows:

Coup d'etat: The number of extraconstitutional or forced changes in the top government elite and/or its effective control of the nation's power structure in a given year. The term "coup" includes, but is not exhausted by, the term "successful revolution". Unsuccessful coups are not counted.

Revolution: Any illegal or forced change in the top governmental elite, any attempt at such a change, or any successful or unsuccessful armed rebellion whose aim is independence from the central government.

[15] Instead of the turnover of the leader only, this database records the percentage turnover of veto players. In presidential systems, veto players are defined as the president and the largest party in the legislature, and in parliamentary systems, the veto players are defined as the PM and the three largest government parties.

resources underlying them. The failure of the financial sector to internalise these risks places these costs upon the peoples of the countries concerned.

We find strong evidence to support our main prediction that unsound lending to dictators in resources rich countries results in instability, and ultimately in slower economic growth. Here, resources become a curse when imperfect domestic and international institutions (political and financial markets) interact to produce political instability, which in turn impedes economic growth. Poor lending practices is one channel to the resource curse.

There are many approaches advocated to deal with this sort of moral hazard. Bulow (2002) believes that the problem is sourced fundamentally in the intervention of external institutions in rescuing commercial banks from defaults. Banks engage in moral hazard in these lending practices on account of a fundamental failure of belief in the possibility of default. He recommends that banks should be made to execute loan agreements under domestic laws, enforceable only in domestic courts, in order to ensure that the debtor state's interests are taken into consideration. It is argued by some that advance due diligence in lending should be a requirement for the enforceability of the resulting debt. (Jayachandran, Kremer and Schafter, 2006) One possibility is to require that any loans be more structured obligations, relying on specified investments rather than general assets. This would ensure that banks required investments as a result of loans, and that these investments were of a sort that could generate returns to the bank. Finally, it may be more appropriate to encourage FDI rather than sovereign debt, again rendering recourse to domestic institutions necessary. All of these approaches may reduce the availability of debt in general, but our analysis indicates that this may be a good thing.

Bibliography

[1] Acemoglu, D., S. Johnson, and J.A. Robinson (2001): The Colonial Origins of Comparative Development: An Empirical Investigation. *American Economic Review*, 91: 1369–1401.

[2] Acemoglu, D., S. Johnson, and J.A. Robinson (2003): An African Success Story: Botswana, In D. Rodrik (Ed): *Search of Prosperity: Analytical Narrative on Economic Growth*, Princeton University Press.

[3] Acemoglu, D., J.A. Robinson, and T. Verdier (2004): Kleptocracy and Divide-and-Rule: A Model of Personal Rule, *Journal of the European Economic Association*, 31: 162–192.

[4] Ai C. and E. Norton (2003): Interaction terms in Logit and Probit Models. *Economics Letters*, 80: 123–129.

[5] Alesina A. and R. Perotti (1996): Income Distribution, Political Instability, and Investment, *European Economic Review*, 40: 1203–1228.

[6] Alesina A., S. Özler, N. Roubini and P. Swagel (1996): Political Instability and Economic Growth. *Journal of Economic Growth*, 1: 189–211.

[7] Arellano, M. (2006): Evaluation of Currency Regimes: The Unique Role of Sudden Stops: Comments, *Economic Policy*, 45: 119–152.

[8] Auty, R.M. (2000): Resource Abundance and Economic Development, *Oxford University Press*.

[9] Azam, J.P. (1995): How to Pay for the Peace? A Theoretical Framework with References to African Countries. *Public Choice*, 83: 173–184.

[10] Baland, JM. and P. François (2000): Rent-seeking and Resource Booms. *Journal of Economics Development*. 61: 527–542.

[11] Banks, A. (2001): *Cross-National Time-Series Data Archive*, Center for Comparative Political Research, State University of New York (Binghamton).

[12] Beck, T., G. Clarke, A. Groff, P. Keefer, and P. Walsh (2001): New Tools in Comparative Political Economy: The Database of Political Institutions. *World Bank Economic Review* 15(1): 165–176.

[13] Bueno de Mesquita, B., A. Smith, R. Siverson and J. Morrow (2003): *The Logic of Political Survival*, MIT Press.

[14] Bulow, J. (2002): First World Governments and Third World Debt. *Brookings Papers on Economic Activity*, Vol. 2002(1): 229–255

[15] Bulow, J. and K. Rogoff (1989): A Constant Recontracting Model of Sovereign Debt. *Journal of Political Economy*, 97(1):155–178.

[16] Collier, P. and A. Hoeffler (1998): On Economic Causes of Civil War. *Oxford Economic Papers*, 50: 563–573.

[17] Collier, P. and A. Hoeffler (2004): Greed and Grievance in Civil War, *Oxford Economic Papers*, 56(4): 563–595.

[18] Correlates of War Project (2005): National Material Capabilities Data, Version 3.0.

[19] Dunning, T. (2005): Resource Dependence, Economic Performance, and Political Stability, *Journal of Conflict Resolution*, 49: 451–482.

[20] Easterly, W. and R. Levine (1997): Africa's Growth Tragedy: Policies and Ethnic Divisions, *Quarterly Journal of Economics*, 112(4): 1203–1250.

[21] Eaton, J. and M. Gersovitz (1981): Debt with Potential Repudiation: Theoretical and Empirical Analysis, *Review of Economic Studies*, 48: 289–309.

[22] Edwards, S. (1998): Openness, Productivity and Growth: What Do We Really Know? *Economic Journal*, 108: 383–398.

[23] Fearon J. and D. Laitin (2003): Ethnicity, Insurgency and Civil War, *American Political Science Review*, 97: 75–90.

[24] Gleditsch, K.S. and G. Chiozza (2006): *Archigos. A Data Base on Leaders 1875 - 2004*. July 2006 Version.

[25] Hall, R. and C.I. Jones (1999): Why Do Some Countries Produce So Much More Output per Worker than Others? *Quarterly Journal of Economics*, 114: 83–116.

[26] Heston, A., R. Summers and B. Aten (2006): *Penn World Table Version 6.2, Center for International Comparisons of Production, Income and Prices*, University of Pennsylvania.

[27] Islam, N. (1995): Growth Empirics: A Panel Data Approach, *Quarterly Journal of Economics*, 110: 1127–1170.

[28] Jayachandran, S. and M. Kremer (2006): Odious Debt. *American Economic Review*, 96(1): 82–92.

[29] Jayachandran, S., M. Kremer and S. Shafter (2006): Applying the Odious Debt Doctrine While Preserving Legitimate Lending, Paper presented at the Center for International Development, 2006.

[30] Lindert, P.H. and Morton, P.J. (1989): How Sovereign Debt Has Worked, In Jeffrey Sachs (ed.): Developing Country Debt and Economic Performance, 1: 39-106, University of Chicago Press, Chicago.

[31] Londregan, J.B. and K.T. Poole (1990): Poverty, The Coup Trap and the Seizure of Executive Power, *World Politics* 42: 151–183.

[32] Manzano, O. and R. Rigobon, R. (2001). Resource Curse or Debt Overhang? NBER Working Paper No 8390, Cambridge MA.

[33] Marshall, M.G. and K. Jaggers (2002): POLITY IV Project: Political Regime Characteristics and Transitions, 1800-2002, University of Maryland.

[34] Mason, R. and T. Swanson (1996): Long-term Liability and the Choice of Liquidation, *The Geneva Papers on Risk and Insurance*, 21: 204–223.

[35] McGuire, M.C. and M. Olson (1993): The Economics of Autocracy and Majority Rule: The Invisible Hand and the Use of Force, *Journal of Economic Literature*, 34: 72–96.

[36] Mehlum, H., K. Moene, R. Torvik (2006): Institutions and the Resource Curse, *Economic Journal*, 116: 1–20.

[37] Olson, M. (1993): Dictatorship, Democracy and Development, *American Political Science Review*, 87: 567–575.

[38] Overland, J., K. L. Simons, and M. Spagat (2005): Political Instability and Growth in Dictatorships, *Public Choice*, 25: 445–470.

[39] Ozler, S., and G. Tabellini (1991): External Debt and Political Instability, *NBER Working Paper 3772*.

[40] Provencher B. (1997): Structural versus Reduced-Form Estimation of Optimal Stopping Problems, *American Journal of Agricultural Economics*, 79: 357–368.

[41] Przeworski A., and F. Limongi (1993): Political Regimes and Economic Growth, *Journal of Economic Perspectives*, 7: 51–69.

[42] Raffer, K. and H. Singer (2001): *The Economic North-South Divide : Six Decades of Unequal Development*, Edward Elgar: Cheltenham.

[43] Robinson J.A. (2001): When is a State Predatory? *Working Paper*.

[44] Robinson J.A., R. Torvik, T. Verdier (2006): Political Foundations of the Resource Curse, *Journal of Development Economics*, 79: 447–468.

[45] Rodrik, D., A. Subramanian and F. Trebbi (2004): Institutions Rule: The Primacy of Institutions Over Geography and Integration in Economic Development. *Journal of Economic Growth*, 9(2): 131–165.

[46] Rodrik, D. and F. Rodriguez (2000): *Trade Policy and Economic Growth: A Skeptic's Guide to the Cross-National Evidence*. NBER Macroeconomics Annual 2000, eds. Ben Bernanke and Kenneth S. Rogoff, MIT Press, Cambridge, MA.

[47] ROSS, M. (1999): The Political Economy of the Resource Curse, *World Politics* 51: 297–322.

[48] ROSS, M. (2001): Does Oil Hinder Democracy, *World Politics*, 53: 325–361.

[49] ROSS, M. (2005): Booty Futures. *UCLA Department of Political Science Working Papers.*

[50] RUST, J. (1987): Optimal Replacement of GMC Bus Engines: An Empirical Model of Harold Zurcher, *Econometrica*, 55: 999–1033.

[51] RUST, J. (1988): Maximum Likelihood Estimation of Discrete Control Processes, *SIAM Journal on Control and Optimization*, 26: 1006–1023.

[52] RUST, J. (1994): Structural Estimation of Markov Decision Processes, *Handbook of Econometrics*, Vol 4: 3081–3145.

[53] SACHS, J., AND A. WARNER (1995): Natural Resource Abundance and Economic Growth, *NBER Working Paper 5398.*

[54] SACHS, J., AND A. WARNER (2001): Natural Resources and Economic Development: The Curse of Natural Resources. *European Economic Review* 45: 827–838.

[55] SAMPSON, A. (1982): *The Money Lenders: Bankers and a World in Turmoil*,New York: Viking Press.

[56] SMITH, B. (2004): Oil Wealth and Regime Survival in the Developing World, 1960–1999, *American Journal of Political Science*, 48: 232–246.

[57] SMITH, R.J. AND R.W. BLUNDELL (1986): An Exogeneity Test for a Simultaneous Equation Tobit Model with an Application to Labor Supply, *Econometrica*, 54, 679-685.

[58] STIGLITZ, J.E. AND A. WEISS (1981): Credit Rationing in Markets with Imperfect Information, *American Economic Review*, 71: 393–410

[59] STIJNS, J.P. (2005): Natural Resource Abundance and Economic Growth Revisited, *Resources Policy*, 30: 107–130.

[60] USUI, N. (1997): Dutch Disease and Policy Adjustments to the Oil Boom: A Comparative Study of Indonesia and Mexico, *Resource Policy*, 23: 151–162.

[61] WEINTHAL, E. AND P.J. LUONG (2006): Combating the Resource Curse: An Alternative Solution to Managing Mineral Wealth, *Perspectives on Politics*, 4: 35–53.

[62] WINTROBE, R. (1990): The Tinpot and the Totalitarian: An Economic Theory of Dictatorship, *American Political Science Review*, 84: 849–872.

[63] WORLD BANK (2006): World Development Indicators.

[64] WORLD BANK (2007): Global Development Finance.

[65] YANIKAYA, H. (2003): Trade and economic Growth: A Cross Country Empirical Investigation, *Journal of Development Economics*, 72: 57–89.

Figure 3.6: Evolution of Average lending and Resource Rent (% GDP)

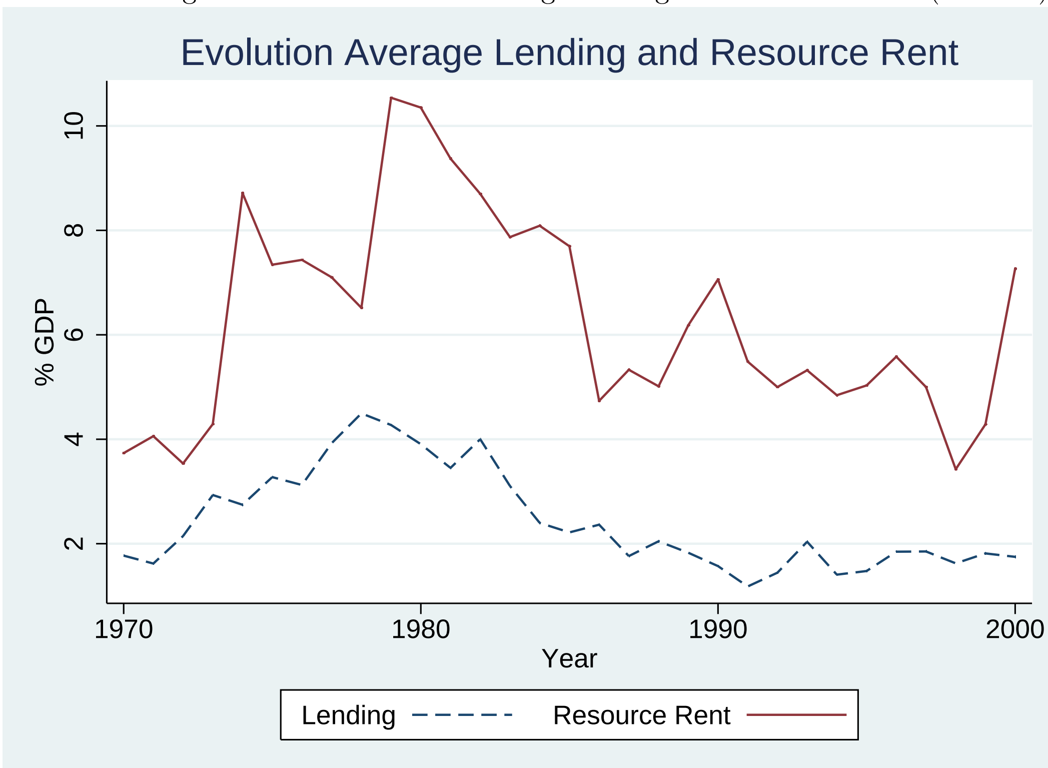


Table 3.1: List of Countries in the dictatorships sample

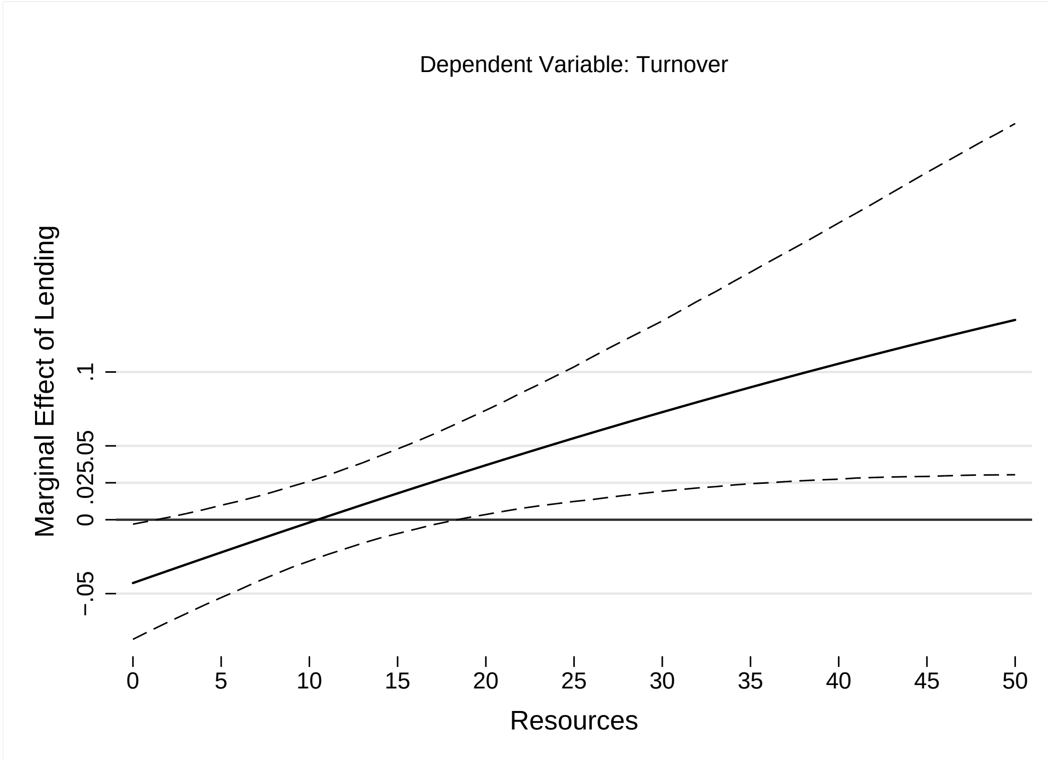
List of Countries	
Algeria	Madagascar
Angola	Malaysia
Argentina	Mali
Bangladesh	Mauritania
Benin	Mexico
Bolivia	Morocco
Botswana	Mozambique
Brazil	Nepal
Burkina Faso	Nicaragua
Burundi	Niger
Cameroon	Nigeria
Central African Republic	Oman
Chile	Pakistan
China	Peru
Congo Brazzaville	Philippines
Cote d'Ivoire	Rwanda
Ecuador	Senegal
Egypt	Sierra Leone
El Salvador	South Africa
Gabon	Sri Lanka
Gambia	Sudan
Ghana	Syria
Guatemala	Tanzania
Guinea	Thailand
Honduras	Togo
Indonesia	Tunisia
Iran	Turkey
Jordan	Uganda
Kenya	Zaire
Liberia	Zambia
	Zimbabwe

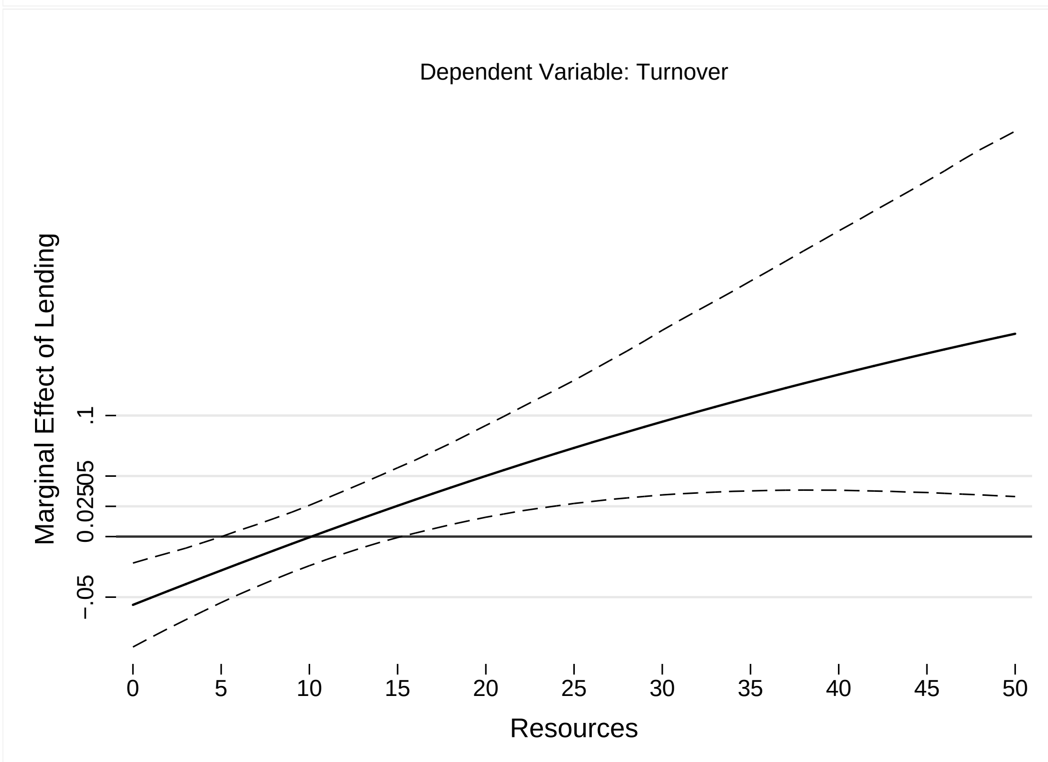
Table 3.2: Growth and Political Instability Regressions - Leadership Turnover

	Turnover - Leaders in Dictatorships		Turnover - Leaders in Democracies	
	(1)	(2)	(3)	(4)
PANEL A: Growth Equation				
Dependent Variable: Real per Capita GDP Growth				
Turnover	-9.4246***	-9.0502***	-8.3808**	-8.1232**
	[0.8965]	[0.8528]	[3.6474]	[3.5514]
Lag Real per capita GDP (in logs)	-1.4529*	-4.5679***	-4.3171	-11.8040*
	[0.8168]	[1.2386]	[2.9035]	[6.1173]
Population Growth	0.0257	0.1622	1.2462	-0.0258
	[0.2548]	[0.1946]	[1.4768]	[2.1873]
Average Years of Schooling	0.2094	0.1716	1.2187	1.6582
	[0.1988]	[0.4868]	[0.8942]	[1.8184]
Inflation	-0.0005***	-0.0004***	-0.0892***	-0.0842***
	[0.0001]	[0.0001]	[0.0204]	[0.0227]
Investment (% GDP)	0.1033**	0.1820**	-0.1293*	0.1953**
	[0.0507]	[0.0767]	[0.0726]	[0.0844]
Trade (% GDP)	-0.0006	-0.0213**	0.034	-0.0104
	[0.0069]	[0.0098]	[0.0396]	[0.0548]
Native European Language (%)	2.0594	6.1090**	44.3181	
	[2.1523]	[2.7040]	[30.2721]	
Sub-Saharan Africa	-4.0168***		-21.7309	
	[1.0436]		[16.5169]	
Middle East and North Africa	-1.5368			
	[1.1137]			
Latin America	-2.6361		-41.1146	
	[1.7807]		[28.5909]	
Constant	15.6031**	34.1214***	30.7012*	93.3770*
	[6.4242]	[8.3124]	[15.7838]	[50.0483]
Country Dummies	No	Yes	No	Yes
Region Dummies	Yes	No	Yes	No
PANEL B: Instability Probit Equation				
Dependent Variable: Leaders' Turnover				
Resource Rent (% GDP)	-0.0214***	-0.0300**	0.0011	-0.0061
	[0.0079]	[0.0118]	[0.0101]	[0.0111]
Private Lending (% GDP)	-0.0427**	-0.0597***	0.0379*	0.0269
	[0.0205]	[0.0194]	[0.0205]	[0.0260]
Resource*Lending	0.0040***	0.0058***	0.0007	0.0016
	[0.0013]	[0.0013]	[0.0008]	[0.0011]
Real per capita GDP (in logs)	-2.9857***	-3.2480**	-4.4147	-3.9943
	[1.0530]	[1.3966]	[5.1703]	[5.7546]
Real per capita GDP^2 (in logs)	0.1694***	0.1867**	0.2245	0.2097
	[0.0645]	[0.0837]	[0.3145]	[0.3432]
Ethnic Fractionalization	0.8293***	0.6226**	-0.4859	-0.5412
	[0.1999]	[0.2483]	[0.6911]	[0.6747]
Region Dummies	Yes	Yes	Yes	Yes
Wald Test of indep eq- Chi2(1)	73.79***	78.64***	6.97***	5.85**
Log Pseudo Likelihood	-4252.75	-4184.15	-782.81	-777.66
Number of Clusters (Countries)	49	49	8	8
Observations	1218	1218	227	227

Clustered standard errors in brackets.*** indicates 1% significance; ** 5%; and * 10%.
All equations control for Institutions (proxied by % population speaking a European Language at birth) and time dummies

Figure 3.7: Marginal Effect of Lending on Political Instability - Column (1)-(2) Table 3.2





The dotted lines represent the confidence interval at 5% level

Table 3.3: Effects of Lending on Growth

Effect of Lending on Growth	Growth (1)	Growth (2)
Coefficient Turnover	-9.425	-9.050
Pr(Turnover=1|MeanLending+Std Dev)	0.274	0.250
Pr(Turnover=1|MeanLending)	0.202	0.160
Increase in Probability of Turnover	0.072	0.091
Total	**-0.68**	**-0.82**

Variables are set at mean level (average country) except for Resource levels (30% GDP), Log GDP per capita, and its square are set as in Nigeria

Effect of Lending on Growth	Growth (1)	Growth (2)
Coefficient Turnover	-9.425	-9.050
Pr(Turnover=1|MeanLending+Std Dev)	0.139	0.136
Pr(Turnover=1|MeanLending)	0.093	0.075
Increase in Probability of Turnover	0.046	0.061
Total	**-0.43**	**-0.55**

All variables are set at mean level except Ethnic Diversity at median and Resource=30% as in Nigeria

Table 3.4: Second Stage Instrumental Variables - Probit for Turnover Equation

Second Stage IV - Exogeneity Test in the Probit Regression		
	Turnover with residuals	Turnover without residuals
	(1)	(2)
Dependent Variable: Leaders' Turnover		
Resource Rent (% GDP)	-0.121	-0.0407***
	[0.1497]	[0.0150]
Private Lending (% GDP)	0.0791	-0.0980***
	[0.1536]	[0.0240]
Resource*Lending	-0.0067	0.0081***
	[0.0172]	[0.0016]
Real per capita GDP (in logs)	0.0504	-1.0469
	[0.2147]	[1.4051]
Real per capita GDP^2 (in logs)		0.0681
		[0.0892]
Ethnic Fractionalization	1.6504	0.7850***
	[1.2389]	[0.3034]
Residuals Resource Rent	0.0803	
	[0.1510]	
Residuals Lending	-0.1778	
	[0.1510]	
Residuals Resource*Lending	0.0148	
	[0.0168]	
Test All Residuals = 0 - Chi2 (3)	1.98	-
P-Value	0.58	-
Number of Clusters (Countries)	49	49
Log Pseudo-Likelihood	-439.71	-439.71
Pseudo R-square	0.0868	0.0868
Observations	1171	1171
F-test first stage - Resource Equation	4.15***	4.15***
F-test first stage - Lending Equation	2439.58***	2439.58***
F-test first stage - Resource*Lending Equation	12.40***	12.40***

Clustered standard errors in brackets.*** indicates 1% significance; ** 5%; and * 10%. Sample: Dictatorships
All equations control for Institutions (proxied by % population speaking a European Language at birth) and time dummies

Table 3.5: Growth and Political Instability Regressions - Alternative Instability Measures

	Turnover - All Veto Players		Occurrence of Coups d'Etat	
	(3)	(4)	(1)	(2)
PANEL A: Growth Equation				
Dependent Variable: Real per Capita GDP Growth				
Instability	-8.9676***	-8.7869***	-5.6415*	-6.0876*
	[1.4543]	[1.4703]	[3.0197]	[3.4949]
Lag Real per capita GDP (in logs)	-1.2919*	-5.7725***	-1.2380*	-4.8675***
	[0.7700]	[1.1262]	[0.7198]	[1.2235]
Population Growth	-0.0091	0.1438	-0.023	0.1656
	[0.2677]	[0.2034]	[0.2684]	[0.1890]
Average Years of Schooling	0.1548	0.9695	0.1788	0.4839
	[0.2132]	[0.7552]	[0.2134]	[0.4625]
Inflation	-0.0005***	-0.0004***	-0.0006***	-0.0005***
	[0.0002]	[0.0001]	[0.0002]	[0.0002]
Investment (% GDP)	0.0776	0.1981**	0.0864	0.1861**
	[0.0629]	[0.0905]	[0.0590]	[0.0838]
Trade (% GDP)	-0.0008	-0.0272**	0.0005	-0.0241**
	[0.0083]	[0.0137]	[0.0077]	[0.0113]
Country Dummies	No	Yes	No	Yes
Region Dummies	Yes	No	Yes	No
PANEL B: Instability Probit Equation				
Dependent Variable: Coups and Revolutions (Columns (1)-(2)); Turnover Veto Players (Columns (3)-(4))				
Resource Rent (% GDP)	-0.0231**	-0.0349**	-0.1123***	-0.1199***
	[0.0115]	[0.0139]	[0.0342]	[0.0382]
Private Lending (% GDP)	-0.0312	-0.0372	-0.0953**	-0.1001**
	[0.0277]	[0.0253]	[0.0457]	[0.0442]
Resource*Lending	0.0030**	0.0048***	0.0138***	0.0146***
	[0.0015]	[0.0013]	[0.0039]	[0.0038]
Real per capita GDP (in logs)	-3.8808***	-5.0758***	-8.9147***	-9.6694***
	[1.3029]	[1.4392]	[1.6426]	[1.8088]
Real per capita GDP^2 (in logs)	0.2095**	0.2796***	0.5266***	0.5712***
	[0.0828]	[0.0896]	[0.0990]	[0.1078]
Ethnic Fractionalization	1.2363***	1.0779***	0.4003	0.4211
	[0.2873]	[0.3768]	[0.4226]	[0.4494]
Region Dummies	Yes	Yes	Yes	Yes
Wald Test of indep eq- Chi2(1)	27.63***	25.98***	3.71*	2.83*
Log Pseudo Likelihood	-3483.40	-3411.07	-3830.58	-3761.44
Number of Clusters (Countries)	49	49	49	49
Observations	1040	1040	1171	1171

Clustered standard errors in brackets.*** indicates 1% significance; ** 5%; and * 10%. Sample: Dictatorships
All equations control for Institutions (proxied by % population speaking a European Language at birth), time dummies

3.7 Appendix A.1: Proof of Proposition 1 - Comparative Statics

Comparative Statics $V(k,d)$

From the Envelope Theorem we can derive the marginal changes of v^{stay} and v^{loot} with respect to k and d:

$V(k,d)$ **is strictly increasing in** k **as:**
$\dfrac{\partial v^{stay}(k,d)}{\partial k} = \left(1-\rho(k',s)\right)\left(f'(k)+(1-\delta)\right)u'(c^{stay}) > 0$; and $\dfrac{\partial v^{loot}(k,d)}{\partial k} = \dfrac{r\theta_k}{1+r}\dfrac{u'(c^{loot})}{1-\beta} > 0$

$V(k,d)$ **is decreasing in** d **as:**
$\dfrac{\partial v^{stay}(k,d)}{\partial d} = -(1+r)\left(1-\rho(k',s)\right)u'(c^{stay}) < 0$; and $\dfrac{\partial v^{loot}(k,d)}{\partial d} = 0$

Monotonicity of $V(k,d)$ **with respect to** θ_z**,** θ_k **and** Z

$\dfrac{\partial v^{loot}(k,d)}{\partial \theta_z} = \dfrac{rZ}{1+r}\dfrac{u'(c^{loot})}{1-\beta} > 0$; and $\dfrac{\partial v^{stay}(k,d)}{\partial \theta_z} = \beta\left(1-\rho(k',s)\right)\dfrac{\partial EV}{\partial \theta_z}(k',d')$

$\dfrac{\partial v^{loot}(k,d)}{\partial \theta_k} = \dfrac{rk}{1+r}\dfrac{u'(c^{loot})}{1-\beta} > 0$; and $\dfrac{\partial v^{stay}(k,d)}{\partial \theta_k} = \beta\left(1-\rho(k',s)\right)\dfrac{\partial EV}{\partial \theta_k}(k',d')$

$\dfrac{\partial v^{loot}(k,d)}{\partial Z} = \dfrac{r\theta_z}{1+r}\dfrac{u'\left(c^{loot}\right)}{1-\beta} > 0$; and $\dfrac{\partial v^{stay}(k,d)}{\partial Z} = \left(1-\rho(k',s)\right)\left[\phi u'\left(c^{stay}\right)+\beta\dfrac{\partial EV(k',d')}{\partial Z}\right]$

We now need to determine the sign of $\dfrac{\partial EV}{\partial \theta_z}$, $\dfrac{\partial EV}{\partial \theta_k}$ and $\dfrac{\partial EV}{\partial Z}$. We know that $EV(k',d')$ is the unique fixed point of a contraction mapping Λ (see Rust 1988 and 1994) such that when ε has an extreme value distribution, we have:

$EV = \Lambda(EV) = \log\left[\exp\left(v^{stay}(k',d')\right)+\exp\left(v^{loot}(k',d')\right)\right]$

So we have $H(EV;\theta_z,Z) \equiv EV - \Lambda(EV) = (I-\Lambda)(EV) = 0$. By the implicit function theorem:

$$\frac{\partial EV}{\partial \theta_z} = \left(I-\Lambda'(EV)\right)^{-1}\frac{\partial \Lambda(EV)}{\partial \theta_z}$$

Now by differentiating Λ with respect to EV, we obtain $\Lambda'(EV) = \beta\left(1-\rho(k'',s')\right)Pr\left(\chi=0|k',d'\right)$ so that:

$$(I-\Lambda)'(EV) = 1-\beta\left(1-\rho(k'',s')\right)Pr\left(\chi=0|k',d'\right)$$

In addition we can show that:

$$\frac{\partial\Lambda(EV)}{\partial\theta_z} = \frac{rZ}{1+r}\frac{u'\left(c'^{loot}\right)}{1-\beta}Pr\left(\chi=1|k',d'\right)$$

Hence we obtain:

$$\frac{\partial EV}{\partial\theta_z} = \frac{Pr\left(\chi=1|k',d'\right)}{1-\beta\left(1-\rho(k'',s')\right)Pr\left(\chi=0|k',d'\right)}\frac{rZ}{1+r}\frac{u'\left(c'^{loot}\right)}{1-\beta} > 0$$

Similarly we determine:

$$\frac{\partial EV}{\partial\theta_k} = \frac{Pr\left(\chi=1|k',d'\right)}{1-\beta\left(1-\rho(k'',s')\right)Pr\left(\chi=0|k',d'\right)}\frac{rk}{1+r}\frac{u'\left(c'^{loot}\right)}{1-\beta} > 0$$

$$\frac{\partial EV}{\partial Z}(k',d') = \frac{\phi u'(c'^{stay})Pr\left(\chi=0|k',d'\right)+\frac{r\theta_z}{1+r}\frac{u'\left(c'^{loot}\right)}{1-\beta}Pr\left(\chi=1|k',d'\right)}{1-\beta\left(1-\rho(k'',s')\right)Pr\left(\chi=0|k',d'\right)} > 0$$

Given that $\frac{\partial EV}{\partial\theta_z}$, $\frac{\partial EV}{\partial\theta_k}$ and $\frac{\partial EV}{\partial Z}$ are all strictly positive, it follows that V is strictly increasing in θ_z, θ_k and Z.$\blacksquare$

Comparative statics of $\Delta V(k,d)$

Comparative statics of $\Delta V(k,d)$ with respect to k and d

$$\frac{\partial\Delta V(k,d)}{\partial k} = \left(1-\rho(k',s)\right)\left(f'(k)+(1-\delta)\right)u'(c^{stay}) - \frac{r\theta_k}{1+r}\frac{u'(c^{loot})}{1-\beta} \tag{3.18}$$

$$\frac{\partial\Delta V(k,d)}{\partial d} = -(1+r)\left(1-\rho(k',s)\right)u'(c^{stay}) < 0$$

Comparative static of $\partial \Delta V(k,d)$ with respect to θ_z, θ_k and Z

$$\frac{\partial \Delta V(k,d)}{\partial \theta_z} = \beta\left(1-\rho(k',s)\right)\frac{\partial EV}{\partial \theta_z}(k',d') - \frac{rZ}{1+r}\frac{u'(c^{loot})}{1-\beta}$$

Replacing $\frac{\partial EV}{\partial \theta_z}$ by its expression and given c^{loot} is constant by assumption, $u'\left(c^{loot}\right) = u'\left(c'^{loot}\right)$, we obtain:

$$\frac{\partial \Delta V(k,d)}{\partial \theta_z} = \frac{rZu'\left(c^{loot}\right)}{(1+r)(1-\beta)}\frac{\beta\left(1-\rho(k',s)\right)Pr\left(\chi=1|k',d'\right)+\beta\left(1-\rho(k'',s')\right)Pr\left(\chi=0|k',d'\right)-1}{1-\beta\left(1-\rho(k'',s')\right)Pr\left(\chi=0|k',d'\right)} < 0 \tag{3.19}$$

Now it is clear that $\beta\left(1-\rho(k',s)\right)Pr\left(\chi=1|k',d'\right)+\beta\left(1-\rho(k'',s')\right)Pr\left(\chi=0|k',d'\right) < 1$. It follows that the $\frac{\partial \Delta V(k,d)}{\partial \theta_z} < 0$. That is the return to staying decreases as θ_z increases.

Similarly we can calculate $\frac{\partial \Delta V(k,d)}{\partial \theta_k}$:

$$\frac{\partial \Delta V(k,d)}{\partial \theta_k} = \frac{rku'\left(c^{loot}\right)}{(1+r)(1-\beta)}\frac{\beta\left(1-\rho(k',s)\right)Pr\left(\chi=1|k',d'\right)+\beta\left(1-\rho(k'',s')\right)Pr\left(\chi=0|k',d'\right)-1}{1-\beta\left(1-\rho(k'',s')\right)Pr\left(\chi=0|k',d'\right)} < 0 \tag{3.20}$$

That is the return to staying decreases as θ_k increases.

Computation of $\frac{\partial \Delta V(k,d)}{\partial Z}$

$$\frac{\partial \Delta V(k,d)}{\partial Z} = \left(1-\rho(k',s)\right)\left[\phi u'\left(c^{stay}\right)+\beta\frac{\partial EV(k',d')}{\partial Z}\right] - \frac{r\theta_z}{1+r}\frac{u'(c^{loot})}{1-\beta}$$

$$\begin{aligned}\frac{\partial \Delta V(k,d)}{\partial Z} &= \frac{\beta\left(1-\rho(k',s)\right)\phi u'(c'^{stay})\left[1+\beta\left(1-\rho(k'',s')\right)Pr\left(\chi=0|k',d'\right)\right]}{1-\beta\left(1-\rho(k'',s')\right)Pr\left(\chi=0|k',d'\right)} \\ &+ \frac{r\theta_z u'\left(c^{loot}\right)\left[\beta\left(1-\rho(k',s)\right)Pr\left(\chi=1|k',d'\right)+\beta\left(1-\rho(k'',s')\right)Pr\left(\chi=0|k',d'\right)-1\right]}{(1+r)(1-\beta)\left(1-\beta\left(1-\rho(k'',s')\right)Pr\left(\chi=0|k',d'\right)\right)}\end{aligned} \tag{3.21}$$

The first term is positive while the second term is negative since the expression into the square brackets is negative as we have argued above. It follows that the effect of resources on the relative returns to staying is non monotonic. It depends on the relative impact of resources on the productive activity (term 1) and on the liquidity of resources provided by the banks (term 2). If the returns to liquidity is higher, then the gains from staying decreases, giving the the dictator more incentives to loot. On the other hand if the return of resources in the productive activities is higher, then the dictator has an incentive to stay. ■

3.8 Appendix A.2: Proof of Proposition 2

Case 1: $v^{loot}(k,d) > \overline{v}^{loot}(k,d)$ *for a given* d *and* θ_k

By definition of $\overline{v}^{loot}$, $v^{loot}(k,d) > \overline{v}^{loot}(k,d)$ implies that for any value of capital k, $v^{stay}(k,d) < v^{loot}(k,d)$. Looting is always optimal independently of k.

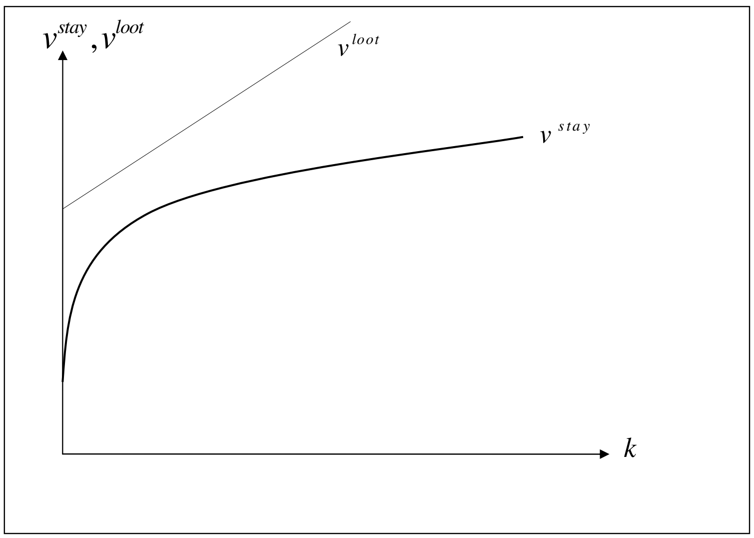


Figure 3.8: Case 1: Dictator Always Loots

Case 2: $\underline{v}^{loot}(k,d) < v^{loot}(k,d) < \overline{v}^{loot}(k,d)$ *for a given* d *and* θ_k

Given that 1) $\underline{v}^{loot}(k,d) < v^{loot}(k,d) < \overline{v}^{loot}(k,d)$ for some d and θ_k; 2) both v^{loot} and v^{stay} are continuous in k and strictly increasing; and 3) the value of staying has decreasing returns to capital while the value of looting has constant returns to capital, there exist two points of intersection between v^{stay} and v^{loot}. The value v^{stay} has increased fast enough (we assume for low k, v^{stay} faster than v^{loot}) to intersect v^{loot} from below at $\tilde{k}_1$. As k increases the combination of point 2 and 3 results in v^{stay} intersecting v^{loot} from above at $\tilde{k}_2$. Formally, there exist two capital levels $\tilde{k}_1$ and $\tilde{k}_2$ such that for $\tilde{k}_1 < \tilde{k}_2$:

1. $v^{stay}(\tilde{k}_1,d) = v^{loot}(\tilde{k}_1,d)$ and $\dfrac{\partial v^{stay}}{\partial k}(\tilde{k}_1,d) > \dfrac{\partial v^{loot}}{\partial k}(\tilde{k}_1,d)$

2. $v^{stay}(\tilde{k}_2, d) = v^{loot}(\tilde{k}_2, d)$ and $\dfrac{\partial v^{stay}}{\partial k}(\tilde{k}_2, d) < \dfrac{\partial v^{loot}}{\partial k}(\tilde{k}_2, d)$

3. $v^{stay}(k, d) < v^{loot}(k, d)$ for $k < \tilde{k}_1$ and $k > \tilde{k}_2$; and $v^{stay}(k, d) > v^{loot}(k, d)$ for $\tilde{k}_1 < k < \tilde{k}_2$

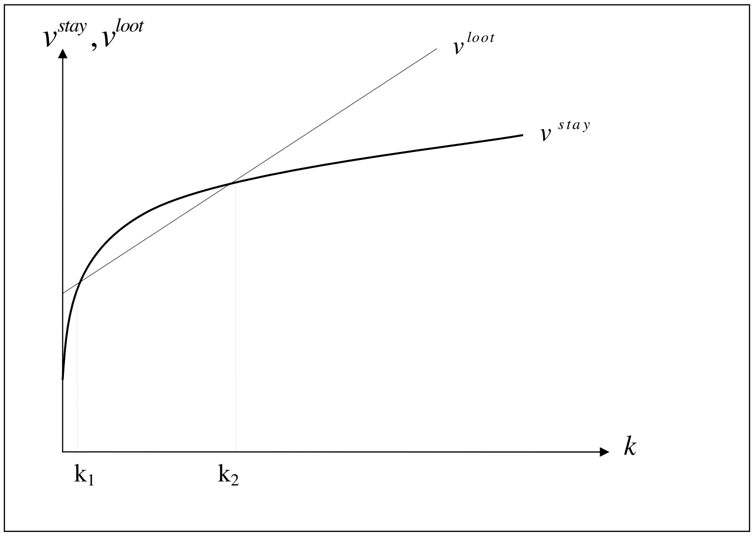


Figure 3.9: Case 2: Dictator Loots for Low and High k

Case 3: $v^{loot}(k, d) < \underline{v}^{loot}(k, d)$ for a given d and θ_k

Given that 1) $v^{loot}(k, d) < \underline{v}^{loot}(k, d)$ for some debt level d; 2) both v^{loot} and v^{stay} are continuous in k and strictly increasing; and 3) the value of staying has decreasing returns to capital while the value of looting has constant returns to capital, it follows that there exists a unique $\tilde{k}_3$ such that

$$v^{stay}(\tilde{k}_3, d) = v^{loot}(\tilde{k}_3, d) \text{ and } \frac{\partial v^{stay}}{\partial k}(\tilde{k}_3, d) < \frac{\partial v^{loot}}{\partial k}(\tilde{k}_3, d) \text{ for some } d$$

The inequality is necessary because as v^{loot} is initially below v^{stay}, it has to grow faster than v^{stay} to catch up. For any $k < \tilde{k}_3$, $v^{stay}(k, d) > v^{loot}(k, d)$. For any $k > \tilde{k}_3$, $v^{stay}(k, d) < v^{loot}(k, d)$.

To summarise, if $v^{loot}(k, d) < \underline{v}^{loot}(k, d)$ for some debt level d, then there exists a unique $\tilde{k}_3$ such that $v^{stay}(\tilde{k}_3, d) = v^{loot}(\tilde{k}_3, d)$ and $\big(1 - \rho(k', s)\big)\Big(f'(\tilde{k}_3) + (1 - \delta)\Big)u'(c^{stay}) < \dfrac{r\theta_k}{1 + r}\dfrac{u'(c^{loot})}{1 - \beta}$. The dictator loots for any capital level above $\tilde{k}_3$ and stays otherwise.

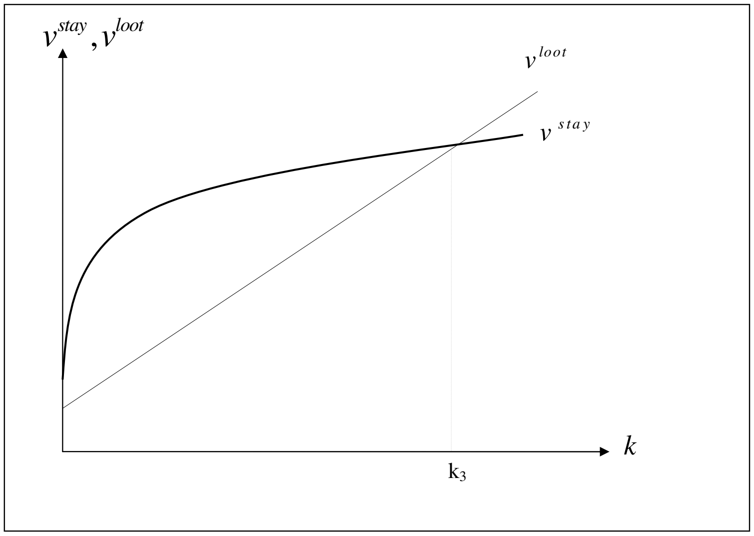


Figure 3.10: Case 3: Dictator Loots only for High k

Comparative static of $\tilde{k}_i$ $(i = 1, 2, 3)$ with respect to θ_z and θ_k

Using $\dfrac{\partial EV}{\partial \theta_k}$ and $\dfrac{\partial EV}{\partial \theta_z}$ determined in Appendix A and the implicit function theorem, we obtain:

$$\frac{\partial \tilde{k}_i}{\partial \theta_k} = \frac{\dfrac{rku'(c^{loot})}{(1+r)(1-\beta)} \left(\dfrac{\beta(1-\rho(k',s))Pr\,(\chi = 1|k',d') + \beta\,(1-\rho(k'',s'))\,Pr\,(\chi = 0|k',d') - 1}{1-\beta\,(1-\rho(k'',s'))\,Pr\,(\chi = 0|k',d')} \right)}{(1-\rho(k',s))\,(f'(k)+(1-\delta))\,u'(c^{stay}) - \dfrac{r\theta_k}{(1+r)(1-\beta)} u'(c^{loot})}$$

$$\frac{\partial \tilde{k}_i}{\partial \theta_z} = \frac{\dfrac{rZu'(c^{loot})}{(1+r)(1-\beta)} \left(\dfrac{\beta(1-\rho(k',s))Pr\,(\chi = 1|k',d') + \beta\,(1-\rho(k'',s'))\,Pr\,(\chi = 0|k',d') - 1}{1-\beta\,(1-\rho(k'',s'))\,Pr\,(\chi = 0|k',d')} \right)}{(1-\rho(k',s))\,(f'(k)+(1-\delta))\,u'(c^{stay}) - \dfrac{r\theta_k}{(1+r)(1-\beta)} u'(c^{loot})}$$

We established in Appendix A.1 that the numerator is negative so that the signs of these ratios depend on the sign of the denominator. When the marginal liquidity of capital is larger than the marginal product of capital, then the denominator is negative and $\tilde{k}_i$ increases with both θ_k and θ_z. In particular, we can infer from the proof above that the denominator is negative at $\tilde{k}_2$ and $\tilde{k}_3$ (see Case 2 and Case 3) and positive at $\tilde{k}_1$ (see Case 2). Therefore, it follows that $\tilde{k}_1$ is decreasing in θ_k and θ_z while $\tilde{k}_2$ and $\tilde{k}_3$ are increasing with these parameters.■

Chapter 4

Resources, Conflict and Development – Public Good Provision in Resource-Rich Economies[1]

4.1 Introduction

Recent studies in political economy have found that the quality of leaders, particularly in authoritarian regimes, is a key determinant of economic outcome (Jones and Olken, 2005). If true, the fate of resource-rich countries, often ruled by non-democratic or authoritarian regimes (Ross, 2001) is shaped by the policy choices made by these regimes.[2] Robinson (2001) has analysed some of the key policy choices made in dictatorships. In particular, he investigates what drives non-democratic countries to choose predatory policies while pro-development policies—in the form of public good investment—are more efficient. He shows that the threat of political replacement consecutive to developmental policies may deter public investment. In this context, he argues that the presence of natural resources—easily appropriable by incumbent elites—creates an even greater disincentive to invest in necessary public goods.

Under this backdrop, the propensity of resources to generate civil conflicts (Collier and Hoeffler, 1998 and 2004), or political replacement, may explain that some autocrats see underdevelopment and repression as optimal policies as they prevent potential contenders from threatening their hold on the country's riches. For instance, Zaire under Mobutu's reign saw its road

[1] This chapter draws from a joint work with Katharina Wick of Tilburg University.

[2] Our work focuses on dictatorships and does not explain why countries like Norway, the US, Canada or Australia have escaped the so-called curse. Nor does it say much about the evidence of the resource curse among regions of the same country—see Michaels (2006) for evidence in American states.

network literally "disintegrate"; out of the 90,000 miles of road at independence in 1960, only 6,000 miles were left by 1980. Robinson (2001) Under-investment in essential infrastructure was so common that some observers view it as a deliberate strategy of underdevelopment to maintain his position and thwart potential opposition. (Callaghy, 1984; Robinson, 2001; and Acemoglu et al., 2004) Similarly, in the nineties under authoritarian regimes, child immunisation against DPT (diphtheria, pertussis and tetanus) and measles fell in Nigeria from 54% to 26% and from 54% to 35% respectively.

However, the major shortcoming of these papers is their failure to explain the substantial disparity in the provision of productive public goods among resource-rich countries. Malaysia for instance has consistently invested in physical and social infrastructure. Over the 1990s, measles immunisation progressed by 18 percentage points (from 70% to 88%), while secondary school enrollment increased from 56% to 69%. Power generation also almost doubled between 1990 and 1995 from 282 to 520 kWh per capita. Given the importance of social and physical infrastructure as a determinant of growth and development (Calderon and Serven, 2004), these large variations in public good provision may contribute to explain the large variations in economic performance among resource-rich countries.

Such heterogeneity calls for a *conditional theory.* (Dunning 2005) Why do resource-rich countries vary considerably in providing essential and productive public goods to their populations? For instance, why did Botswana consistently invest the revenues from diamonds in productive infrastructure, education and health (Acemoglu et al., 2003) while Nigeria (Barro and Subramanian, 2003) and many others did not? This chapter tries to provide some answers to this question.

In this chapter, we investigate what determines the decision of a self-interested ruling elite (represented by an autocrat), in a resource-rich country, to invest in productivity enhancing public goods[3] given the looming threat of conflict. In particular, we examine the conditions under which an autocrat finds it optimal to buy the peace by creating incentives for the people to allocate their effort to productive activities (which both can benefit from) rather than to fight over the control of the resources. We develop a Stackelberg game to analyse the strategic interaction between a ruler and its population, where potential conflict over natural resources

[3]The idea that it makes rational sense for an autocratic ruler to invest in public goods as they increase production which in turn accrues (at least in part) to the ruler is discussed for example in McGuire and Olson (1996).

drives the optimal policy choice made by the ruler. In particular, we are concerned with the extent to which the ruler's decision to provide a public good is affected by the potential conflict over natural resources.

In this model, the ruler has two instruments to keep the population from contesting the resources. One is to try to lure the people into production by increasing productivity (by means of public good provision), the other is to simply militarily oppress them. The people, by contrast, choose the allocation of their time between working in the non-resource sector and fighting to appropriate resources. We show that the ruler's policy choice depends critically on 1) the investment worthiness of the non-resource sector; 2) the extent of the resource wealth; and 3) the ruler's and the people's relative effectiveness in fighting over the resource. The dictator is likely to invest in public goods when the non-resource sector is productive enough. He is less likely to do so if he is relatively effective in appropriating the resources—compared to the people. If, on the other hand, the ruler is relatively ineffective in controlling the resources, he is more likely to invest in development of the economy.

We provide empirical evidence that gives support to the predictions of our theoretical framework using data on physical infrastructure (power generating capacity, and road network) and social infrastructure (education and health) as proxies for public goods provision. We use a panel with and without country fixed effects to estimate both the effect of resources and the effect of the ruler's effectiveness in controlling resources on public good provision. We find that the combination of resource wealth and the ruler's effectiveness in controlling resources is negatively associated with public good levels. This finding corroborates our theory and points to a channel through which leaders' choices in resource-rich countries may impede or encourage investment in public goods.

The paper follows the tradition of conflict models in economics. Like Grossman (1994) and Azam (1995), we assume the *people* might rebel and fight against the *ruling elite*. The dilemma between repressing the people or buying the peace is also analysed within this literature by Azam (1995) and Wick (2008). Our paper also relates to the empirical literature on resources and conflict. Seminal contributions by Collier and Hoeffler (1998, 2004) present empirical evidence that resource wealth triggers conflicts and civil war. Their work provides support for two assumptions we make: 1) that agents in resource-rich countries have a strong incentive to engage in appropriation rather than productive activities; 2) that the outbreak of a conflict is more likely when earnings foregone from rebellion are low.

This chapter makes two contributions to the current literature. First, it offers a conditional theory that accounts for the diverging policy choices among resource-rich countries and therefore contributes to a better understanding of the resource curse. Second, our predictions are tested empirically. To the best of our knowledge only Mehlum et al. (2006) make such contributions to the resource curse literature.

The chapter is organised as follows: In section 4.2, we lay out the fundamentals of the model and explain our assumptions in detail. We then turn to a concrete specification of the model. In section 4.3, we discuss the ruler's decision to invest and find the determinants of his policy choice. Based on this we derive in some testable predictions of the theoretical model. Section 4.4 provides an empirical analysis. Finally, section 4.5 concludes.

4.2 The model

Consider a resource-rich country populated by two groups, the ruling elite represented by a self-interested and authoritarian ruler and the population.[4] The economy consists of two sectors, a resource sector which generates a resource rent Z and a non-resource sector (agriculture or manufacturing). Both sectors are potential sources of income for both groups. Following Caselli (2006), the non-resource sector output is divided between the two groups according to some exogenous parameter τ. On the other hand, the ruling elite considers the resource stock and the associated earnings Z as its own property. The division of the resource rent may create a conflict between the ruling elite and the population and depends on their respective efforts to appropriate it.

The ruler and the population have two possible actions at their disposal. The population allocates its time endowment (T) between working in the non-resource sector (W) and fighting (E) the ruler in an attempt to capture part of the resource earnings. By contrast, the ruler can initiate a development policy by investing in a productivity enhancing public good ϕ. He can also use force and repress (R) the population to deter it from contesting the resource rent.

[4]Following Robinson (2001), our model only applies to authoritarian regimes, where a ruling group takes decisions purely motivated by self-interest. This captures the situation in many (developing) resource-rich countries.

4.2.1 Fundamentals of the model

The non-resource sector produces according to the production function $(1+A)f(\phi, W)$, where A is productivity, $\phi = \{0,1\}$ is the binary investment decision (1 represents investment, and 0 means no investment).[5]

Assumptions PF[6]: $\frac{\partial f}{\partial \phi} > 0$, $\frac{\partial f}{\partial W} > 0$, $\frac{\partial^2 f}{\partial W^2} \leq 0$ and $\frac{\partial^2 f}{\partial \phi \partial E} < 0$

We assume that production increases with investment and work effort, and exhibits non-increasing returns to labour. Moreover, a marginal rise in the fighting effort causes production to decrease at an increasing rate when investment is undertaken. In other words, the marginal cost in terms of lost production increases with ϕ.

The population allocates its time T between working W and fighting E so that $T \geq W + E$. Its effort in contesting the ruler's control over the resource rent has an adverse effect on the level of output produced in the non-resource sector.[7] However, it gives the population the opportunity to appropriate or grab a share of the resource rent according to a so-called grabbing function $G(E, R)$. Consequently, a share of the resource $(1 - G(\cdot))$ accrues to the government.

Assumptions GF: $\frac{\partial G}{\partial E} > 0$, $\frac{\partial G}{\partial R} < 0$, $\frac{\partial^2 G}{\partial E^2} < 0$, $\frac{\partial^2 G}{\partial R^2} > 0$, and $\frac{\partial^2 G}{\partial R \partial E} < 0$

We assume that the share of resources grabbed by the population increases with their fighting effort E and decreases with the ruler's repression R. The grabbing function is also assumed to have decreasing returns in E and is convex in R. In other words, both the marginal benefit to the people from fighting $\frac{\partial G}{\partial E}$, and the marginal benefit to the ruler from repressing $\left|\frac{\partial G}{\partial R}\right|$ decrease respectively in E and R. In addition, a marginal increase in E causes grabbing to increase at a decreasing rate as R increases, that is the marginal benefit to the population from grabbing decreases with R.

[5]See for example Dunning (2005) who also models public good investment as a binary choice variable.

[6]Since ϕ is a discrete variable strictly speaking the partial derivative with respect to ϕ is not defined as such. For expositional purposes, and notational ease, we however use it throughout this paper.

[7]Because the endowment constraint of the people is binding in the equilibrium, an increase in fighting effort results necessarily in a decrease in working effort ($\frac{\partial W}{\partial E} \geq -1$), leading to a lower level of output in the non-resource sector.

The ruler chooses two actions. First, he can invest in a productivity enhancing public good. This investment (e.g. road network, a hospital or a school) comes at investment cost I. The payoff from investing in a public good increases with the level of productivity A. We investigate when—i.e. at which levels of productivity A—a self-interested ruling elite chooses to invest in a public good. Second, the ruler chooses the repression effort R to prevent the people from grabbing resources and incurs some costs $c(R, \phi)$.

Assumptions CF: $\dfrac{\partial c}{\partial \phi} > 0$, $\dfrac{\partial c}{\partial R} > 0$, $\dfrac{\partial^2 c}{\partial R^2} = 0$, and $\dfrac{\partial^2 c(R, \phi)}{\partial R \partial \phi} > 0$

The total cost of repression is assumed to increase with the amount of repression R and with public good provision. In addition, the marginal cost of repression increases with ϕ. Because investment in public goods results in better educated and healthier people, running a repressive dictatorship then becomes more costly to the ruler. This follows Robinson's (2001) argument that many authoritarian rulers are unwilling to construct or maintain socially productive infrastructure because providing such public goods may "reduce the cost of contesting elite control". As an example we may reasonably assume that it is harder to repress well educated people because they have more interest in public affairs and demand more accountability from the government.[8] A similar assumption is also found in Bourguignon and Verdier (2000) and Dunning (2005).

To sum up, the interaction between the two agents takes place according to the following timing:

1. For a given A, the ruler decides whether to invest: $\phi = \{0, 1\}$

   Then the **subgame** Γ starts:

2. **Stage 1** of the subgame Γ: Population reacts choosing a fighting effort E (where the working effort W is determined simultaneously)

[8] Formally correct would be the following specification. We assume that the flow variable ϕ increases the stock of human capital in the economy, that is $H = h(\phi)$, with $\frac{\partial h}{\partial \phi} > 0$. As just discussed, we further assume that people with higher human capital are harder to repress, that is repression costs are higher. Formally this means repression costs $c = c(H)$ with $\frac{\partial c}{\partial H} > 0$. One can now readily verify that $\frac{\partial c}{\partial \phi} > 0$. As a shortcut we include ϕ directly into the repression cost function.

3. **Stage 2** of the subgame Γ: Ruler chooses a repression level R in response to E

4. Conflict is settled with each contender grabbing a share of the available natural resources according to his equilibrium strategy. Output in the non-resource sector is produced and divided between the two groups according to the parameter τ.

First, the ruler chooses whether or not to invest in the public good. Conditional on the investment decision observed by the population, a contest over the resources takes place in subgame Γ where the players decide sequentially their appropriative efforts. This subgame features a Stackelberg contest where the population has the first move. The ruler reacts by an appropriate repression level. With this timing, we take the view that the lack of the ruler's provision of necessary public goods will fuel discontent among the population and lead to rebellion. We have nonetheless tried a different time sequence where the ruler is the first mover in the subgame. We found that the results are qualitatively similar: the order has no impact on the comparative statics although it affects the equilibrium levels of fighting and repression. We chose the timing laid out above because it provides simpler expressions for the equilibrium levels and the comparative statics that are fairly easy to interpret. By backwards induction, we first solve for the equilibrium outcome in the subgame Γ and later analyze the investment decision of the ruler.

4.2.2 Specification of the model

In this section we derive the results of the model using a specific functional form. We specify the total production of the economy, given inputs (A, ϕ, W) as:

$$(1 + A)f(\phi, W) = (1 + A)(1 + \phi)(1 + W) \tag{4.1}$$

It is easily verified that for $\phi = 0$ the production function exhibits decreasing returns to scale. If $\phi = 1$ on the other hand we find that the production function exhibits decreasing returns if and only if $W < \frac{1}{\lambda}$, where λ is the scaling factor of inputs.[9]

The repression costs are specified as:

$$c(\phi, R) = c(1 + \phi)R \tag{4.2}$$

[9]Traditionally returns to scale are increasing iff $f(\lambda\phi, \lambda W) > \lambda f(\phi, W)$.

Resource earnings are split between the two parties according to the so-called "grabbing function". This is given by:

$$G(E,R) = \min\left(\frac{E^{\alpha}}{R^{\gamma}}, 1\right), \tag{4.3}$$

where G denotes the share of the resource grabbed by the rebels and $0 < \alpha < 1$ and $0 < \gamma < 1$. These conditions ensure that G is well behaved. The two parameters α and γ capture the elasticity of the grabbing function with respect to the respective fighting inputs, E and R. If $\alpha < \gamma$, a one percent increase in the fighting input by the government has more effect on the grabbing outcome than a similar increase in the rebels' fighting. Thus the difference $\alpha - \gamma$ reflects the relative effectiveness of the opponents in the contest. If $\alpha < \gamma$, the ruler is more effective in keeping control of the resources whereas if $\alpha > \gamma$, the population is more effective in grabbing resources. Said differently, if $\alpha < \gamma$ the same effort level of both groups is translated in more effective fighting power of the government as compared to the people's. The two parameters α and γ play a crucial role in determining the outcome of the model.

We are now ready to solve the subgame Γ by backward induction. Note that we will focus on interior solutions.[10] In the second stage of the subgame, the ruler's problem is:

$$\max_{R} \; \tau(1+A)(1+\phi)(1+W) + \left(1 - \frac{E^{\alpha}}{R^{\gamma}}\right) Z - c(1+\phi)R - I \tag{4.4}$$

The ruler's reaction function is:

$$R(E) = \left(\frac{\gamma Z}{c(1+\phi)}\right)^{1/(\gamma+1)} E^{\alpha/(\gamma+1)} \tag{4.5}$$

In the first stage of the subgame Γ, the people maximize their own payoff taking into account the ruler's reaction:

$$\max_{E} \; (1-\tau)(1+A)(1+\phi)(1+W) + \left(\frac{\gamma Z}{c(1+\phi)}\right)^{-\gamma/(\gamma+1)} E^{\alpha/(\gamma+1)} Z \tag{4.6}$$

$$s.t.\; E + W \leq T \tag{4.7}$$

Note that the endowment constraint is always binding. If that was not the case then at the opti-

[10] Formally this means we assume $(1+A)\,(1+\phi)^{\frac{\alpha-\gamma}{\alpha}} > \frac{\alpha}{(\gamma+1)(1-\tau)} \left(\frac{c}{\gamma}\right)^{\frac{\gamma}{\alpha}} Z^{\frac{\alpha-\gamma}{\alpha}}$.

mum, we could slightly increase E and R, satisfy the constraint while increasing the population's payoff. This is a contradiction of the optimum.

The subgame perfect equilibrium of Γ is given by (E^*, R^*):

$$E^* = K_1 \left(\frac{Z}{1+\phi}\right)^{\frac{1}{\gamma+1-\alpha}} (1+A)^{-\frac{\gamma+1}{\gamma+1-\alpha}} \qquad \text{where} \quad K_1 = \left(\frac{\alpha}{(\gamma+1)(1-\tau)}\right)^{\frac{\gamma+1}{\gamma+1-\alpha}} \left(\frac{c}{\gamma}\right)^{\frac{\gamma}{\gamma+1-\alpha}} \tag{4.8}$$

$$R^* = K_2 \left(\frac{Z}{1+\phi}\right)^{\frac{1}{\gamma+1-\alpha}} (1+A)^{-\frac{\alpha}{\gamma+1-\alpha}} \qquad \text{where} \quad K_2 = \left(\frac{\alpha}{(\gamma+1)(1-\tau)}\right)^{\frac{\alpha}{\gamma+1-\alpha}} \left(\frac{\gamma}{c}\right)^{\frac{1-\alpha}{\gamma+1-\alpha}} \tag{4.9}$$

$$G = K_3 \left(\frac{Z}{1+\phi}\right)^{\frac{\alpha-\gamma}{\gamma+1-\alpha}} (1+A)^{-\frac{\alpha}{\gamma+1-\alpha}} \qquad \text{where} \quad K_3 = \left(\frac{\alpha}{(\gamma+1)(1-\tau)}\right)^{\frac{\alpha}{\gamma+1-\alpha}} \left(\frac{c}{\gamma}\right)^{\frac{\gamma}{\gamma+1-\alpha}} \tag{4.10}$$

Proposition 1

1) *The population's fighting effort decreases with investment and higher productivity, but increases with resource wealth.*

2) *The ruler's repression level decreases with investment and higher productivity, but increases with resource wealth.*

3) *Grabbing decreases with higher productivity. It is ambiguous with respect to investment and resource wealth, and depends on the opponents effectiveness in the contest.*

Proof: derive the partial derivatives.■

This proposition suggests three important results. First, investment in the public good reduces both the population's fighting effort E and the ruler's repression R. Indeed, the people fight less as a result of an investment in ϕ since the increase in marginal cost of fighting in terms of lost production is greater than the increase in marginal benefit of fighting. In other words, by investing in ϕ, the ruler raises the population's opportunity cost of fighting so that fighting becomes less profitable than engaging in the productive activity. Moreover, because investment increases the marginal costs of R by Assumption CF, the provision of a public good leads to a lower level of R for each level of E.

Second, more fighting leads to more repression because an increase in E raises the marginal benefit of repressing (i.e. R has more effect on the grabbing outcome if E is high by Assumption GF) without affecting the marginal costs of repressing. A consequence of these two results is that E and R change in the same direction, which implies that the effect of ϕ and Z on the grabbing function is a priori ambiguous. In particular, the effect depends on the sign of $\alpha - \gamma$. Grabbing increases in ϕ when $\alpha < \gamma$ and decreases in ϕ when $\alpha > \gamma$. Indeed, the provision of a public good causes E and R to decrease proportionately so that the ratio $\frac{E^*}{R^*}$ is independent of ϕ.[11] When $\alpha > \gamma$ the decrease in the fighting effort E has a larger impact on grabbing than the decrease in repression R so that the ruler can control more resources and $G(.)$ decreases. This is because the loss of an effective unit of E is more detrimental to the population when $\alpha > \gamma$ than the loss of a (less effective) unit of R is to the ruler. When $\alpha < \gamma$, the opposite is true.

Third, an increase in resource wealth raises the stakes of controlling the resources and therefore intensifies conflicts (more fighting and more repression). Both opponents increase their effort in contesting the resource. Thus, the effect on grabbing is ambiguous and depends on the effectiveness in fighting: the most effective party will have the advantage.
In contrast, by increasing the people's opportunity cost of fighting, a more productive non resource sector (i.e. a higher value of A) is conducive to a less conflict-prone environment. The population reduces its fighting effort E. This in turn leads to a lower level of repression R. It also results in a decrease in grabbing $G(.)$, because a higher A decreases E more than R.

4.3 Ruler's investment decision

4.3.1 Characterisation of the decision

In order to understand when a self-interested ruler in a resource-rich country finds it optimal to invest, we now consider his investment decision given the subgame perfect equilibrium discussed above. In the previous section we laid out the players' responses to a public good investment.

[11] $\frac{E^*}{R^*} = \frac{c}{\gamma} \frac{\alpha}{(1+\gamma)(1-\tau)} \frac{1}{(1+A)}$ is independent of ϕ. Independence depends on the assumption that both the production function and the cost of repression are linear in $1+\phi$.

Under certain conditions, the provision of a public good might bring about an undesirable outcome from the point of view of the ruler (through the effect of public good provision on the conflict outcome), since—as we just saw—the sign of the change in grabbing as a result of public good provision is ambiguous. If those conditions occur, they discourage public good investment. Given the equilibrium strategy in subgame Γ, the ruler's investment decision depends solely on the productivity level A. The objective of the present section is to find the productivity levels A for which the ruler finds it in his best interest to invest.

The ruler solves the following problem:

$$\max_{\phi} \left(\Pi_G(A, \phi = 1) - I, \Pi_G(A, \phi = 0)\right) \tag{4.11}$$

He chooses the strategy (investment or no investment) that gives him the highest payoff. Investment is optimal if and only if the relative benefit of investing exceeds the cost (I) :

$$\Delta\Pi_G \equiv \Pi_G(A, \phi = 1) - \Pi_G(A, \phi = 0) \geq I \tag{4.12}$$

Before solving this problem, we first carry out a discussion of the relative value of investing $\Delta\Pi_G$. A formal analysis of the properties of $\Delta\Pi_G$ is undertaken in Appendix A.1.

$$\begin{aligned} \Delta\Pi_G &= \tau(1+A)(1+T) + \overbrace{\tau(1+A)[E^*(\phi=0) - 2E^*(\phi=1)]}^{(i)} \\ &- \underbrace{[G(\phi=1) - G(\phi=0)]}_{(ii)} Z - \underbrace{c[2R^*(\phi=1) - R^*(\phi=0)]}_{(iii)} \end{aligned} \tag{4.13}$$

The relative value of investing $\Delta\Pi_G$ is equal to the increase in output resulting from investment plus *additional effects* captured by three additional components: *(i)* represents the impact of the people's fighting effort on the non-resource output when a public good is provided; *(ii)* is the difference in grabbing due to investment; and *(iii)* reflects the difference in repression costs triggered by investment. This can be written as:

$$\Delta\Pi_G = \tau(1+A)(1+T) + \underbrace{[\tau P_1 - cP_2 - P_3] Z^{\frac{1}{\gamma+1-\alpha}} (1+A)^{-\frac{\alpha}{\gamma+1-\alpha}}}_{\text{additional effects}} \tag{4.14}$$

where $P_1 = \left[1 - \left(\frac{1}{2}\right)^{\frac{\alpha-\gamma}{\gamma+1-\alpha}}\right] K_1$, $P_2 = \left[\left(\frac{1}{2}\right)^{\frac{\alpha-\gamma}{\gamma+1-\alpha}} - 1\right] K_2$, $P_3 = \left[\left(\frac{1}{2}\right)^{\frac{\alpha-\gamma}{\gamma+1-\alpha}} - 1\right] K_3$.

These effects reflect the impact of public good provision on the contest in resource-rich countries. Their direction and magnitude depend on the sign of $\alpha - \gamma$. When $\alpha < \gamma$, slightly less effort is devoted to resource appropriation (E^* and R^* decrease slightly) as a consequence of public good investment. This has the positive effect of raising the output. However this positive effect is outweighed by two negative effects. First, the population grabs more of the resources because the decrease in E^* and R^* has a detrimental effect on the resource appropriation of the more effective contender (the ruler in this case). This finding was discussed in section 4.2. Second, public good provision results in higher total costs of repression because the increased unit cost of repression offsets the decrease in R^*. Thus the sum of the additional effects of public good investment is negative if $\alpha < \gamma$.

On the other hand, public good investment causes both the people and the ruler to decrease substantially their appropriation effort when $\alpha > \gamma$. This has three positive effects on the ruler's payoff: First, the output from the non-resource sector increases as the people provide significantly more working effort. Second, the people grab less of the resource, and therefore more of the resource is left for the ruler.[12] Third, total repression costs decline since the increase in unit costs of repression is offset by the dramatic fall in the ruler's repression level.

We can now shed light on our main question as to when an authoritarian ruler finds it optimal to invest in public goods rather than carry out predatory policies.

Lemma:

1) For any α and γ, if $\Delta\Pi_G(A = 0) < I$, then there exists a unique A^* such that investment is optimal for any $A \geq A^*$. A^* is defined as $\Delta\Pi_G(A^*) = I$

2) For any α and γ, if $\min_A [\Delta\Pi_G(A)] > I$, then investment is optimal for any A.

Proof: See Appendix A.2.■

[12] As explained in the discussion following proposition 1, a proportionate decrease in E^* and R^* has a detrimental effect on the resource appropriation of the more effective contender (in this case the people).

Intuitively, only sufficiently high productivity levels in the non-resource sector give the ruler the incentive to invest in the economy. In other words, there is a productivity threshold A^* above which investment becomes optimal. The level of the threshold is informative of the likelihood of the ruler to undertake an investment in public goods. The higher the productivity threshold, the less likely investment will be; inversely, a lower threshold makes investment more likely.

The productivity threshold A^* solves $\Delta\Pi_G(A^*) = I$ so that:

$$\tau(1+A^*)(1+T) + (\tau P_1 - P_2 - P_3)Z^{\frac{1}{\gamma+1-\alpha}}(1+A^*)^{\frac{-\alpha}{\gamma+1-\alpha}} - I = 0 \qquad (4.15)$$

Resource wealth affects the threshold A^* and the direction of their relationship is determined by the sign of $\alpha - \gamma$.

Proposition 2:

In a resource-rich country the ruler's investment decision is characterized by:

1) If $\alpha > \gamma$ then $\dfrac{\partial A^*}{\partial Z} < 0$

2) If $\alpha < \gamma$ then $\dfrac{\partial A^*}{\partial Z} > 0$.

Proof: See Appendix A.3.■

This proposition says that increased resource wealth provides a disincentive to invest in productive public goods if the ruler is relatively more effective in contesting the resource. In addition, increased resource wealth provides an incentive to invest in productive public goods if the people are relatively more effective in grabbing the resource. A corollary of this proposition is stated as follows.

Corollary:

$A^*_{\alpha>\gamma} < A^*_{\alpha<\gamma}$, that is in a resource-rich country the provision of public goods requires a lower productivity when $\alpha > \gamma$ than when $\alpha < \gamma$.

Proof: See Appendix A.4.■

The model accounts for the differing investment behaviour of rulers in resource-rich countries according to the respective effectiveness of the population and the ruler in contesting the resource rent. A ruler who can secure the control over resources easily will tend to invest less in public goods than a ruler whose population is effective in contesting the resource rent. By investing in a productive public good, the ruler provides an incentive to work in the non-resource sector rather than fight over the resource riches. Providing such incentive is obviously more pressing when the ruler faces a population effective in fighting and appropriating the resources.

4.3.2 Testable predictions

The key prediction of the model is that the effect of the resource rent on the investment decision depends on the effectiveness of the two parties in contesting resources. We test this prediction by estimating the following econometric specification:

$$PG_{it} = \beta_0 + \beta_1 Resources_{it} + \beta_2 Strong_{it} + \beta_3 Resources_{it} * Strong_{it} + \beta_4 X_{1it} + \varepsilon_{it} \qquad (4.16)$$

where PG_{it} denotes country i's level of the public good at time t; $Resources_{it}$ is the amount of resource rent; $Strong_{it} = 1$ indicates that the ruler is more effective than the people in appropriating resources (that is in terms of the theoretical model the case where $\alpha < \gamma$); X_{1it} denotes all the other control variables. We are interested in coefficients β_1 and β_3: β_1 represents the marginal effect of resources on the public good provision when $Strong_{it} = 0$; while β_3 indicates how the effect of resource rent differs between an effective ruler ($Strong_{it} = 1$) and an ineffective one ($Strong_{it} = 0$). Finally, the sum $\beta_1 + \beta_3$ reflects the effect of resource rent when $Strong_{it} = 1$. The model predicts that $\beta_1 > 0$ and $(\beta_1 + \beta_3) < 0$, implying that while an ineffective ruler has an incentive to provide more public goods as resource rent increases, public good supply decreases with the resource rent in the presence of an effective ruler. This happens if the negative interaction effect outweighs the positive direct effect, i.e. if $\beta_1 > 0$, $\beta_3 < 0$ and $|\beta_3| > \beta_1$.

Second, we test the prediction that, ceteris paribus, public good investment is (i) less likely when the ruler is effective in controlling the resources; and (ii) more likely when he is not effective in doing so. This prediction is tested using specification (4.16). We predict that $\beta_2 + \beta_3 Resources_{it} < 0$ as the resource level increases.

4.4 Empirical Analysis

4.4.1 Data

Our data set runs from 1970 to 2000 and contains 67 countries that have been led by an authoritarian regime at some point since 1970. We use the variable polity2 from Polity IV dataset to indicate whether a regime is authoritarian. For any given year, a country with a polity2 score less than or equal to 0 is considered authoritarian.

Dependent variables Following the literature on the determinants of provision of public goods, we define public goods as "goods or services enjoyed by all or a large share of a jurisdiction".[13] As the dependent variable, we use physical infrastructure—power generating capacity and road network—and social infrastructure—education and health indicators. These variables are used as a proxy for public good provision. We believe that the provision of these public goods by the state is indicative of the state's commitment to development policies. Although the model treats the decision of providing a public good as discrete, the empirical analysis will be concerned with public goods as continuous variables. Empirically, it is more meaningful to think of the supply of public goods in terms of levels and not as a binary decision. For instance, whether a country extends its road network by 1 km or 100 km is the same binary decision while it is certainly different if we consider the potential contribution of 1km and 100 km to development.

The data on the stock of physical infrastructure includes 1) electricity generating capacity measured as the number of kWh available per capita in log (from Canning, 1998) and spans the period 1970–1995; 2) the road network in km per square km expressed in log (from Canning and the World Development Indicators, 2006) and covers the period 1970–2000.

The data on illiteracy rate comes from the World Development Indicators and covers the years 1970–1999. For clarity, this variable has been transformed into literacy rate (where literacy rate

[13] See for example Lake and Baum (2001), Deacon (2003), and Deacon and Saha (2006) for a review of the literature.

is 100 minus illiteracy rate).

The public health data measures the percentage of children aged 12-23 months who have been immunised against DPT and Measles. The immunisation series come from the World Development Indicators (1980–2000).

Key Independent Variables In the theoretical model, we have established that the ruler's relative effectiveness in appropriating the resource crucially determines public good provision. We hypothesise that such effectiveness is derived from the form of the political power. In particular, we assume that the elite is effective in appropriating and keeping the resources for its own benefit whenever the state is controlled by the most autocratic regimes. Here, we capture such regimes as those ruled by leaders who have no finite term constraint.[14] When they face popular discontent, these strong regimes are able to successfully contain civil strife through repression (Fearon and Laitin, 2003; Hegre et al., 2001; and Muller and Weede, 1990), and are therefore considered to be relatively effective in controlling resource rents. We construct a dummy variable $Strong_{it}$ (with value 1 when the ruler has no finite term) from the Database of Political Institutions compiled by Beck et al. (2004 update). This series covers the period 1975–2000.

We use resource rents as the measure of *contestable* resource endowment. The data is provided by K. Hamilton and G. Ruta from the World Bank and covers the period 1970–2000. Resource rent is measured as the product of the quantity of resources extracted by the difference between the resource price and the average extraction cost. It is expressed as a percentage of the GDP.[15]

Descriptive Evidence Table 4.1 below displays the mean and standard deviation of our main variables broken down into two sub-samples: rulers *with* finite term constraint and rulers *without* finite term. Casual observation suggests that the countries governed by rulers with no constraint on their term provide less public goods on average. These countries are also substantially more dictatorial (with a average polity score of -6.18 vs. -0.88 for their constrained counterparts) and more resource abundant (18% of GDP as opposed to 7.6%).

[14]Note that the average polity score for such countries is -6.19 so that these regimes qualify to Fearon and Laitin's definition of full autocracy. As an illustration, Malaysia has been ruled by autocrats with a finite term constraint, while was Nigeria led by dictators with no constraints on their terms.

[15]This measure includes coal, oil, natural gas, and ten different minerals—bauxite, copper, gold, iron, lead, nickel, phosphate, silver, tin, zinc.

Table 4.1: Descriptive Evidence of Key Variables

Sample (1975 - 2000)			
Variables	Obs	Mean	Std. Dev.
Power Generation (kWh per capita in log)	1363	4.60	1.53
Phone Lines (per 1000 people in log)	1326	2.46	1.56
Literacy Rate in %	1542	59.79	23.00
Immunization DPT in %	1284	62.72	26.37
Immunization MSL in %	1257	63.38	25.10
Polity Score	1704	-2.75	6.16
Resource Rent in % GDP	1565	11.04	16.11
Sub-Sample: Rulers *with* Finite Term			
Variables	Obs	Mean	Std. Dev.
Power Generation (kWh per capita in log)	843	4.65	1.35
Phone Lines (per 1000 people in log)	829	2.59	1.49
Literacy Rate in %	985	64.57	22.25
Immunization DPT in %	885	65.68	23.42
Immunization MSL in %	869	66.53	22.55
Polity Score	1105	-0.88	6.31
Resource Rent in % GDP	1041	7.56	10.53
Sub-Sample: Rulers *without* Finite Term			
Variables	Obs	Mean	Std. Dev.
Power Generation (kWh per capita in log)	520	4.51	1.78
Phone Lines (per 1000 people in log)	497	2.26	1.65
Literacy Rate in %	557	51.34	21.85
Immunization DPT in %	399	56.15	30.98
Immunization MSL in %	388	56.32	28.82
Polity Score	599	-6.19	4.02
Resource Rent in % GDP	524	17.96	21.99

4.4.2 Estimation Results

The five public good equations will be estimated individually in this panel. We suspect that these equations may not be independent as the values of the variables are collected from the same set of observations (same countries). The simultaneous estimation of these equations using a seemingly unrelated regressions (SUR) method may be warranted to control for this correlation to avoid inefficient estimates. However, this is not an issue here. Because all public good equations have the same regressors, there is no efficiency gain using a SUR estimation. (Greene 2000, p. 616-617)

Following the work by Lake and Baum (2001), and Canning (1995) on public good provision, we control for geographic variables such as population and urbanization. In addition, we control for productivity, proxied by the real GDP per capita. As the real GDP per capita might be endogenous—reverse causality—we instrument it by its three-year lag to avoid serial correlation. We also include time dummies to control for aggregate effects that impact on all countries in a given year and country fixed effects.

Table 4.3 presents the estimation results for prediction 1. We investigate whether the effect of the level of resources on public good provision depends on the relative effectiveness to control resources.

We first analyse the finding for the physical infrastructure. The effect of resource rents on public good provision when the regime is not effective in controlling the resources is positive and but not statistically significant for power generation. One standard deviation increase in resource rent (16.1) raises power generation by 3.2% (16*0.002). For road network, resources have an unexpected negative effect significant at the 10% level (one standard deviation increase of resources results in 4.8% decrease in the road network). However, the ruler's choice differs significantly when he is effective in controlling the resources. The negative and statistically significant effect of the interaction term indicates that, all else equal, an effective ruler will provides less of both public goods. Furthermore, the magnitude of the differing behaviour is so large that the negative interaction effect outweighs the positive main effect for power generation (-16%) and reinforces the negative main effect for road network (-9.7%). Thus, the total effect—i.e. the effect of resources when an effective ruler is in power—is negative and significant as predicted. One standard deviation increase in resources causes power generation to decrease by almost 13% and road network by 14.5%.

Concerning literacy rate and immunisation against DPT and measles, the results are qualitatively very much in line with power generation. The main effect of resources is positive but not significant, while the total effect is negative and statistically significant. Our result suggests that an increase in resources by one standard deviation reduces immunisation against DPT and measles by 5.8 and 7.2 percentage points, and literacy rate by 0.7 percentage point.

The overall conclusion is that there is little relationship between public good levels and resources when the ruler is ineffective in controlling the resources—although it is positive as predicted—but this relationship becomes negative and statistically significant with a "strong" ruler. Moreover the magnitude of the effect is sizable except for literacy.

From Table 4.3, we also test the prediction that, a ruler relatively effective in fighting over resources provides comparatively lower levels of public goods. The interest lies in the sign of $\beta_2 + \beta_3 Resources_{it}$. The coefficient β_2 of the variable "No finite term" tests whether the two types of rulers significantly differ in their public good provision when the resource rent is equal to 0. Most importantly, the interaction effect $\beta_3 Resources_{it}$ indicates that the difference in public good provision between the two types of rulers depends on the level of the rent, for all types of infrastructure. At higher resource levels, the gap widens, making the strong or effective dictator less likely to invest.

For illustration purposes, Table 4.4 shows the effect of an effective or strong ruler on public good provision, when the resource rent is equal to 0, 11% (sample mean) and 30% (case of a resource-rich country like Nigeria). As the resource level increases, the effect of a strong dictator becomes more negative and significant. For a country with a sizable resource base (e.g. 30%), a strong ruler is an obstacle to the provision of public goods. The effect is generally large and significant except for literacy: -19% for power generation, -19.4% for road network, -15.4 and -16 percentage points for immunisation against DPT and measles. Finally, Figures 4.1 to 4.3 illustrate how the differential effect deepens with the level of resource rent for the various types of public good.

Overall, the empirical evidence is consistent with the main results of the model, namely that 1) the effect of resources on the provision of public goods hinges generally on the ruler's relative effectiveness in fighting; and 2) a ruler who is relatively more effective in controlling the resource endowment—i.e. when $\alpha < \gamma$ according to our model—tends to provide less public good. Finally, although we find that an ineffective ruler has a positive effect on public good provision, this effect is not significant.

As a robustness check, we also perform an estimation without country fixed effects but controlling for regional dummies. To mitigate the problem of omitted variables bias, we control for institutional features (proxied by the percentage of the population speaking a European language as in Hall and Jones, 1999), ethnic diversity (measure of ethnic fractionalization), former colonial power (French and British), and the size of the country. The results, presented in Table 4.5, do not differ from those reported above using country fixed effects, except for road network. In that equation, the coefficient of resource rent is negative and the interaction effect is positive, which is the exact opposite to what we expect and to our result with the fixed effect estimation. This may suggest the presence of omitted variables in the road network equation.

Our results are robust to the range of public goods considered, whether they are physical or social. They are also robust to the use of an alternative proxy for the effectiveness in controlling resources. We create a dummy variable denoted "Strong Executive" which indicates whether the executive is controlled by a monarch or a military regime (see Table 4.6 and 4.7). Monarchies tend to benefit from long lasting and established systems that enable effective appropriation of the resource rent, while military regime have the power to control and defend the rent. We find similar results to the one presented above. Besides, our findings using this alternative proxy are consistent with the evidence of the poor record of military dictatorships in providing public goods. (Lake and Baum, 2001)

4.5 Conclusion

In this paper we follow an idea that has gained much support in recent years, namely the role of policy choices in producing resource curse outcomes. As the term "policy *choice*" suggests such outcomes are by no means deterministic, and thus our model is one of the few that attempts to provide a *conditional* theory of the resource curse.

In particular, we follow the idea that easily appropriable resource rents may lead (among other things) to distortions in public policy (Bulte et al., 2005). Recognising the inherent threat of conflict in resource-rich countries, we present a model in which the ruler's policy choice, is entirely driven by economic motives. Our model points to reasons why some resource abundant countries have performed poorly whereas others have proved highly successful. We suggest that the stark difference in policy decisions regarding public good provision among resource-rich countries is a plausible reason. This difference results from various factors—the degree of resource wealth, the investment worthiness of the economy and most importantly the ruler's relative effectiveness in controlling the resource—which determine whether developmental or repressive policies are carried out. Testing our model empirically, we find evidence that 1) the effect of resource wealth crucially depends on the ruler's relative strength; and 2) a relatively strong leader who can control effectively resources tends to invest less in public good.

Along with Mehlum et al. (2006) who point to the differing effect of institutions on economic outcome in resource-rich countries, this paper demonstrates that a better understanding of the resource curse puzzle requires conditional rather than uni-dimensional theories.

Bibliography

[1] Acemoglu, D., J. A. Robinson, and T. Verdier (2004): Kleptocracy and Divide-and-Rule: A Model of Personal Rule, *Journal of the European Economic Association*, 31: 162–192.

[2] Acemoglu, D., S. Johnson, and J. A. Robinson (2003): An African Success Story: Botswana, In D. Rodrik (Ed): *Search of Prosperity: Analytical Narrative on Economic Growth*, Princeton University Press.

[3] Atkinson, G. and K. Hamilton (2003): Savings, Growth and the Resource Curse Hypothesis. *World Development*, 31: 1793–1807.

[4] Auty, R.M. (2000): *Resource Abundance and Economic Development*, Ed. Oxford University Press.

[5] Azam, J. P. (1995): How to Pay for the Peace? A Theoretical Framework with References to African Countries. *Public Choice*, 83: 173–184.

[6] Banks, A. (2001): *Cross-National Time-Series Data Archive*, Center for Comparative Political Research, State University of New York (Binghamton).

[7] Barro, R. J. and J. Lee (2000): International Data on Educational Attainment: Updates and Implications. *CID Working Paper*, No. 42.

[8] Barro, R. J. (1997): *Determinants of Economic Growth: A Cross-Country Empirical Study*, Cambridge MA: MIT Press.

[9] Barro, R. J. and A. Subramanian (2003): Addressing the Natural Resources Curse: An Illustration from Nigeria, *NBER Working Paper*.

[10] Beck, T., G. Clarke, A. Groff, P. Keefer, and P. Walsh (2001): New Tools in Comparative Political Economy: The Database of Political Institutions. *World Bank Economic Review* 15(1): 165–176.

[11] Bourguignon, F. and T. Verdier (2000): Oligarchy, Democracy, Inequality and Growth. *Journal of Development Economics*, 62: 285–313.

[12] Bueno de Mesquita, B., J. D. Morrow, R. M. Siverson and A. Smith (2003): *The Logic of Political Survival.* Cambridge, MA: MIT Press.

[13] Bulte, E., R. Damania and R. Deacon (2005): Resource Intensity, Institutions, and Development. *World Development*, 33: 1029–1044.

[14] Calderon, C. and L. Serven (2004): The effects of Infrastructure Development on Growth and Income Distribution. *Policy Research Working Paper Series*, No. 3400, The World Bank.

[15] Callaghy, T.M. (1984) : *The State-Society Struggle: Zaire in Comparative Perspective.* Columbia University Press, New York.

[16] Canning, D. (1998): A Database of World Infrastructure Stocks, 1950-95. *World Bank Policy Research Working Paper*, No. 1929.

[17] Caselli, F. (2006): Power Struggles and the Natural Resource Curse. *Working Paper.*

[18] Caselli, F. and W.J. Coleman (2006): On the Theory of Ethnic Conflict. *Working Paper.*

[19] Collier, P. and A. Hoeffler (1998): On the Economic Causes of Civil War. *Oxford Economic Papers*, 50: 563–573.

[20] Collier, P. and A. Hoeffler (2004): Greed and Grievance in Civil War. *Oxford Economic Papers*, 56: 563–595.

[21] Deacon, R., and S. Saha (2006): Public Good Provision by Dictatorships: A Survey, In A. F. Ott and R. J. Cebula, eds., *The Companion in Public Economics: Empirical Public Economics*, Edward Elgar Publishing.

[22] de Nardo, J. (1985): *Power in Numbers*, Princeton, NJ: Princeton University Press.

[23] Dunning, T. (2005): Resource Dependence, Economic Performance, and Political Stability. *Journal of Conflict Resolution*, 49: 451–482.

[24] Ellingsen, T. and N. P. Gleditsch (1997): Democracy and Armed Conflict in the Third World, In K. Volden and D. Smith (Eds), *Causes of Conflict in Third World Countries*, North-South Coalition and International Peace Research Institute.

[25] Fearon, J. D. and D. Laitin (2003): Ethnicity, Insurgency, and Civil War, *American Political Science Review*, 97: 75–90.

[26] Francisco, R.A. (1995): The Relationship between Coercion and Protest: An Empirical Evaluation in Three Coercive States, *Journal of Conflict Resolution*, 39(2): 263–282.

[27] Grossman, H. (1994): Production, Appropriation and Land Reform, *American Economic Review*, 705–712.

[28] Gylfason, T. (2001): Natural Resources, Education and Economic Development, *European Economic Review*, 45: 847–859.

[29] Hegre, H., T. Ellingsen, S. Gates, and N. P. Gleditsch (2001): Toward a Democratic Civil Peace? Democracy, Political Change, and Civil War, 1816-1992, *American Political Science Review*, 95(1): 33–48.

[30] Isham, J., M. Woolcock, L. Pritchett and G. Busby (2005): The Varieties of Resource Experience: Natural Resource Export Structures Affect the Political Economy of Economic Growth, *World Bank Economic Review*, 19: 141–174.

[31] Lake, D. A. and M. A. Baum (2001): The Invisible Hand of Democracy: Political Control and the Provision of Public Services, *Comparative Political Studies*, 34(6): 587–621.

[32] McGuire, M.C. and M. Olson (1996): The Economics of Autocracy and Majority Rule: The Invisible Hand and the Use of Force, *Journal of Economic Literature*, 34(1): 72–96

[33] Mehlum, H., K. Moene, R. Torvik (2006): Institutions and the Resource Curse, *Economic Journal*, 116: 1–20.

[34] MICHAELS, G. (2006): The Long Term Consequences of Resource Based Specialization. *CEPR Discussion Paper* 6028.

[35] MULLER, E.N. AND E. WEEDE (1990): Cross-National Variations in Political Violence: A Rational Action Approach. *Journal of Conflict Resolution*, 34: 624–51.

[36] NDULU, B. AND S. O'CONNELL (1999): Governance and Growth in Sub-Saharan Africa. *Journal of Economic Perspectives*, 13: 41–66.

[37] ROBINSON, J.A. (2001): When is a State Predatory? *Working Paper.*

[38] ROBINSON, J. A. AND R. TORVIK (2005): White Elephants, *Journal of Public Economics* 89: 197–210.

[39] ROSS, M. L. (1999): The Political Economy of the Resource Curse, *World Politics* 51: 297–322.

[40] ROSS, M. L. (2001): Does Oil Hinder Democracy, *World Politics* 53: 325–361.

[41] ROSSER, A. (2006): The Political Economy of the Resource Curse: A Literary Survey, *IDS Working Paper* 268, Brighton: Institute of Development Studies.

[42] SACHS, J. AND A. M. WARNER (1995): Natural Resource Abundance and Economic Growth, *NBER Working Paper 5398.*

[43] SACHS, J. AND A. M. WARNER (2001): Natural Resources and Economic Development: The Curse of Natural Resources. *European Economic Review* 45: 827–838.

[44] TORNELL, A. AND P. LANE (1999): The Voracity Effect, *American Economic Review*, 89: 22–46.

[45] WACZIARG, R. (2002): Review of Easterly's The Elusive Quest for Growth, *Journal of Economic Literature*, XL, 907–918.

[46] WICK, K. AND E. BULTE (2006): Contesting Resources: Rent Seeking, Conflict and the Natural Resource Curse, *Public Choice*, 128: 457–476.

[47] WICK, K. (2008): Conflict and Production: An Application to Natural Resources, *The B.E. Journal of Economic Analysis & Policy*, 8(1)(Topics): Article 2.

[48] Wintrobe, R. (1990): The Tinpot and the Totalitarian: An Economic Theory of Dictatorship. Cambridge, UK: *Cambridge University Press.*

[49] World Bank (2006): World Development Indicators.

Table 4.2: List of Countries in the Sample

List of Countries	
Algeria	Madagascar
Angola	Malaysia
Argentina	Mauritania
Bahrain	Mexico
Bangladesh	Morocco
Benin	Mozambique
Bolivia	Nepal
Brazil	Nicaragua
Burkina Faso	Niger
Burundi	Nigeria
Cameroon	Oman
Central African Republic	Pakistan
Chile	Peru
China	Philippines
Congo Brazzaville	Qatar
Cote d'Ivoire	Rwanda
Ecuador	Saudi Arabia
Egypt	Senegal
El Salvador	Sierra Leone
Gabon	Singapore
Ghana	South Africa
Guatemala	Sri Lanka
Guyana	Sudan
Haiti	Suriname
Honduras	Syria
Indonesia	Thailand
Iran	Togo
Iraq	Tunisia
Jordan	Turkey
Kenya	UAE
Korea South	Uganda
Kuwait	Zaire
Liberia	Zambia
	Zimbabwe

Table 4.3: Effect of Resource Rent on Public Good Provision with Fixed Effects

Dependent Variable: Provision of Public Good

	(1) Power Generation Capacity per Cap	(2) Density Road Network	(3) Literacy	(4) Immunization DPT	(5) Immunization Measles
Resources	0.002	-0.003*	0.02	0.056	0.02
	[0.002]	[0.001]	[0.019]	[0.108]	[0.124]
No Finite Term	0.125***	-0.02	1.154***	-2.556	-1.476
	[0.025]	[0.031]	[0.270]	[1.586]	[1.748]
Resources*No Finite Term	-0.010***	-0.006***	-0.063**	-0.414***	-0.468***
	[0.003]	[0.002]	[0.025]	[0.136]	[0.156]
Real GDP in log	0.840***	0.458***	1.904***	1.837	14.992***
	[0.064]	[0.048]	[0.613]	[3.201]	[4.142]
Population in log	1.377***	1.185***	34.191***	7.696	15.189
	[0.310]	[0.193]	[1.941]	[11.738]	[12.353]
Urban Population in %	0.021***	-0.002	0.173***	0.155	0.162
	[0.003]	[0.002]	[0.031]	[0.173]	[0.208]
Constant	-30.569***	-30.023***	-657.128***	-127.08	-379.183
	[6.520]	[4.135]	[42.982]	[257.978]	[268.620]
Resources + Resources*No Finite Term	-0.008***	-0.008***	-0.043*	-0.358***	-0.449***
	[0.003]	[0.002]	[0.022]	[0.118]	[0.144]
Country fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	1104	1102	1250	1036	1011
R-square	0.97	0.96	0.99	0.83	0.79
Number of Countries	57	45	54	56	56
Time Period	1975 - 1995	1975 - 2000	1975 - 1999	1980 - 2000	1980 - 2000

Robust standard errors. Control for Population, Urban population, Country fixed effect and Year dummies.
*** indicates 1% significance; ** 5%; and * 10%.

Table 4.4: Difference in Public Good Provision with a "strong" ruler

Variables	Differential Provision Rent = 0	Differential Provision Rent = 11% (mean)	Differential Provision Rent = 30%
Power Generation in log	0.125***	0.013	-0.189***
Road Network in log	-0.02	-0.082***	-0.194***
Literacy Rate in %	1.154***	0.459	-0.739
Immunization DPT in %	-2.556	-7.104***	-15.375***
Immunization MSL in %	-1.476	-6.629***	-15.998***

This table is obtained from Table 4.3 by setting Rent to 0, 11% (mean) and 30% (Nigeria) using country fixed effects

Table 4.5: Effect of Resource Rent on Public Good Provision without Fixed Effects

Dependent Variable: Provision of Public Good	(1)	(2)	(3)	(4)	(5)
	Power Generation Capacity per Cap	Density Road Network	Literacy	Immunization DPT	Immunization Measles
Resources	0.012***	-0.016***	0.371***	0.037	0.091
	[0.003]	[0.003]	[0.060]	[0.084]	[0.089]
No Finite Term	-0.101*	-0.253***	-0.302	-7.591***	-7.005***
	[0.057]	[0.049]	[1.162]	[1.725]	[1.716]
Resources*No Finite Term	-0.019***	0.010***	-0.729***	-0.332***	-0.335***
	[0.004]	[0.003]	[0.071]	[0.099]	[0.105]
Real GDP in log	0.600***	0.308***	7.241***	6.491***	5.781***
	[0.050]	[0.033]	[0.861]	[1.213]	[1.228]
Population in log	0.004	0.515***	-0.809*	-2.008***	-1.450**
	[0.024]	[0.023]	[0.427]	[0.684]	[0.689]
Urban Population in %	0.030***	0.003***	0.323***	0.007	0.066
	[0.002]	[0.001]	[0.034]	[0.044]	[0.044]
Constant	-3.088***	-5.243***	16.754*	39.920***	20.854
	[0.585]	[0.401]	[8.888]	[14.474]	[14.445]
Resources + Resources*No Finite Term	-0.007***	-0.007***	-0.358***	-0.295***	-0.244***
	[0.002]	[0.002]	[0.037]	[0.054]	[0.061]
Controls					
Regional Dummies	Yes	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes	Yes
Ethnic Diversity	Yes	Yes	Yes	Yes	Yes
Coloniser (British and French)	Yes	Yes	Yes	Yes	Yes
Institutional Feature	Yes	Yes	Yes	Yes	Yes
Country Area	Yes	Yes	Yes	Yes	Yes
Observations	1084	1102	1250	1015	990
R-square	0.79	0.82	0.70	0.69	0.68
Number of Countries	56	45	54	55	55
Time Period	1975 - 1995	1975 - 2000	1975 - 1999	1980 - 2000	1980 - 2000

Robust standard errors. Control for Institution, Ethnic Diversity, Colonizer, Country area, Population, Urban population, Region and Year dummies. *** indicates 1% significance; ** 5%; and * 10%.

Figure 4.1: Effect of "Strong" Ruler on Power Generation and Road Network

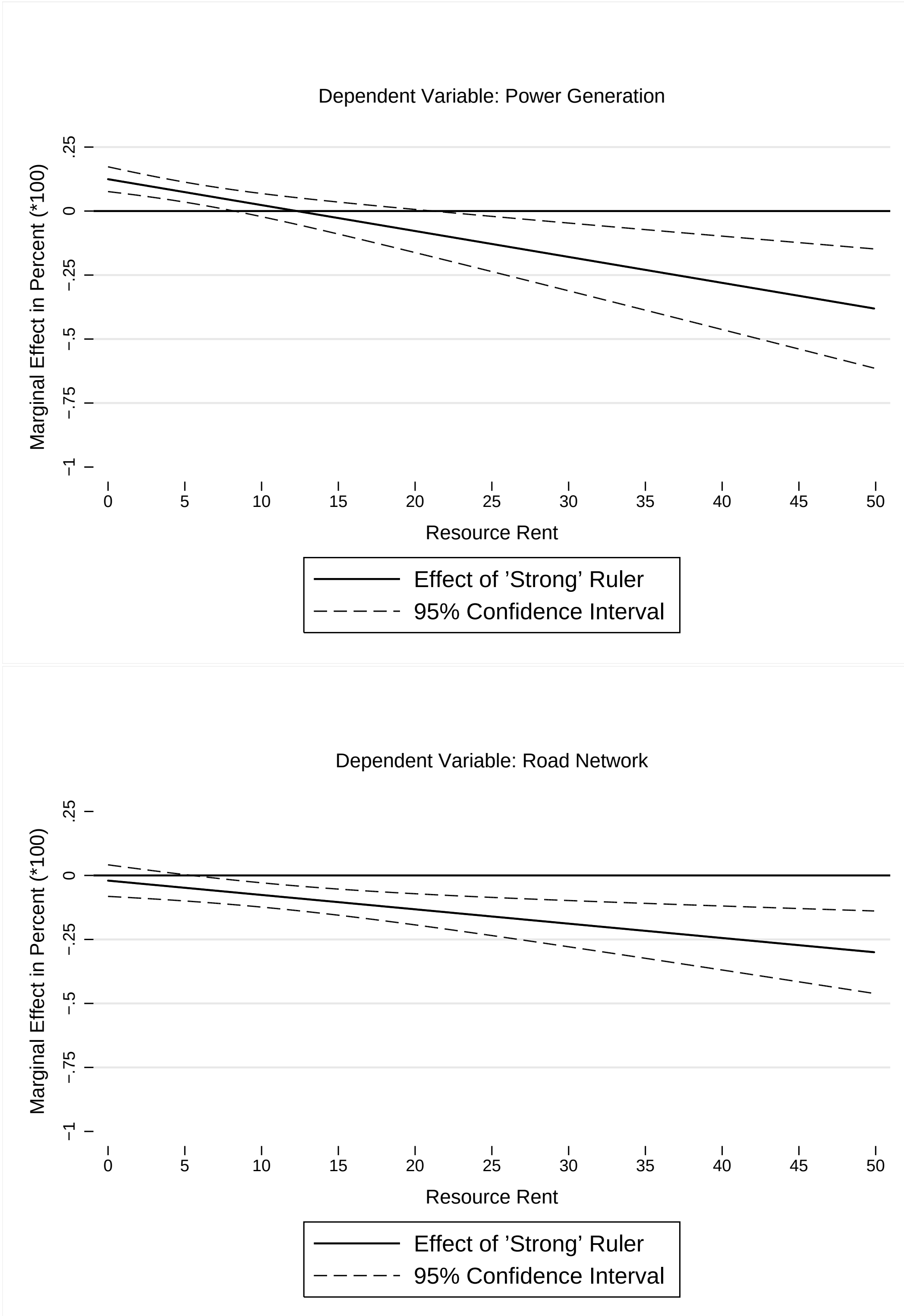


Figure 4.2: Effect of "Strong" Ruler on Literacy

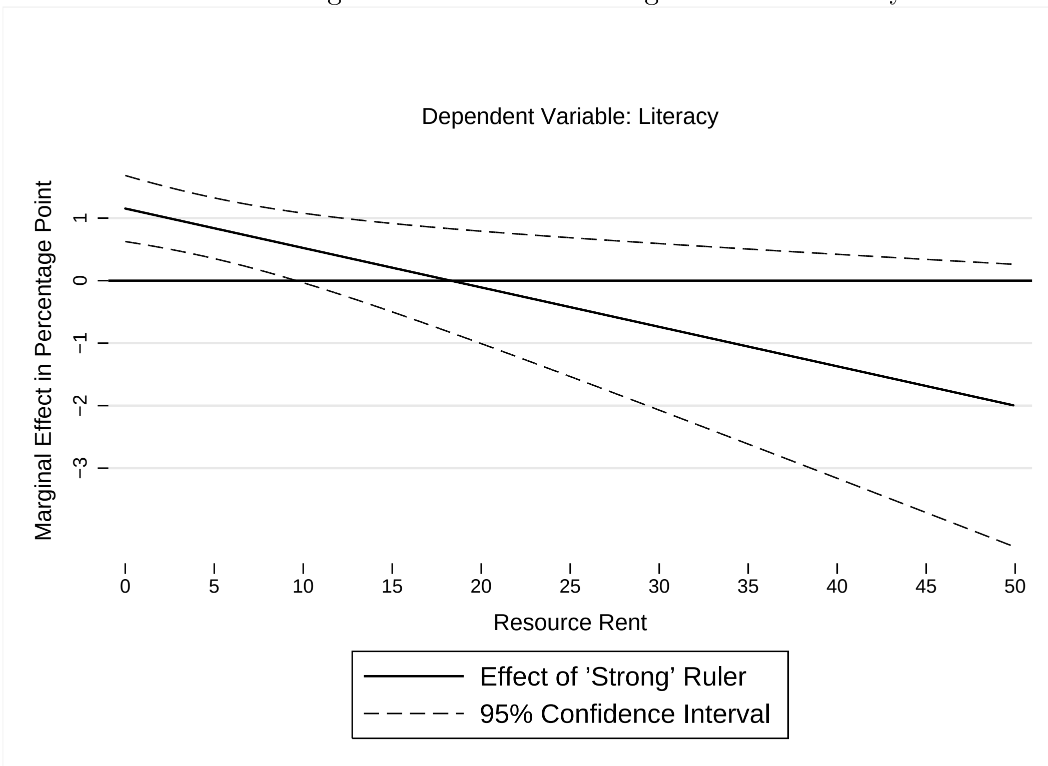


Figure 4.3: Effect of "Strong" Ruler on Immunisation

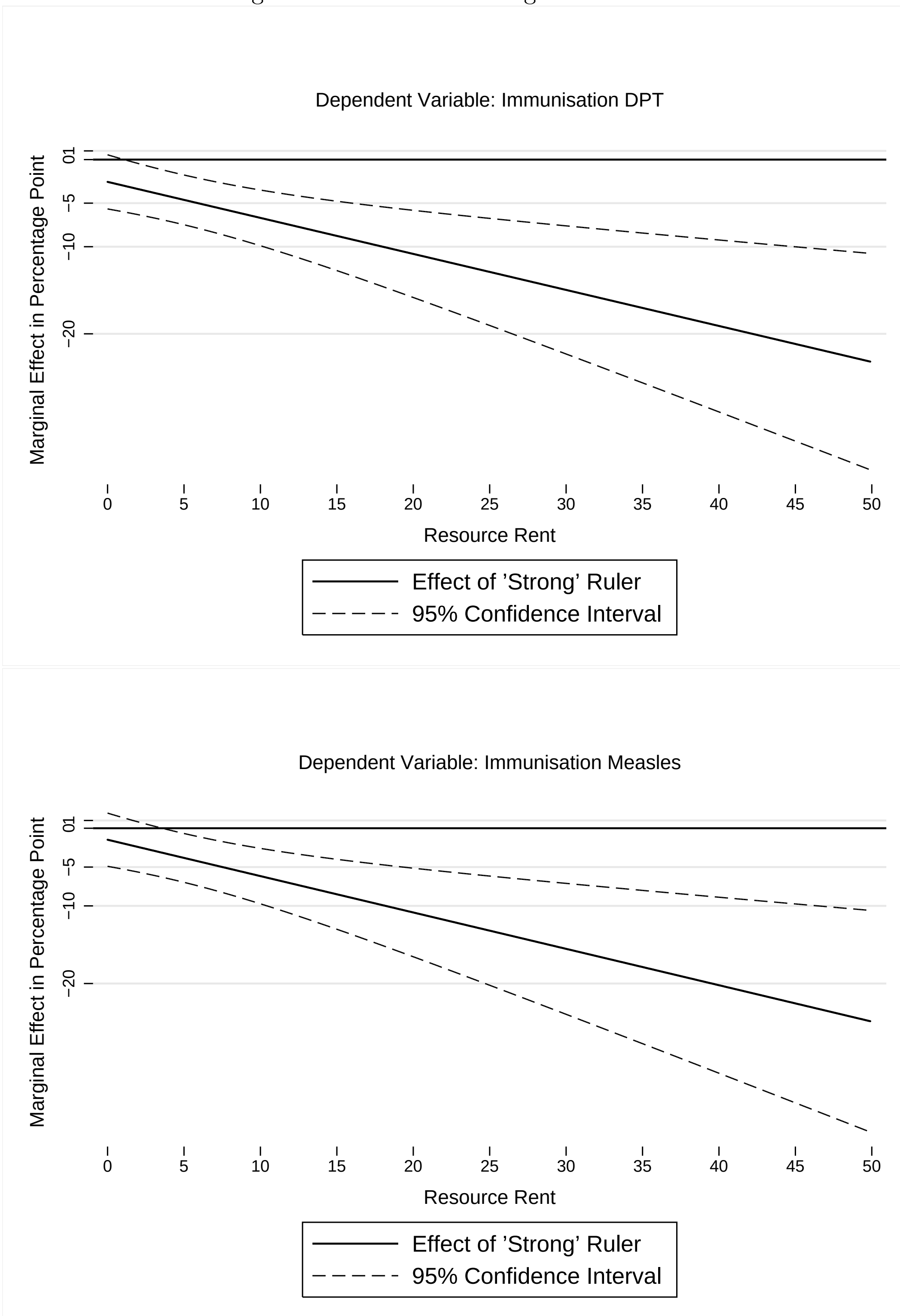


Table 4.6: Effect of Resource Rent on Public Good Provision: Alternative Measure

Dependent Variable: Provision of Public Good

	(1)	(2)	(3)	(4)	(5)
	Power Generation Capacity per Cap	Density Road Network	Literacy	Immunization DPT	Immunization Measles
Resources	0.014***	-0.013***	0.339***	0.042	0.145
	[0.003]	[0.002]	[0.056]	[0.086]	[0.089]
Strong Executive	0.055	-0.058	3.637***	3.239**	-0.248
	[0.051]	[0.040]	[1.084]	[1.550]	[1.554]
Resources*Strong Executive	-0.026***	0.002	-0.818***	-0.448***	-0.527***
	[0.004]	[0.003]	[0.064]	[0.097]	[0.102]
Real GDP in log	0.641***	0.352***	8.049***	7.878***	7.465***
	[0.047]	[0.033]	[0.829]	[1.218]	[1.253]
Population in log	0.02	0.535***	-0.536	-1.095	-0.861
	[0.025]	[0.023]	[0.443]	[0.706]	[0.696]
Urban Population in %	0.030***	0.003**	0.318***	-0.014	0.044
	[0.001]	[0.001]	[0.032]	[0.046]	[0.046]
Constant	-3.517***	-6.016***	5.52	20.993	-7.677
	[0.566]	[0.402]	[8.681]	[13.914]	[14.157]
Resources + Resources*Strong Executive	-0.012***	-0.011***	-0.479***	-0.406***	-0.382***
	[0.003]	[0.002]	[0.037]	[0.056]	[0.059]
Observations	1193	1192	1359	1029	1004
R-square	0.79	0.82	0.70	0.67	0.67
Number of Countries	56	45	54	55	55
Time Period	1970 - 1995	1970 - 2000	1970 - 1999	1980 - 2000	1980 - 2000

Robust standard errors. Control for Institution, Ethnic Diversity, Colonizer, Country area, Population, Urban population, Region and Year dummies. *** indicates 1% significance; ** 5%; and * 10%.

Table 4.7: Difference in Public Good Provision with a "strong" ruler: Alternative Measure

Dependent Variables	Differential Provision Rent = 0	Differential Provision Rent = 11% (mean)	Differential Provision Rent = 30%
Power Generation in log	0.055	-0.234***	-0.733***
Road Network in log	-0.058	-0.037	-0.0002
Literacy Rate in %	3.637***	-5.359***	-20.899***
Immunization DPT in %	3.239**	-1.693	-10.212***
Immunization MSL in %	-0.248	-6.045***	-16.058***

This table is obtained from Table 4.6 by setting Rent to 0, 11% (mean) and 30% (Nigeria)

4.6 Appendix A.1: Properties of function $\Delta\Pi_G(A)$

Properties

1) If $\alpha < \gamma$ then $\Delta\Pi_G$ is strictly increasing and strictly concave in A

2) If $\alpha > \gamma$ then $\Delta\Pi_G$ is strictly decreasing in $[0, \underline{A}]$ and strictly increasing in $(\underline{A}, +\infty)$ where $\underline{A} = \left(\frac{\alpha}{\gamma+1-\alpha}\frac{\tau P_1 - cP_2 - P_3}{\tau(1+T)}\right)^{\frac{\gamma+1-\alpha}{\gamma+1}} Z^{\frac{1}{\gamma+1}} - 1$. $\Delta\Pi_G$ is also strictly convex everywhere.

Let $\Delta\Pi_G(A) = J(A) + [\tau P_1 - cP_2 - P_3]Z^{\frac{1}{\gamma+1-\alpha}}(1+A)^{-\frac{\alpha}{\gamma+1-\alpha}}$ where $J(A) = \tau(1+A)(1+T)$.
It is straight forward to establish that:

$$\frac{\partial\Delta\Pi_G}{\partial A} = \tau(1+T) - \frac{\alpha}{\gamma+1-\alpha}[\tau P_1 - cP_2 - P_3]Z^{\frac{1}{\gamma+1-\alpha}}(1+A)^{-\frac{\gamma+1}{\gamma+1-\alpha}}$$
$$\frac{\partial^2\Delta\Pi_G}{\partial A^2} = \frac{\alpha(\gamma+1)}{(\gamma+1-\alpha)^2}[\tau P_1 - cP_2 - P_3]Z^{\frac{1}{\gamma+1-\alpha}}(1+A)^{-\frac{2\gamma+2-\alpha}{\gamma+1-\alpha}}$$
$$\lim_{A\to\infty} \Delta\Pi_G(A) - J(A) = 0$$

Case 1: $\alpha < \gamma$

In this case, we established that $P_1 < 0$, $P_2 > 0$ and $P_3 > 0$. As a consequence, $\frac{\partial\Delta\Pi_G}{\partial A} > 0$ and $\frac{\partial^2\Delta\Pi_G}{\partial A^2} < 0$ for any A, i.e. $\Delta\Pi_G$ is strictly increasing and strictly concave in A. In addition, $\Delta\Pi_G(A)$ is below $J(A)$ for any A, and converges asymptotically to $J(A)$.

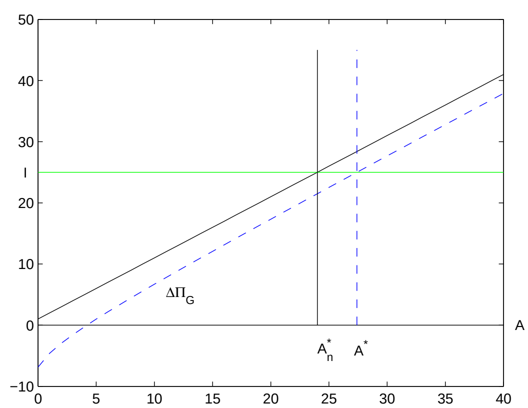


Figure 4.4: $\Delta\Pi_G$ as a function of A when $\alpha < \gamma$

When $\alpha < \gamma$, an increase in A has two reinforcing positive effects on $\Delta\Pi_G$: first, a direct positive effect of increasing output (through $J(A)$), and second an additional (positive) effect that is shrinking with A. Both effects contribute to increase $\Delta\Pi_G$.

Case 2: $\alpha > \gamma$

$$\frac{\partial \Delta\Pi_G}{\partial A} \begin{cases} < 0 & \text{if } A < \underline{A} \\ = 0 & \text{if } A = \underline{A} \\ > 0 & \text{if } A > \underline{A} \end{cases}, \text{ where } \underline{A} = \left(\frac{\alpha}{\gamma + 1 - \alpha} \frac{\tau P_1 - cP_2 - P_3}{\tau(1+T)} \right)^{\frac{\gamma+1-\alpha}{\gamma+1}} Z^{\frac{1}{\gamma+1}} - 1.$$

In addition, $\dfrac{\partial^2 \Delta\Pi_G}{\partial A^2} > 0$ for any A. So $\Delta\Pi_G(A)$ is strictly convex and decreases in the interval $[0, \underline{A}]$, reaches the minimum at $\underline{A}$ and increases in the interval $[\underline{A}, +\infty)$. Note that as $\Delta\Pi_G(A)$ is decreasing in the interval $[0, \underline{A}]$, $\min[\Delta\Pi_G(A)] = \Delta\Pi_G(A = \underline{A}) < \Delta\Pi_G(A = 0)$.

$\Delta\Pi_G(A)$ is also above $J(A)$ for any A, and converges asymptotically to $J(A)$.

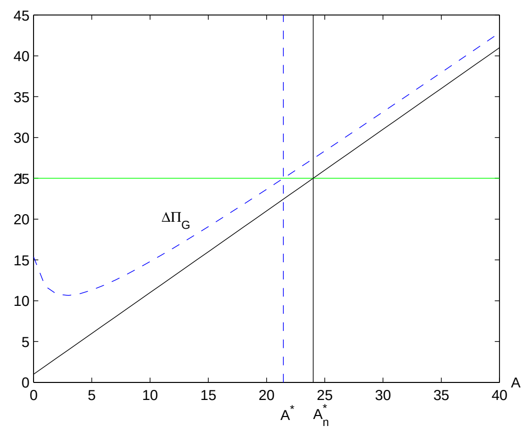


Figure 4.5: $\Delta\Pi_G$ as a function of A when $\alpha > \gamma$

When $\alpha > \gamma$, an increase in A is associated with two opposite effects: an increase in the output level through $J(A)$, and a decrease in the positive additional effects. The latter effect dominates for low levels of productivity, so that $\Delta\Pi_G$ decreases in A. The former effect dominates for high levels of productivity resulting in the increase of $\Delta\Pi_G$.■

4.7 Appendix A.2: Proof of the Lemma

According to (4.12), investment is optimal if and only if $\Delta\Pi_G(A) \geq I$.

Case 1: $\alpha < \gamma$

Since $\lim_{A\to\infty} \Delta\Pi_G(A) = +\infty$, and I is finite, the continuity of $\Delta\Pi_G(A)$ guarantees that $\Delta\Pi_G(A)$ must cross I at least once if $\min[\Delta\Pi_G(A)] = \Delta\Pi_G(A=0) < I$ (Existence).

If $\Delta\Pi_G(A=0) < I$, then uniqueness is guaranteed since $\Delta\Pi_G(A)$ is strictly increasing in A whereas I is constant in A. Hence there exists a unique productivity level A^* such that investment is optimal whenever $A > A^*$.

On the other hand if $\min[\Delta\Pi_G(A)] = \Delta\Pi_G(A=0) > I$, then $\Delta\Pi_G(A) > I$ for any A, that is whatever the value of A, the ruler will always find it optimal to invest.

Case 2: $\alpha > \gamma$

Since $\lim_{A\to\infty} \Delta\Pi_G(A) = +\infty$, and I is finite, the continuity of $\Delta\Pi_G(A)$ guarantees that $\Delta\Pi_G(A)$ must cross I at least once if $\min[\Delta\Pi_G(A)] = \Delta\Pi_G(A=\underline{A}) < I$ (Existence).

- If $\min[\Delta\Pi_G(A)] < \Delta\Pi_G(A=0) < I$, then uniqueness is guaranteed since $\Delta\Pi_G(A)$ is strictly increasing in the interval $(\underline{A}, +\infty)$ and I is constant in A. Hence there exists a unique productivity level A^* such that investment is optimal whenever $A > A^*$.
- If $\min[\Delta\Pi_G(A)] < I < \Delta\Pi_G(A=0)$, then $\Delta\Pi_G(A)$ crosses I twice in A^*_{low} and in A^*_{high}. Hence investment is optimal for any $A < A^*_{low}$ and for any $A > A^*_{high}$.

  Note that it is obvious that $A^*_{low} < \underline{A}$ and $A^*_{high} > \underline{A}$.

  This case is presented for completeness of the proof. However, we will assume that I is large enough so that there exists at most only one threshold.

On the other hand if $\Delta\Pi_G(A=0) > \min[\Delta\Pi_G(A)] > I$, then $\Delta\Pi_G(A) > I$ for any A, that is whatever the value of A, the ruler will always find it optimal to invest. ■

4.8 Appendix A.3: Characterization of A^*

Applying the implicit function theorem using equation (4.15) yields:

$$\frac{\partial A^*}{\partial Z} = -\frac{\frac{1}{\gamma+1-\alpha}\left[Z^{\frac{\alpha-\gamma}{\gamma+1-\alpha}}(1+A^*)^{\frac{-\alpha}{\gamma+1-\alpha}}[\tau P_1 - P_2 - P_3]\right]}{\tau(1+T) - \frac{\alpha}{\gamma+1-\alpha}Z^{\frac{1}{\gamma+1-\alpha}}(1+A^*)^{\frac{-\gamma-1}{\gamma+1-\alpha}}[\tau P_1 - P_2 - P_3]}$$

The denominator is equal to $\dfrac{\partial \Delta\Pi_G(A^*)}{\partial A}$ and the sign of the numerator depends on the sign of $\alpha - \gamma$.

Case 1: $\gamma > \alpha$

We established in Appendix A.1 that in this case, $\dfrac{\partial \Delta\Pi_G}{\partial A} > 0$ for any A so that by continuity the denominator is positive at $A = A^*$. Moreover, since the numerator is negative we have $\dfrac{\partial A^*}{\partial Z} > 0$. An increase in resource abundance increases the threshold, reducing the incentive to invest.

Case 2: $\alpha > \gamma$

The numerator is positive while the denominator is negative if $A < \underline{A}$ and positive if $A > \underline{A}$ (see Appendix A.1). As a result,

- If $\min[\Delta\Pi_G(A)] < \Delta\Pi_G(A=0) < I$, then $\dfrac{\partial A^*}{\partial Z} < 0$ since $A^* > \underline{A}$
- If $\min[\Delta\Pi_G(A)] < I < \Delta\Pi_G(A=0)$ (there are two thresholds A^*_{low} and A^*_{high}), then $\dfrac{\partial A^*_{low}}{\partial Z} > 0$ since $A^*_{low} < \underline{A}$ and $\dfrac{\partial A^*_{high}}{\partial Z} < 0$ since $A^*_{high} > \underline{A}$.

  This case is presented for completeness of the proof. However, we will assume that I is large enough so that there exists at most only one threshold. ■

4.9 Appendix A.4: Proof Corollary

1) Case 1: $\alpha < \gamma$

We have established that in this case $P_1 < 0$, $P_2 > 0$ and $P_3 > 0$, i.e. $\Delta\Pi_G(A) < J(A)$ for all A.

Therefore for any A, $\Delta\Pi_G(A) - I < J(A) - I$. Define $A = A_n^*$ the productivity level such that $J(A_n^*) - I = 0$. By continuity, for $A = A_n^*$, $\Delta\Pi_G(A_n^*) - I < J(A_n^*) - I$, i.e. $\Delta\Pi_G(A_n^*) - I < 0$. At $A = A_n^*$, it is not optimal for the ruler to undertake an investment. As a result $A_n^* < A^*$. This case is depicted in Figure 4.6.

2) Case 2: $\alpha > \gamma$

We have established that in this case $P_1 > 0$, $P_2 < 0$ and $P_3 < 0$. i.e. $\Delta\Pi_G(A) > J(A)$ for all A.

It follows that for any A, $\Delta\Pi_G(A) - I > J(A) - I$. By continuity, for $A = A_n^*$, $\Delta\Pi_G(A_n^*) - I > 0$. That is investment is optimal for a lower productivity level $A^* < A_n^*$. This case is depicted by Figure 4.6

We have now established that :

- $A^* > A_n^*$ if $\alpha < \gamma$, in other words A^*(strong ruler) $> A_n^*$
- $A^* < A_n^*$ if $\alpha > \gamma$, in other words A^*(strong people) $< A_n^*$

Moreover, A_n^* is independent of Z by assumption. In proposition 3 we showed that A^*(strong ruler) increases in Z and A^*(strong people) decreases in Z. It follows that for any Z, we have: A^*(strong people) $< A_n^* < A^*$(strong ruler).■

Part II

North–South Sequential Innovation Problem

"Sometime in prehistory, in the part of the world that is now the country of Peru, a raging storm felled a giant tree that came to rest in a pool of stagnant water. It lay there for some time, the water leaching the various constituents—tannins, glycosides, sugars, and alkaloids—from the bark of the tree. Eventually, a native passed that way. He was extremely ill, burning with fever that Hippocrates called intermittent, which during the Middle Ages was known as the ague, and which we today call malaria. His fever had caused intense thirst, and he drank copiously from the pond. Shortly thereafter a miracle occurred, and his fever vanished. The disease that proved fatal to such well-known victims as Alexander the Great had undergone remission." (Varro E. Tyler)

Chapter 5

Intellectual Property Rights and Sequential Innovation: Literature Overview[1]

5.1 Intellectual Property Rights (IPR)

5.1.1 What are Intellectual Property Rights?

General Characteristics Intellectual property rights refer to the legal protection conferred to individuals or firms over their creation—scientific and technological invention with industrial application, artistic creation, etc. They give the creator an exclusive right over the use of his creation. Traditional physical property differs greatly from intellectual property (IP) in that it refers to excludable tangible goods over which its owner can claim permanent ownership. Intellectual property, on the other hand, is amorphous and ubiquitous in nature and takes the form of intangible goods or products of the mind, that are by essence non excludable so that the owner cannot easily exclude others from its use as he deems fit. For this reason, to provide individuals the incentive to engage in creative activities despite the difficulty to appropriate its benefits, society has created a surrogate property right in informational goods analogous to property rights in tangible goods.

Thus intellectual property rights grant the right holder a temporary exclusive right of use and marketing over his creation. They can be opposed against third parties in case of violation. Intellectual property laws specify the scope of protection, the exclusive rights granted, the

[1] Section 5.4.1 and section 5.4.2 of this chapter draw from Sarr, et al. (2008).

limitation to the rights, the duration of protection—20 years for patents, and the life of the author plus 70 years for copyrights—and the enforcement mechanism. After expiration of the right, the product falls into the public domain and can be used freely.

The principle of territoriality is a major characteristic of intellectual property rights. It reflects the idea that an IPR is valid only within the geographical territory (nation or a community of nations like the EU) conferring it. In this sense, there is no such thing as an international intellectual property right. However, there has been a need for harmonisation of IP laws on the international level because the protection granted in a specific jurisdiction often requires cross-border recognition to be effective. (Cullet et al., 2006) This issue was first addressed in the 19th century with the signature of the Paris Convention for the Protection of Industrial Property in 1883 driven by the industrial lobby. Its purpose was to protect more effectively the nascent mechanical and chemical industries against intense industrial espionage and gross imitation which were believed to undermine genuine effort of innovation. Further development involved the Berne Convention on copyright, subsequent revisions of the Paris Convention and finally the agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) under the auspice of the World Trade Organization (WTO). (Cullet et al., 2006) Each of these steps constituted a move toward the strengthening of intellectual property rights regimes.

There exist various forms of IPRs: patents, copyrights, trade secrets, trademarks, etc. We describe below some of them.

Different Forms of IPRs

Patents: Patents are a set of exclusive rights granted to inventors to make, use and sell useful innovations for a fixed period of time in exchange for disclosure into the public domain. Patents are the single most commonly used intellectual property rights in the bio-science industries, and arguably provide the most robust protection against imitation and unauthorised use. Our discussion on IPRs will focus mainly on patents, which we will characterise in detail later in this chapter.

Copyrights: A copyright grants the author of an expressive work the exclusive rights to control its reproduction and distribution for a limited period of time in exchange for disclosure into the public domain. Copyright law protects "original work of authorship" regardless whether the author registers his work at the Copyright Office. (Besen and Raskind, 1991) The protection covers the life of the author plus 70 years. The subject matter includes literary works, musical works, motion pictures and other audiovisual works, pictorial, graphic and sculptural works, etc. Copyright ownership grants five exclusive rights: reproduction, adaptation, distribution, public performance and public display (see Section 106 of the US Copyright Act). Reproduction is arguably the most important right. It entitles the right holder to make copies of his own work and authorise others to do so.

Trade secret: Trade secret law protects an inventor's information against discovery by "improper means" and confers the right to exclusive use if 1) the information is secret; 2) if secrecy gives the information a commercial value; and 3) if the owner has made reasonable effort to keep the information secret. However, a trade secret is not protected against independent discovery or reverse engineering. Unlike patents or copyright, a trade secret law provides a legal means to prevent disclosure. However, patent protection is usually stronger than protection via trade secret. (Rodriguez-Stevenson, 2000)

Trademark: A trademark consists of any word, name, device, or other symbol that identifies a unique source of a product or service. (Blair and Cotter, 1998) It gives the owner the right to exclude others from using the same or similar mark susceptible to misleading consumers.

5.1.2 Economic Rationale: Innovation and the Internalisation of Information Externalities

The economic rationale for granting property rights to innovations was first formally explained by Nelson (1959) and Arrow (1962). Their argument proceeds as follows. Because innovation or knowledge is a public good (non rival and non-excludable), it is likely to be under-supplied as its social value exceeds its private value. A mechanism ensuring that positive externalities are internalized is therefore necessary. The implementation of an intellectual property rights regime is one such mechanism. By granting a temporary monopoly over the use and exploitation of an innovation, intellectual property regimes give the innovator the incentive to invest by ensuring that he captures part of the social value he has generated. Intellectual property rights, as a second best instrument, therefore aim at maximising social welfare by balancing the static inefficiency of monopoly distorsion with the dynamic efficiency of spurring innovation. (Nordhaus 1969)

5.1.3 Patent Design with Stand-Alone Innovations

Requirements for Patentability Stringent requirements need to be satisfied for an invention to be granted protection under the patent system: *usefulness, non-obviousness*, and *novelty*. An invention must be useful in the sense that it is susceptible of industrial application. Non-obviousness or inventive step refers to the requirement of a leap of imagination or inspiration for conferral of a patent. Simple discovery is not enough, but there must be some individual contribution shown as well in the sense that the improvement should not be trivial for an expert in the field. Novelty refers to the requirement that there is no pre-existing use or prior art incorporating the innovation, i.e. it must be genuinely "new". Prior art comprises everything made available to the public by means of a written or oral disclosure, by use, or in any other way before the priority or filing date of the patent application (European Patent Convention, Art. 52). What constitutes prior art is however different in US patent law. There, prior art is defined under 35 USC 102[2] which states: "A person shall be entitled to a patent unless known or used by others in this country, or was patented or described in a printed publication in this or a foreign country". Unlike in Europe, prior knowledge or use in a different country does not prevent a patent application in the United States. However, a prior patent or a printed publication anywhere in the world will bar an applicant for patent in the United States.

In addition to these requirements, the patentee must disclose critical information about his invention to allow others to use it at the expiration of the patent—i.e. 20 years from the date of filing. This information includes the "claims"[3] and the "best mode" or preferred embodiment of the invention. (35 USC 112; Blair and Cotter, 1998)

In most countries patents are granted according to the so-called the 'first-to-file' principle. In contrast, the United States reward innovators based on the 'first-to-invent' rule. The latter system is relatively less efficient than the former for two reasons. First, administrative costs are significantly reduced under the first-to-file system since priority depends only on the date stamped on an application (Menell and Scotchmer, 2005), and so generates few disputes unlike the first-to-invest system (Macedo, 1990). Second, the first-to-invent rule may provide incentives to delay information diffusion as the inventor wants to effectively extend the expiration date of a patent. (Scotchmer and Green, 1990)

[2]Title 35, United States Code, Section 102

[3]A patent claim is a statement that describes the structure of an invention in precise and exact terms. It marks the boundaries of the patent and allows courts to determine whether a patent has been infringed.

Optimal Design: Patent Length Nordhaus (1969) was the first to formalise the fundamental tradeoff between static and dynamic efficiency in designing patent policy, i.e. innovation can be spurred only at the expense of competition. The creation of a monopoly is deemed a lesser evil to circumvent the free riding problem inherent to the informational nature of innovation. His aim is to determine what should be the optimal length of a patent, i.e. the number of years that the patent is valid. He shows that an optimal patent monopoly should be *temporary* or finite. The idea is that to provide the inventor enough incentives he should be able to reap all the social benefit of his creation, so that the patent should last indefinitely. On the other hand because the patent induces deadweight loss to society, it will be efficient to reduce its life to zero. Hence, a temporary monopoly is a means to balance these two conflicting objectives. Thus, the length of a patent is the policy lever that determines how much profit will be earned by an innovator.

Optimal Design: Patent Breadth or Scope While the definition of patent length is clear and unambiguous, the notion of patent breadth, or patent scope has been somewhat slippery in the literature. The breadth of the patent measures the extent of the patent protection. A broad patent is one that is difficult to 'invent around' without infringing it whereas a narrow patent provides only little protection against imitation so that it is fairly easy to imitate it without infringement. Given this loose description, the definition of patent breadth in the literature varies from one author to another. (Menell and Scotchmer, 2005; Takalo, 2001) For instance, Klemperer (1990) introduces a notion of patent breadth that reflects the distance in the product space between the patented product and the nearest non-infringing substitute. Gallini (1992) however, defines the breadth technologically, as an increase in imitation costs caused by patent protection while in Gilbert and Shapiro (1990) the breadth points to the innovator's profit when the patent is still effective.

These various interpretations of the breadth of a patent result in very different conclusions as to the design of an optimal patent policy. For example, Gilbert and Shapiro (1990) find that the optimal patent should be long and narrow. That is, it should have an infinite length while its scope should be just broad enough to cover R&D sunk costs. By contrast, Gallini (1992) concludes that an optimal patent should be short and broad, in other words, one that minimises both the deadweight loss and imitation costs. In her model, the innovator's profit does not strictly increase with patent life since longer patents make unwarranted imitation more likely without necessarily spurring innovation. Thus, the patent should be just long enough so that the innovator can reap the return on her investment and broad in order to deter wasteful imitation.

Denicolo (1996) reconciles these contradictory findings by demonstrating that these different conclusions stem from the divergent influence of patent breadth on post-innovation profits and social welfare. In particular, he shows that the optimal patent has infinite breadth and minimum length, when both the incentive to innovate and the post-innovation social welfare are convex functions of the patent breadth, the reverse being true if they are concave.

5.2 The Issue of Sequential Innovation

Earlier economic analysis has considered R&D innovations as a stand alone process, i.e. innovations were not based to any important extent on pre-existing research. However, in many instances information is passed down through a chain of innovators as it is processed toward marketability. For example, it is not uncommon for some entities to be specialised in basic research while others are focused on the development of products based upon the primary knowledge supplied by the former. Thus, the end product results from the accumulation of information across both stages of these types of R&D industries.

An important problem noted in the sequential research literature is that, when innovation is sequential, early innovators in a non-integrated vertical industry may lack the incentive to invest if they do not hold a distinct property right. (Scotchmer, 1996) This point is fundamental in the literature and indicative of the presumption in favour of primary property rights in sequential R&D.

This raises another important issue regarding the efficiency of the governance structure. If both innovators are granted patents and continue to operate independently, then the double monopoly distortion within the vertical industry may induce a welfare loss. When successive monopolies operate in the same vertical industry, the impact is to impose successive margins within the chain of production. This implies distortions to efficient resource allocation, even greater than those emanating from a single monopoly. (Vernon and Graham, 1971) This distortion would create incentives for closer coordination or integration.

5.2.1 Compensating Information Production: Length and Novelty Requirement

The issue of compensating information production is considered within the R&D literature under the novelty requirement. This requirement for innovations is usually analysed in terms of the delineation of the lines between successive, independent innovations. Information diffusion is a crucial issue in cumulative research because it has an important impact on both research costs and the rate of discovery. Scotchmer and Green (1990) discuss the trade-off between the protection of the innovators' profit and the benefits from the disclosure of information. These two goals are served by different sorts of patent requirements: length and breadth. Length is usually discussed in regard to the novelty requirement for successive patenting, while breadth is usually discussed in regard to the distinctiveness required to avoid patent infringement—not just to acquire one's own patent.

The profit from an innovation is greater if the patent has a longer life, and this depends on the timing of its replacement by the next "vintage" of technology. Green and Scotchmer (1995) show that when innovation is cumulative, the first innovator's patent should be longer than it is with a stand alone innovation. This is because when the social value of the second innovation is a joint product of both innovations, the first innovator cannot appropriate all the social value he generates. Hence, unless the patent life is long enough to ensure him a sufficient profit to cover his sunk costs, he will underinvest in R&D.

O'Donoghue, et al. (1998) however warn that the statutory patent life often falls short of the "effective patent life"—defined as the expected time until a patented product is supplanted—when innovation is sequential (for survey evidence see Mansfield, 1986; Schankerman and Pakes, 1986; Lanjouw, 1998). They argue that the effective patent life mostly depends on the breadth of the patent as the scope determines the extent to which a given product loses its incumbency. In this regard, a finite and broad patent is a means to extend the effective patent life and ensure that effective and statutory patent life coincide. They show that such policy increases the rate of innovation by ensuring that only substantial improvements are noninfringing.

Consistent with this analysis, Scotchmer and Green (1990) argue that a strong novelty requirement may be an important instrument for the management of patent-based profit, by protecting the length of a monopoly against insignificant advances. However, the disclosure of information within the public domain is socially beneficial because it accelerates the rate of discovery and reduces the aggregate cost of research by shortening the investment period. A weak novelty requirement encourages inventors to patent every small technological advance. Information becomes common and can be used to develop new products.

The case for a weak novelty requirement must be balanced against the fact that first innovators may prefer secrecy over disclosure to protect their profit as opposed to what happens with a strong novelty requirement. Besides, it is argued (Eswaran and Gallini, 1996) that a strong novelty requirement makes firms concentrate on the most socially valuable projects. For these reasons, it is usually assumed that less-frequent but more substantial steps of innovation are important for patent policy. All of this points to the need for courts to define "novelty" in a way that recognises substantial contributions to successive research.

5.2.2 Patent Breadth and the Division of Profits

One of the major issues addressed in the literature of cumulative research is the question of how the division of the rents between the first generation innovator and any subsequent ones is determined (Scotchmer, 1991; Green and Scotchmer, 1995; Chang, 1995; Scotchmer, 1996; Gallini and Scotchmer, 2002).

Patent breadth—interpreted as the minimum improvement required to avoid infringement of the first generation product—is a key determinant of the division of the profit. Green and Scotchmer (1995) argue that when the value and the costs of a project are certain, patents should be broad so that they instruct courts to protect the first innovator from any innovations that represent minor or relatively inconsequential improvements.

Scotchmer (1996) investigates whether the second patent should be granted or denied when the first patent is infringed. Based on the assumption that the second generation product always infringes the original patent (i.e. the patent is assumed to be very broad), the author analyses how the division of profits is affected by the patentability of the second product. She shows that provided *ex ante* licensing is feasible, there are sufficient incentives for the second innovator to invest, as an *ex ante* agreement allows firms to share profits in a way that avoids *ex post* holdup problem. So, denying patentability to the second generation product is a means to transfer profit to the first innovator.

The critical assumption here is that there is no impediment to *ex ante* licensing and such an agreement induces no significant transaction costs. Given this assumption, granting a patent only to the first innovator combined with *ex ante* licensing is sufficient to provide the right incentives. The decision to place the patent in the hands of the first innovator stems from the fact that without his investment, no second generation product can be developed.

The possibility of contracting as well as the transaction costs will determine the extent to which firms will be involved in an agreement. If *ex ante* licensing is feasible, the breadth of the patent will determine the extent of infringement and thereby the division of profits. (Green and Scotchmer, 1995) In principle, *ex post* licensing—where the licence is signed after the second innovator decides to sink costs and the new product infringes the first generation product—can also be used. However, *ex post* licensing may not emerge in equilibrium because the second innovator may lack the incentive to invest efficiently when it bears the full research costs upfront while having to agree to share his *ex post* revenue with the licensor. In fact *ex post* licensing along with the breadth of the patent are usually seen to serve as the threat points for the bargaining over an *ex ante* license.

The review of the I/O literature on successive R&D makes clear that the issues relating to patent rights and claims in these industries are important to the determination of the profits and its division. When individual entities interact in the creation of related information and innovations, it is the willingness of states to recognise these contributions and of courts to enforce these rights that determines the share that each innovator receives.

5.3 Dispute Resolution and Mechanisms: Role of Courts in Sequential R&D

Intellectual property rights as such are not very useful as an incentive mechanism if they are not enforced in case of infringement. By enforcing these protected rights, courts determine both the efficiency of the outcome and the distribution between the parties.

5.3.1 Dispute Resolution in Patent Cases

Once a patent holder has detected the violation of his right by a third party, he may agree to settle the issue by signing a licensing contract in which the infringer will be granted the right to pursue his activity against the payment of a fee—in the form of a royalty for example.

Alternatively, the infringer may simply stop the infringement after notification. When neither of these outcomes is achieved, the patentee will sue the other party for infringement to obtain an injunction relief—and may potentially claim damages. The defendant may in turn challenge the validity of the existing patent, or may argue that he committed no infringement based on the patent claims. (Binenbaum, et al., 2003) In Europe, the validity of a patent is challenged via an *opposition* procedure in the European Patent Office (EPO).[4] No similar procedure exists in the US. There, the reexamination of a case is restricted to issues relating to the prior art that were not considered during the patent application in the US Patent and Trademark Office (USPTO). (Binenbaum et al., 2003)

It is estimated that with the strengthening of the IPR system since the early eighties, the number of litigations has risen by 70 percent especially in the industries relying heavily on intellectual property like life sciences, electronics and computers. (Kortum and Lerner, 1997; Menell and Scotchmer, 2005). Lerner (1995) estimates that 6 in 100 patents are subject to litigations in the biotechnology industry against an overall average litigation rate of 2 in 100 patents. (Allison et al., 2004) There is strong evidence that litigation costs are considerable and increasing: according to Lerner (1995), patent litigation within the USPTO and federal courts amounted to $1 billion in 1991—a considerable amount if compared to the $3.7 billion spent on basic research.

5.3.2 Remedies

As we already mentioned the two most common remedies used by courts in infringement cases are injunctions and damages, referred to as property rules and liability rules by Calabresi and Melamed (1972). An injunction rule is a property rule that confers the holder of an entitlement the right to enjoin infringing use of his entitlement. On the other hand, a damage rule is a liability rule that aims at discouraging infringement by ordering the offender to pay compensation for unauthorised use. (Schankerman and Scotchmer, 2001) In principle, damages can be awarded for two reasons: for "unjust enrichment" and for "lost profit/reasonable royalty". The former is based on the idea that the infringer should be punished for his wrongdoing by imposing him to restitute his ill-gotten profit to the patentholder. This doctrine is no longer used in the United States. The latter means that the patentholder should be awarded a compensation equivalent

[4]The "neem tree" case was a recent, and high-profile case that opposed a coalition of activists (the challengers) to the US based firm W.R. Grace in 2005. (Bullard, 2005)

to his lost profit or to a reasonable royalty.

The existence of two remedies raises the question of their relative efficacy in deterring infringement. Calabresi and Melamed (1972) and Posner (1972) argue that property rules should be preferred as long as transaction costs are low. Low transaction costs enable the opposing parties to bargain à la Coase—a decentralised mechanism—which yields efficient resolution of disputes. However, when transaction costs are high, the dispute may be mediated via a centralised mechanism—courts. With high transaction costs, liability rules (damages) are deemed superior to property rules (injunctions) especially when courts can determine perfectly the actual level of damages resulting from the conflict.

In relation to intellectual property rights, Merges (1994) contends that an injunction relief should be preferred considering that 1) there are only two parties in conflict; 2) the transaction costs between the parties is *a priori* low; and 3) the court is unlikely to set the adequate damage level. The logic of his argument is that one should not overly rely on compulsory licensing[5] as a typical remedy in intellectual property cases.

However, even if injunction rules were the main remedy in resolving disputes regarding intellectual property rights, damage rules would be still keep their relevance. In effect, the right holder may not detect infringement immediately so that there is a need for damage payment. (Blair and Cotter, 1998)

In fact, much of the discussion above assumes that the Coase Theorem applies—namely through the assumption of low transaction costs. But whenever the Coase theorem breaks down, the superiority of the property rule comes into question. This is namely the case in the presence of nuisance. (Pitchford and Snyder, 2003)

5.3.3 Efficient Investment and the Role of the Courts

The role of courts in inducing efficient behaviour has been analysed by Pitchford and Snyder (2003) in the context of nuisance. Their analysis, as they claim, is also applicable to sequential R&D. Suppose a firm A (first mover) decides to set up activities that generate negative externalities (noise, bad smell, pollution, etc.). Suppose now that long after A is established, another firm B (second mover) settles nearby despite the nuisance caused by A. Because of the nuisance, firm

[5] The payment of damages amounts in fact to compulsory licensing since the infringer is allowed to pursue his activity provided compensation is paid.

B may decide to file a legal case against A to make it stop its activity or force it to move away from the neighbourhood. The main issue addressed by Pitchford and Snyder (2003) is whether or not courts should apply the "coming to the nuisance" rule from an efficiency point of view. In other words whether courts should favour the first mover as they have in some important legal cases (e.g. Spur Industries case). The problem facing the two parties here cannot be readily solved with Coasean bargaining. Indeed, when the first mover chose its investment in capacity to produce the externality-generating good, it was unable to identify what firm—among a large set of possible firms—would eventually establish in the neighbourhood in the future. As a result of this "*ex ante* anonymity", the Coase theorem breaks down as A and B are unable to sign an contract over A's *ex ante* investment—leading to contract incompleteness. Given the failure of Coasean efficiency, the authors investigate whether the court's decision about specific property rights and remedies (injunction rule, damage rule and exclusion rule) will induce, *ex ante*, a unilateral socially optimal investment by the first mover A. Pitchford and Snyder show that the use of different remedies yields very different outcomes. Only when the first mover holds the right to decide the externality level under the damage rule, is the *ex ante* unilateral investment socially optimal. Intuitively, because A is made to pay damages to B to have the right to pollute, it is forced to internalise the cost that pollution—and therefore its investment—imposes upon B. This result indicates that the liability rule (damages) is essential to achieve efficiency. By choosing a particular remedy, the court also affects distribution between the parties.

5.3.4 Distribution and the Role of the Courts

One of the major issues addressed in the literature of cumulative research—as we have seen earlier—is the question of how courts determine the division of the rents between the first generation innovator and any subsequent ones (Scotchmer, 1991; Green and Scotchmer, 1995; Gallini and Scotchmer, 2002). The patent policy concerning the breadth of the patent—interpreted as the minimum improvement required to avoid infringement of the first generation product—is a key determinant of the division of the profit.

The willingness of courts to enforce a patent against incursions from products with minor modifications generates important incentives for contracting. With a broad patent the second innovator is more likely to infringe the earlier technology, and is therefore more likely to sign an *ex ante* licensing contract—where the license is signed on before the second innovator decides to sink costs in innovation—to be able to develop an improved product. (Scotchmer, 1996)

5.4 Application: North/South Relations in Sequential R&D

The life sciences industry (pharmaceutical firms and biotechnology) has the specificity that it relies on natural compounds—also called genetic resources—for R&D purposes. We suggest that R&D in this industry is best viewed as an example of information-production, in which the first stage generates pure or primary information and the second stage develops this into a marketable and patentable product. (Swanson and Goeschl, 2000) This manner of interaction between the primary and secondary stages of an R&D industry is a good fit with the cumulative research framework developed within the Industrial Organization (I/O) literature, in which abstract basic research is built upon by developers to generate concrete innovations. (Scotchmer, 1991; Green and Scotchmer, 1995) In this section we first present some evidence on the contribution and the value of natural compounds in R&D process, and then we set out the general implications of this I/O literature for the management of R&D in this bio-technology sector.

5.4.1 Importance of Genetic Resources and Traditional Knowledge in R&D

Role of Genetic Resources. Human society has relied upon the diversity of genetic resources[6] for millennia, as a source of solutions to problems that arise in the biological arena. When a crop has failed, the surviving strains have signaled the presence of a solution concept, and this has guided plant breeders toward varieties that are successful in the existing environment (Evans, 1993). When a pest, pathogen or plague has passed through the human population, the primary source of remedy has been the set of chemicals found within the natural world, identified first by those living in nearest proximity to them (Anderson and May, 1991). These solution concepts have been identified and diffused, and have formed the foundation of the life sciences as we know them. The World Health Organization (WHO, 2003) estimates that 80 percent of the population in developing nations rely on traditional medicine and that nearly 85% of traditional medicine involves the use of plant extracts (Farnsworth, 1988 p. 91 cited by Biber-Klemm and Szymura Berglas, 2006 p. 8) According to ten Kate and Laird (1999) around 40 percent of the 25 best selling drugs in the world are derived from natural compounds. It is

[6] The Convention on Biological Diversity (CBD) defines 'genetic resources' or 'biological resources' as any material of plant, animal, microbial or other origin, containing functional units of heredity, which has an actual or potential value. (Article 2.7)

also estimated that 25 percent of all prescription drugs in the US (Reid et al., 1996 p. 145) and 50 percent worldwide are based on plants. (Principe, 1989) For instance, the use of compounds such as the Malgash rosy periwinkle, the Pacific yew, the Ethiopian soap berry, or the Indian Neem tree extracts have led to the development of products as diverse as anti-cancer drugs and pesticides.

Despite technological progress, the reliance of the pharmaceutical and agro-chemical sector on biological diversity[7] to develop new products including pharmaceuticals, seeds, and cosmetics has sustained the search for genetic materials through bioprospecting.[8] In this thesis, we will focus on bioprospecting for the purpose of drug development. Bioprospecting companies originate mostly from high income countries—the North—and have the technology and capability to produce innovations based on the biological information isolated and extracted from plants. These natural compounds are found to a large extent in 'biodiversity hot spots'[9] mostly located in low income countries—the South. Thus, the bioprospectors' reliance on the South's biodiversity requires the two parties to cooperate. However, for decades, bioprospectors tapped into the common heritage doctrine to freely access genetic resources and associated traditional knowledge without compensating their providers. This among other factors, provides the South little incentive to invest in preserving diversity given the opportunity offered by alternative land use towards more profitable activities such as agriculture or the timber trade.

Role of Traditional Knowledge Traditional knowledge (TK) refers here to the accumulated stock of human capital and knowledge over the centuries about the properties of medicinal plants. Within the R&D process, it may be particularly useful in the screening process for potential inputs. It may help increase the rate of discovery while decreasing substantially the research costs required to make it. (Balick, 1990; Sheldon and Balick, 1995). For example, in a study testing the incremental impact of traditional human capital on success rates in bioprospecting, Balick (1990) reports the results of screening for activity against the human immunodeficiency virus (HIV) where 25 percent of collections pre-screened by indigenous plant experts indicated activity as opposed to 6 percent in the random sample. Similar results were obtained in related

[7]Biodiversity is defined as the variability among living organisms (CBD, Article 2(1))

[8]Bioprospecting can be defined as the exploration of biodiversity for commercially valuable genetic and biochemical resources. (Reid et al., 1996 p. 142)

[9]"70 percent of the world's biodiversity is found in 12 'mega-diverse' countries—Columbia, Ecuador, Peru, Brazil, Zaire, Madagascar, China, India, Malaysia, Indonesia, Australia and Mexico." (Biber-Klemm and Szymura Berglas, 2006 p. 6)

studies (Cox, 1990; King, 1992). These studies underline the significant human capital base accumulated at the primary R&D level and its contribution to the innovation process. (Evenson and Gollin, 1998)

5.4.2 Bioprospecting & the Values of Biodiversity for R&D

The importance of genetic resource for R&D has often been presented as a rationale for conservation in the face of an ever-dwindling supply of diversity mainly in the tropical regions of the world where most of the biodiversity stock remains. Starting with Oldfield (1989), the preservation of biological diversity has repeatedly been cast as a problem of supplying the broadest portfolio of biological options. In this sense, the value of genetic resources derives primarily from the diversity of genetic or chemical information they represent. (Weitzman, 1998) This value is then captured via a search process over information (Simpson, Sedjo and Reid, 1996—SSR).

In an influential contribution, SSR ground the value of biodiversity in the activity of bioprospecting in an R&D intensive industry. They aim to quantify the marginal willingness to pay for an additional sample by reference to the potential value of adding another member to the set of genetic resources available for screening. Their approach is focused on the private objective of firms seeking patents through random searches in natural habitats assuming each sample searched has an independent likelihood of providing the solution. The value of a marginal genetic resource within such a habitat refers to its contribution to the anticipated royalties from licensed sales after a successful search. Against this value is balanced the cost of undertaking another search and the prospect that earlier searches have already resolved the problem. The primary point of SSR is that, given a specified number of targets, the value of the marginal genetic resource must be declining on account of the decreasing likelihood that the solution has not previously been located and the increasing costliness of another search for the same (valued) target.

SSR (1996) find that the maximum willingness to pay for bio-diverse lands in Western Ecuador, one of the 'biodiversity hot spots', does not exceed US$21 per hectare or $9,500 per marginal species. This implies that most areas with even extraordinary biodiversity do not justify significant payments from the pharmaceutical industry for their preservation. This result contrasts with the more optimistic estimates reported in the early valuation literature. For instance, Farnsworth and Soejarto (1985) find that the foregone drugs revenue of extinction of flowering plants exceeds \$1.5 million per species and Principe (1989) estimates that plant extinction will result in \$300,000 lost drugs revenue (see Artuso, 1997 p. 5–7). These overestimations are mostly due to the fact that these authors in fact estimate the average value of a species and fail to factor in redundant species. The conclusion of SSR (1996) is that there is little reason to expect that the industrial use of genetic resources will result in significant payments for the conservation of marginal resources by private investors.

This analysis has been criticised on several grounds. First, using a privately motivated screening process as an approximation of the social values of genetic resources may be problematic. (see Craft and Simpson, 2001)

Second, the assumption of equal but independent likelihoods of success in sampling processes may be both important and unlikely. Rausser and Small (2000) challenge SSR's (1996) conclusion of a low marginal value of bioprospecting. Based on the assumption that the probability of a success differs across leads, they argue that a prior knowledge about these probabilities may help organise the search in an efficient manner. Their numerical simulations akin to SSR (1996) suggest that an organised search yields a marginal value of \$9177 per hectare in Western Ecuador—as opposed to \$21 per hectare found by SSR (1996). Costello and Ward (2006), however, question the validity of the comparison made by Rausser and Small (2000). They show that only 4% of the difference between the two estimates can be explained by a more efficient search as opposed to a random search. Most of the discrepancy is due to different parameter choices about the number of species included in the search and ecological model parameters. These results suggest that, the quality of information available to the bioprospector—for example indigenous knowledge about what species are likely prospects—may be a more important factor in raising the marginal value of bioprospecting than the efficient organisation of the search.

Third, the casting of the problem as the search for the solutions to a pre-determined number of problems is a highly simplified approach to technological innovation in the life sciences (see Goeschl and Swanson, 2002a). It is known that pests and pathogens will continue to erode the solutions that humans put into place in the life sciences (May and Dobson, 1986), but the precise nature of the future problems that will be generated or the sequence in which they will arrive is completely unknown. In both areas, it is very likely that searches that are unsuccessful for one purpose (or problem) might be right on point for a future one. It is also the case that any given solution will drive the likelihood of future types of problems down certain pathways where entirely new samples are generated and new problems created.

Fourth, Kassar and Lasserre (2004) argue that if irreversibility and uncertainty are taken into account, redundancy among species will not be an obstacle to conservation as claimed by SSR (1996) but will in fact provide an additional rationale for the conservation of biodiversity. Indeed if the relative value of species used in addressing biological problems evolves across time in an unpredictable fashion, the valuable species today may prove to be 'useless' in the future and vice-versa. As a result even with perfect substitutability of the species, there is reason for preserving genetic diversity as an insurance against the evolution of the value of information over time. This approach makes clear that the important issues concerning genetic resource conservation values are the dynamic ones. The assumptions about how future paths evolve determine what is valuable, and how these values change in the future.

5.4.3 North/South Aspects of R&D Governance

The industrial organisation literature has analysed the cumulative nature of innovation and its implications for the design of intellectual property rights policy. Emphasis there is placed on giving first-stage innovators adequate incentives to invest and innovate, because no inventions or discovery would be possible without their contribution. It is therefore argued that first innovators should be protected via patents while the second innovator can be even denied patent protection if licensing can be relied upon. (Green and Scotchmer, 1995) It is striking that, in practice in the biological sector, the opposite result has occurred. Only the secondary stage of the research process is granted property rights protection in this sector while the primary traditional stage is left unrewarded despite its crucial contribution to innovation. This raises two problems, one of efficiency, and one of equity.

First, failure to protect genetic resources and associated traditional knowledge may result in biodiversity loss—as is currently the case—and underinvestment in these indispensable information flows derived from genetic diversity.[10] Secondly, in this particular area of R&D, there is a North-South (or distributional) aspect to the I/O problem as well as an efficiency aspect. This is because we can assume here that the R&D firm will nearly always come from the stylised North—where the North has a unique technological capability as well as access to important markets. In contrast, the stylised South can be assumed to be uniquely endowed with rich

[10] This particular issue is analysed in chapter 6

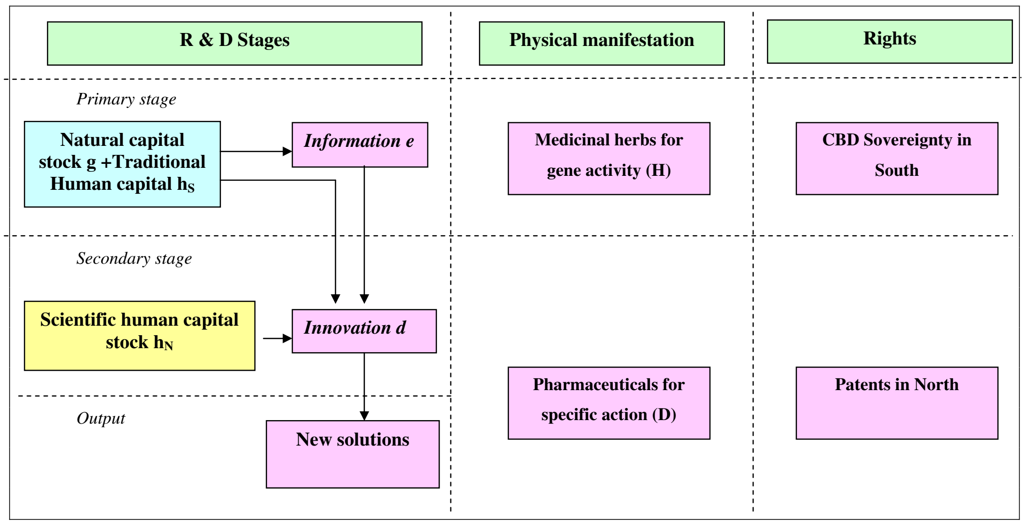
stocks of genetic resources and accumulated traditional knowledge without access to technological capability to develop patentable products. Because the patent system exclusively rewards the North for its innovation, despite the South's undeniable contribution, concern about a fair division of benefits has led some observers to make the case for protecting genetic resource owners and/or traditional knowledge owners with intellectual property rights.

However, compensating the South's information production via North-style intellectual property rights—namely via patents—is a challenging endeavour. The stringent requirements to ensure the patentability of informational goods may be difficult to satisfy. Non-obviousness is the primary hurdle to the recognition of IPR in genetic resources, as naturally-occurring entities are usually termed to be discoveries rather than innovations. And novelty is the primary hurdle to the recognition of IPR in traditional knowledge, as many if not all traditional uses of genetic resources may be shown to have existed at some other place or point in time. Hence, irrespective of the usefulness of the genetic resource or the traditional knowledge in the production of innovation, at present there is little prospect for the recognition of IPR in these stages of the sequential research process.

5.4.4 Vertical 2-Stage Structure of R&D Industry

We model the R&D industry in the biological sector as a non-integrated vertical industry of two stages. In the primary stage, a flow of information—originating within the natural environment and requiring a diverse stock of natural capital, namely land—is captured by virtue of investment in traditional human capital—traditional knowledge—in settings where human populations interact with the natural environment through observation and selection. The combination of the two factors results in a primary sector output of pure information. In the next stage of this vertical industry, the secondary stage biological R&D process collects these informational flows from the primary R&D stage, and invests in physical and human capital—laboratory equipment and scientists—in order to produce innovations, i.e. new products designed to meet consumers' wants and needs. The figure below depicts such a vertical industry.

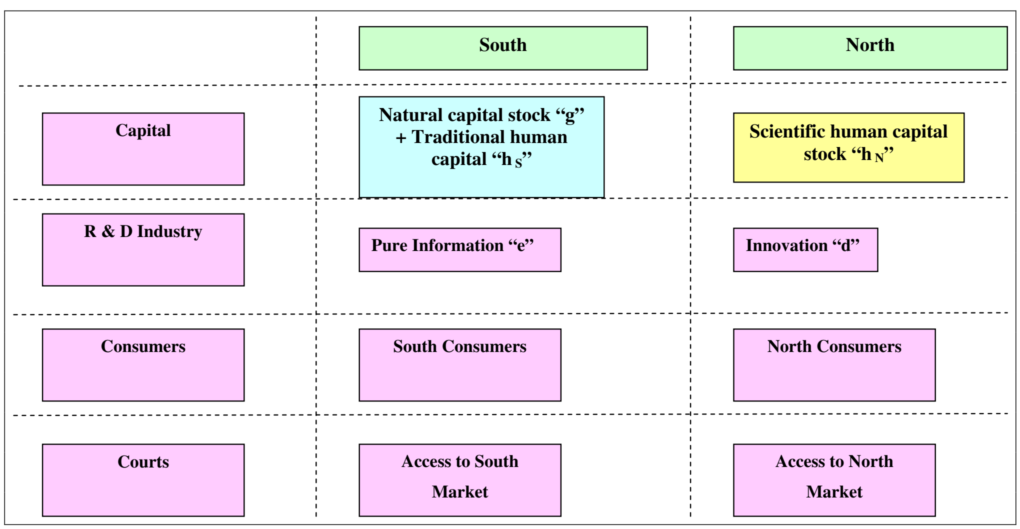
Figure 5.1: R&D stages in the biological sector (adapted from Goeschl and Swanson, 2002b).



"e" is the biological activity recognized by the South

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

Figure 5.2: Structure of North/South Interactions



"e" is the biological activity recognized by the South

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

Bibliography

[1] Anderson, R.M. and R.M. May (1991): *Infectious Diseases of Humans. Dynamics and Control*. Oxford Science Publications. Oxford University Press: Oxford.

[2] Arrow, K. (1962): Economic Welfare and the Allocation of Resources for Invention. In: R. Nelson (Ed), *The Rate and Direction of Inventive Activity*. Harvard University Press: Cambridge.

[3] Artuso, A. (1997): *Drugs of Natural Origin – Economic and Policy Aspects of Discovery, Development, and Marketing*, The Pharmaceutical Products Press.

[4] Balick, M.J. (1990): Ethnobotany and the Identification of Therapeutic Agents from the Rainforest. In: D.J. Chadwick, and J. Marsh (Eds.): *Bioactive Compounds from Plants*. Ciba-Geigy Symposium No. 154, Bangkok 20-22 February. New York: John Wiley, 22–39.

[5] Besen, SM and L.J. Raskind (1991): An Introduction to the Law and Economics of Intellectual Property, *Journal of Economic Perspectives*, 5(1): 3–27.

[6] Biber-Klemm, S. and D. Szymura Berglas (2006): Problems and Goals, In S. Biber-Klemm and T. Cottier (Eds.): *Rights to Plant Genetic Resources and Traditional Knowledge*, CABI: London.

[7] Binenbaum, E., C. Nottenburg, P. Pardey, B. Wright and P. Zambrano (2003): South-North Trade, Intellectual Property Jurisdictions, and Freedom to Operate in Agricultural Research on Staple Crops, *Economic Development and Cultural Change*, 51(2): 309–335.

[8] Blair, R.D. and T.F. Cotter (1998): Economic Analysis of Damages Rules in Intellectual Property Law, *William and Mary Law Review*, 39: 1585–1694.

[9] Bullard, L. (2005): *A Briefing Paper on the First Legal Defeat of a Biopiracy Patent: The Neem Case.* Brussels: Research Foundation for Science, Technology and Ecology, International Federation of Organic Agriculture Movements (IFOAM) & The Greens/ European Free Alliance in the European Parliament: page 6. Available at http://www.ifoam.org/press/press/pdfs/Briefing_Neem.pdf [Accessed 5 May 2006].

[10] Calabresi, G. and A.D. Melamed (1972): Property Rules, Liability Rules, and Inalienability: One view of the Cathedral, *Harvard Law Review*, 85:1089–1126.

[11] Chang, H.F. (1995): Patent Scope, Antitrust Policy, and Cumulative Innovation, *Rand Journal of Economics*, 26: 34–57.

[12] Costello, C. and M. Ward (2006): Search, bioprospecting, and biodiversity conservation. *Journal of Environmental Economics and Management* 52: 615–626.

[13] Cox, P.A. (1990): Ethnopharmacology and the Search for New Drugs. In: D.J. Chadwick, and J. Marsh (Eds.): *Bioactive Compounds from Plants*. Ciba-Geigy Symposium No. 154, Bangkok 20-22 February. New York: John Wiley, 50–55.

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

[15] Cullet, P., C. Germann, A.N. Mueller and G. Pasadilla (2006): Intellectual Property Rights, Plant Genetic Resources and Traditional Knowledge. In S. Biber-Klemm and T. Cottier (Eds.): *Rights to Plant Genetic Resources and Traditional Knowledge*, CABI: London.

[16] Denicolo, V. (1996): Patent Races and Optimal Patent Breadth and Length, *Journal of Industrial Economics*, 44: 249–265.

[17] Eswaran, M. and N. Gallini (1996): Patent Policy and the Direction of Technological Change, *Rand Journal of Economics*, 27(4): 722–746.

[18] Evans, L.T. (1993): *Crop Evolution, Adaptation and Yield.* Cambridge University Press, Cambridge.

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

[20] Farnsworth, N.R. (1988): Screening Plants for New Medicines. In E.O. Wilson (Ed.): *Biodiversity*. Washington DC: National Academy Press.

[21] Farnsworth, N. and D. Soejarto (1985): Potential consequences of plant extinction in the United States on the current and future availability of prescription drugs. *Economic Botany*, 39(2): 231–240.

[22] Gallini, N. (1992): Patent Policy and Costly Imitation, *Journal of Industrial Economics*, 44: 52–63.

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

[24] Gatti, R., T. Goeschl, B. Groom, and T. Swanson (2004): The Biodiversity Bargaining Game, *Cambridge Working Papers in Economics* No. 0447, Sept. 2004 (recent version 2007).

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

[26] Gilbert, R. and C. Shapiro (1990): Optimal Patent Length and Breadth, *Journal of Industrial Economics*, 21: 106–112.

[27] Goeschl, T. and T. Swanson (2002a): The Social Value of Biodiversity for R&D. *Environmental and Resource Economics*, 22: 477–504.

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

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

[30] Kassar, I. and P. Lasserre (2004): Species preservation and biodiversity value: a real options approach. *Journal of Environmental Economics and Management*, 48: 857–879.

[31] King, S.R. (1992): Pharmaceutical Discovery, Ethnobotany, Tropical Forests and Reciprocity: Integrating Indigenous Knowledge, Conservation and Sustainable Development.

In: M. Plotkin and L. Famolare (Eds.): *Sustainable Harvest and Marketing of Rain Forest Products*. Washington D.C.: Island Press.

[32] Klemperer, P. (1990): How Broad Should the Scope of Patent Protection Be?, *Journal of Industrial Economics*, 21: 113–130.

[33] Kortum, S. and J. Lerner (1998), Stronger Protection or Technological Revolution: What is Behind the Recent Surge in Patenting?, *Carnegie-Rochester Conference Series on Public Policy*, 48: 247–304.

[34] Lanjouw, J.O. (1998): Patent Protection in the Shadow of Infringement: Simulation Estimations of Patent Value, *Review of Economic Studies*, 65(4): 671–710.

[35] Lerner, J. (1995): Patenting in the Shadow of Competitors, *Journal of Law and Economics*, 38: 563–595.

[36] Macedo, C. (1990): First-to-File: Is American Adoption of the International Standard in Patent Law Worth the Price?, *AIPLA Quarterly Journal*, 18: 193–234.

[37] Mansfield, E. (1986): Patents and Innovation: An Empirical Study, *Management Science*, 32:173–181.

[38] May, R., M. and A.P. Dobson (1986): Population dynamics and the rate of evolution of pesticide resistance. In: P*esticide Resistance Management*. NAS-NRC Publications: Washington D.C.

[39] Menell, P. and S. Scotchmer (2007): Intellectual Property Law, *Handbook of Law and Economics*, Volume 2, 19: 1473–1570.

[40] Merges, R.P. (1994): Of Property Rules, Coase, and Intellectual Property, *Columbia Law Review*, 47: 2655–2668.

[41] Nelson, R. (1959): The Simple Economics of Basic Scientific Research, *Journal of Political Economy*, 67(3): 297–306.

[42] Nordhaus, W. (1969): *Invention, Growth, and Welfare: A Theoretical Treatment of Technological Change*, MIT Press: Cambridge, Massachusetts.

[43] O'Donoghue, T., S. Scotchmer and J.F. Thisse (1998): Patent Breadth, Patent Life and the Pace of Technological Progress, *Journal of Economics and Management Strategy*, 7: 1–32.

[44] Oldfield, M.L. (1989): *The Value of Conserving Genetic Resources.* Sunderland, MA: Sinauer.

[45] Pitchford, R. and C. Snyder (2003): Coming to the Nuisance: An Economic Analysis from an Incomplete Contracts Perspective, *Journal of Law, Economics & Organization*, 19(2): 491–516.

[46] Polasky, S., C. Costello and A. Solow (2005): The Economics of Biodiversity, In K.-G. Mäler and J.R. Vincent (Eds.): *Handbook of Environmental Economics*, Volume 3, 29: 1517–1560.

[47] Posner, R.A. (1972), *Economic Analysis of Law*, Boston, Little Brown.

[48] Principe, P. (1989): *The Economic Value of Biological Diversity among Medicinal Plants.* Paris: OECD.

[49] Rausser, G.C. and A. Small (2000): Valuing research leads: bioprospecting and the conservation of genetic resources, *Journal of Political Economy*, 108(1): 173–206.

[50] Reid et al. (1996): Biodiversity Prospecting, In Balick, M., E. Elisabetsky and S.A. Laird (Eds.): *Medicinal Resources of the Tropical Forest*, Columbia University Press: New York, 142-173.

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

[52] Sarr, M., T. Goeschl and T. Swanson (2008): The Value of Conserving Genetic Resources for R&D: A Survey, *Ecological Economics*, 67: 184–193.

[53] Schankerman, M. and A. Pakes (1986): Estimates of the Value of Patent Rights in European Countries During the Post-1950 Period, *Economic Journal*, 97:1052–1076.

[54] Schankerman, M. and S. Scotchmer (2001): Damages and Injunctions in Protecting Intellectual Property, *RAND Journal of Economics*, 32(1): 199–220.

[55] Scotchmer, S. and J. Green (1990): Novelty and Disclosure in Patent Law, *RAND Journal of Economics*, 21: 131–146.

[56] Scotchmer, S. (1991): Standing on the Shoulders of Giants: Cumulative Research and the Patent Law, *Journal of Economic Perspectives*, 5: 29–41.

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

[58] Sheldon, J.W. and M.J. Balick (1995): Ethnobotany and the search for balance between use and conservation. In: T. Swanson (ed.): *Intellectual Property Rights and Biodiversity Conservation: an Interdisciplinary Analysis of the Values of Medicinal Plants.* Cambridge: Cambridge University Press, 45–64.

[59] Simpson, D. and A. Craft (1996): The Social Value of Using Biodiversity in New Pharmaceutical Product Research. *Discussion Paper 96–33.* Washington D.C.: Resources for the Future.

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

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

[62] Swanson, T. and T. Goeschl (2000): Property Rights Issues Involving Plant Genetic Resources: Implications of Ownership for Economic Efficiency, *Ecological Economics* 32(1): 75–92.

[63] Swanson, T. and A. Kontoleon (1999): The Economics of Nuisance Disputes. In: *New Encyclopaedia of Law and Economics*, Kluwer: Dordrecht.

[64] Takalo, T. (2001): On the Optimal Patent Policy, *Finnish Economic Papers*, 14(1): 33–40.

[65] ten Kate, K. and S.A. Laird (1999): *The Commercial Use of Biodiversity: Access to Genetic Resources and Benefit Sharing*, London: Earthscan Publications.

[66] Vernon, J.M. and Graham, D.A. (1971): Profitability of monopolization by vertical integration, *Journal of Political Economy*, 79: 924–925.

[67] WEITZMAN, M. (1998): The Noah's Ark Problem, *Econometrica*, 66(6): 1279–1298.

[68] WORLD HEALTH ORGANIZATION (2003): *Traditional medicine*. Fact Sheet No 134.

Chapter 6

North–South Hold-up Problem in Sequential R&D[1]

6.1 Introduction

In 1995, a coalition of NGOs challenged the patent awarded by the US Patent Office to the agro-chemical company, W.R. Grace & Co for its method of stabilising azadirachtin[2] in solution and the stabilised solution itself. The challengers invoked the lack of novelty of the invention on the basis that it was simply an extension of the traditional processes used for millennia for making neem-based products in India. (Shiva, 1996) However, the US Patent Office held that the patent was valid under US legislation. Another patent held by W.R. Grace for a method for controlling fungi on plants also derived from the neem tree was later challenged by a legal opposition, this time in the European Patent Office (EPO). The EPO eventually revoked that patent on the fungicidal product due to its lack of novelty and "inventive step". (Bullard, 2005)

These two cases are illustrative of the inability of the North—which is reliant on biodiversity located in the South—and the South to find a common ground to address the issue of ownership of informational goods such as genetic resources. Yet, the coordination of each region's legal system to enforce rights in information-based genetic resources can potentially generate efficient investment in R&D for health services. The lack of coordination results from a deeply asymmetric situation where North—technology rich and biodiversity poor—and South—gene rich but technology poor—assign property rights over informational goods according to their respective comparative advantage. The North promotes an intellectual property system that

[1]This chapter is a joint work with Tim Swanson of University College London

[2]Azadirachtin is the active chemical compound contained in the neem tree found in India

protects technology-based knowledge and invention at the expense of the discovery of naturally occurring products. In contrast, the South promotes an intellectual property system that protects and rewards the discovery of useful information contained in natural products through a process of observation, experimentation, and environmental stewardship.

The difficulty in reconciling these two systems results in little or no recognition by the North of the South's property rights in genetic information. This situation creates an inherent uncertainty about the enforcement of these rights in the North. In particular, given the sequential nature of R&D in the life sciences industry (agriculture and pharmaceuticals), this absence of coordination may result in underinvestment as predicted by Green and Scotchmer (1995) if the first innovator—here the South—is inadequately compensated for the information supplied to the second innovator. What are the consequences of the uncertainty about the protection of property rights upon investment in preserving genetic diversity, access to genetic resources and drug R&D? What is the role of legal institutions in shaping the incentive to invest? Can an *ex post* remedy yield efficiency given *ex ante* uncertainty of enforcing the South's property rights?

Following Swanson and Goeschl (2000), we suppose that North-South bilateral relationship takes place within a non-integrated vertical industry where the South provides necessary intermediate goods (genetic resources) to the North which subsequently use them as inputs to develop patentable pharmaceuticals. We develop a model of North-South bargaining in a sequential R&D framework to analyse how the problem of rent appropriation impacts the South's investment in preserving genetic diversity and the flow of information generated within this vertical industry. We shed light on the mechanism by which underinvestment in maintaining genetic diversity and inefficient flow of information in bioprospecting occurs. We show that even with the creation of a property right protecting genetic resources, uncertainty *ex ante* about the enforceability of the assigned right across jurisdictions may lead to a hold-up problem—underinvestment in environmental stewardship. As we will see, the bargaining process is subject to renegotiation once uncertainty is resolved by courts' ruling. This renegotiation is likely to dissipate investment returns and prevents the investor from appropriating the full marginal benefit of his investment while bearing all the costs. We also highlight the role that legal institutions play in shaping the incentive to invest. Under some specific conditions and legal remedies, we show that *ex post* the enforcement of property rights across jurisdictions helps circumvent the hold up problem and encourages socially optimal investments. But these conditions are not general.

Section 6.2 presents stylised facts about the North-South bilateral relationship in the framework of sequential investment. We then layout the model and discuss the results in Section 6.3. Section 6.4 concludes the chapter.

6.2 North–South relationship in Sequential R&D: Stylised facts

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

Separate R&D Contributions. Firms from the North and the South, F_N and F_S, can cooperate for mutual benefit through coordination in the supply of inputs within a process of sequential R&D. If they cooperate successfully, then a higher quality of health services is available to consumers. The South is gene rich and technology poor. The firms in the South F_S are specialised in the provision of genetic material g and the maintenance of genetic diversity through investment in land use L. The North is technology rich and biodiversity poor. The firms in the North F_N use information contained in the genetic resources g and combine them with technology in the North to search for new leads and develop new drugs d.

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

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

Separate Court Systems. Court systems exist in each region for enforcement of property rights. There is *ex ante* uncertainty about whether any right conferred in a given jurisdiction—say the right in the genetic resources—will be recognised and enforced by courts in the other region. It is possible for courts to either recognise the property rights declared in the other region and thus enforce them domestically, or to not recognise them at all. Both the Northern and Southern courts, Ct_N and Ct_S, recognise F_S's property right in land L. The property right in g is recognised in the South by Ct_S, i.e. the jurisdiction in which it has been conferred. Similarly, the property right in d is recognised by Ct_N.

Table 6.1: Stylised Facts on North/South Interactions with Land Use Investment

	South	North
Vertical Industry	• F_S: Upstream	• F_N: Downstream
Separate R&D Contributions	• Biodiversity Rich (Land L and Genetic Resources g) • Technology Poor: no d	• Biodiversity Poor: no L and g • Technology Rich: produces drugs d
Separate Markets	• Low income: CG_S have low willingness to pay • Medicinal plants • F_S serves only CG_S	• High income: CG_N have high willingness to pay • Pharmaceuticals • F_N serves only CG_N
Separate Property Rights Systems	• F_S has property rights in L and g	• F_N has a property right in d
Separate Courts Systems	• Ct_S enforces rights in g	• Ct_N enforces right in d. *Ex ante* enforcement of right in g with probability ξ
	Both courts Ct_S and Ct_N recognise F_S's property right in land L	

6.3 Sequential R&D and the Hold-up Problem

6.3.1 Background

Consider two risk-neutral agents F_N (he) representative of the firms from the North and F_S (she) representative of the firms from the South. F_S owns some genetic material g useful in producing medicines that treat conditions both in the North and the South. F_N produces drugs d using g an input.

Governments in these two regions aim at advancing social welfare by maximising both producers' and consumers' surplus. The challenge faced by each government domestically, is to create the proper incentive for firms F_N and F_S to invest in R&D for health services: investment in land use L for the conservation of genetic diversity by F_S, which allows the collection of natural compounds g necessary to produce herbal medicines; and investment in pharmaceutical drug development by F_N. This challenge is addressed in each region by conferral of property rights. The South grants F_S exclusive rights in genetic resources g and L, while the North grants F_N exclusive rights in drug d. These statutory rights are enforced within each region by domestic courts Ct_N and Ct_S.

We assume that there is no coordination between the two regions to harmonise their separate property rights systems. As a result, there is no *ex ante* enforceability of the property rights across jurisdictions. In the absence of *ex ante* enforceability, there is an inherent uncertainty about the state of the world. This uncertainty is captured by the probability $\xi \in [0, 1]$ representing the *ex ante* common belief that the right will be enforced.

This chapter will focus on F_S's incentives to invest in L and to trade the genetic resources g needed by F_N as inputs for drug development. For this reason, we focus on the producers' surplus as a social welfare criterion.

We now model North/South interaction as a bargaining game to investigate the implications of the lack of coordination of the property rights systems on North/South cooperation to invest in R&D in the life sciences sector. In particular, we will examine how the incentive to maintain biodiversity and exchange genetic resources in the South, and the incentive to develop new drugs based on natural inputs in the North, are affected.

6.3.2 Bargaining process

F_N wishes to sign an agreement with F_S to be granted access to g in return for a transfer payment T, in order to search for new leads. If an agreement is reached, F_S will earn $U = u(g, L) + T - c(g) - c(L)$ and F_N will receive $V = v(g, d) - T - c(d)$, where the benefits u and v are strictly increasing and concave in their arguments and their cross derivatives are positive;

$c(g)$ is the cost of supply of g and $c(L)$ is the investment cost in land use L incurred by F_S; $c(d)$ is the cost of drug development to F_N. All cost functions are increasing and convex in their arguments. We also assume that investment in L is observable by F_S and F_N but not verifiable by a third party—the court in the North Ct_N—so that L cannot be contracted. For example, we may think that investment in time and resources for environmental stewardship cannot be observed by Ct_N.

If F_S rejects the offer and denies F_N access to the genetic resources, F_N may nevertheless be tempted to invest in drug development, using g without F_S's consent. This temptation exists because of the absence of *ex ante* enforceability. If F_N decides to invest in d then F_S will file a legal case for infringement of her right in the Northern court. Once the court's ruling has resolved the uncertainty, the two parties are free to renegotiate if there are gains from trade. Given the absence of *ex ante* enforceability, renegotiation is likely to cause the classical hold-up problem much talked about in the literature. (Klein et al., 1978; Williamson, 1979; and Grossman and Hart, 1986)

The sequence of decisions and payoffs is described as follows:

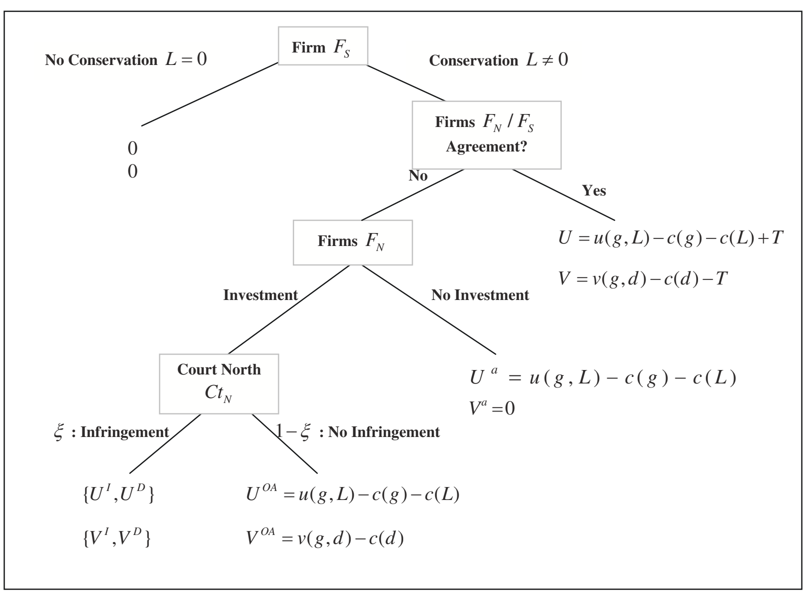


Figure 6.1: Decision Tree: North/South Hold-up Problem

At time t_0: F_S decides whether or not to invest in conservation L to maintain a flow of genetic resources g.

At time t_1: F_N makes an offer to F_S to be granted access to the genetic resources g against a transfer payment. If the contract is accepted then we consider it will be enforced.

At time t_2: If F_S rejects the offer and denies F_N access to g, then F_N must decide whether to use g without F_S's consent and develop a drug.

At time t_3: If F_N opts for drug development d then F_S files a case in the Northern court Ct_N.

At time t_4: Ct_N makes a ruling.

At time t_5: F_N and F_S are free to renegotiate *ex post* after the court's ruling.

6.3.3 Benchmark outcomes

Efficient Outcome Assume that the governments in both regions decide to coordinate their legal systems by mutually recognising the property rights granted in both regions. Then there is no more uncertainty about *ex ante* enforceability of the rights across borders. Under this backdrop, if the two firms F_N and F_S agree to cooperate, then they will choose g, d and L to maximise the joint surplus:

$$\max_{g,d,L} U + V = \max_{g,d,L} u(g, L) + v(g, d) - c(g) - c(L) - c(d)$$

Note that when an agreement is signed we assume that the sequence of actions is as follows: F_S first chooses L, and given L it also chooses g. Then observing these choices, F_N will choose d. Solving backward, F_N invests optimally in development $d = d^*(g)$ given the provision of genetic material g:

$$\frac{\partial v}{\partial d}(g, d^*(g)) = c'(d^*(g)) \tag{6.1}$$

Then F_S chooses the level of genetic resources $g = g^*(L)$:

$$\frac{\partial u}{\partial g}(g^*(L), L) + \frac{\partial v}{\partial g}(g^*(L), d^*(g^*(L))) = c'(g^*(L)) \tag{6.2}$$

Finally, the choice of investment in land use L is determined by:

$$\frac{\partial u}{\partial L}(g^*, L^*) = c'(L^*) \tag{6.3}$$

where $g^* = g^*(L^*)$ and $d^* = d^*(g^*)$. Thus, when property rights are universally recognised and enforced, bargaining yields an efficient outcome from the industry perspective. This solution sets the benchmark against which all comparisons will be made.

Autarky The autarky situation can be seen as the situation where F_N and F_S fail to reach an agreement and F_S can credibly commit to deny F_N access to her resources or possibly prevent unauthorised use (or biopiracy). The payoff functions in autarky are given by:

$$\begin{aligned} U^a &= u(g, L) - c(g) - c(L) \\ V^a &= 0 \end{aligned}$$

The first expression indicates that F_S benefits from the medicine derived from the genetic resources g to address diseases occurring in the South. The second expression represents F_N's payoff when he is denied access to g and cannot develop a new patentable drug based on g. F_S will unilaterally choose the level of genetic resources g^a and land use L^a to maximise her payoff, i.e.

$$\frac{\partial u}{\partial g}(g^a, L^a) = c'(g^a) \tag{6.4}$$

$$\frac{\partial u}{\partial L}(g^a, L^a) = c'(L^a) \tag{6.5}$$

Comparing (6.4) and (6.5) to the optimal outcomes in (6.2) and (6.3), shows that autarky is sub-optimal: $g^a < g^*$ and $L^a < L^*$. Equation (6.4) indicates that F_S fails to internalise the effect g on F_N. In addition, investment in L is smaller in autarky.[3]

We now wish to investigate how the uncertainty about the recognition of the right by courts in the North affects on the one hand, the incentive to invest in genetic diversity L and supply

[3] For any L, $\left(\frac{\partial u}{\partial L}(g^*, L) > \frac{\partial u}{\partial L}(g^a, L)\right)$ as the cross derivative of u is positive by assumption. Then for $L = L^a$, $\left(\frac{\partial u}{\partial L}(g^*, L^a) > \frac{\partial u}{\partial L}(g^a, L^a) = c'(L^a)\right)$. As the marginal cost is increasing in L and $\frac{\partial u}{\partial L}(g^*, L)$ is decreasing in L then the equality between marginal cost and marginal benefit is re-established if and only if L increases. Therefore, it must be the case that $L^* > L^a$.

genetic resources g, and on the other hand, the incentive to develop drugs d derived from these genetic resources.

6.3.4 Bargaining over genetic resources under uncertain *ex ante* enforceability

At time t_1, F_N and F_S bargain over the access to the genetic resources g according to the Nash bargaining solution. The share of the surplus that F_S will extract depends on her bargaining position, which in turn depends F_S's *outside option*, i.e. her payoff if bargaining breaks down permanently. Binmore, Rubinstein and Wolinsky (1986) and Binmore, Shaked and Sutton (1989) have shown that an outside option affects the equilibrium outcome in Nash bargaining, only if at least one of the parties prefers this outcome to an agreement in the absence of the outside option. This is the outside option principle. They also clearly distinguish an outside option from a *threat point* which is the *status quo* value that the two parties earn while they are in disagreement but still bargaining. The threat point of the negotiation here is therefore given by the autarky payoffs $(U^a; V^a = 0)$. F_N and F_S solve the following bargaining problem:

$$\max_{U,V} (U - U^a)^\alpha (V - V^a)^{1-\alpha} \text{ s.t. } U \geq U^{os} \tag{6.6}$$

where U^{os} is F_S's outside option payoff; α and $1 - \alpha$ are F_S's and F_N's bargaining power.

The presence of the outside option affects the equilibrium outcome only if F_S prefers U^{os} to an agreed payoff U characterising the equilibrium in the absence of the outside option. Any offer below U^{os} will be rejected. Similarly, an offer exceeding U^{os} will be a waste for F_N since F_S would accept the contract for less. In the equilibrium (subgame perfect equilibrium), F_N will offer at t_1 a contract that provides F_S no more than her outside option, $U = U^{os}$. Our task now is to determine F_S's outside option depending on the ruling made by the court. If the court holds that there is an infringement in F_S's right, the chosen remedy is either an injunction rule or a damage rule. In contrast, if the court rules that there is no infringement then an open access regime is legitimised. The corresponding payoffs are formalised as $U^{os} = \{EU_1, EU_2\}$ where EU_1 and EU_2 are F_S's expected payoffs when bargaining takes place respectively, under the shadow of the injunction rule and the damage rule. The court's decision has clearly a key role in determining the distribution of the surplus.

6.3.4.1 Outside Option 1: Bargaining under the shadow of injunction.

Choice of g and d before the court's ruling. With probability ξ, the court chooses to enforce F_S's right. Under the injunction rule, $F_N$is not allowed to produce and market a drug derived from g. In the eventuality of infringement, court-induced payoffs are $\Psi_S^I = u(g, L) - c(g) - c(L)$ for F_S and $\Psi_N^I = -c(d)$ for F_N. With probability $1 - \xi$, there is no infringement, which implies that F_N benefits from the open access to g and does not require F_S's prior consent. The payoffs are then $\Psi_S^{OA} = u(g, L) - c(g) - c(L)$ and $\Psi_N^{OA} = v(g, d) - c(d)$.

F_S and F_N choose the genetic resource level g and investment in d before the court in the North makes its decision. Investment L is predetermined at the time these choices are made. The expected payoffs derived from the court's ruling are:

$$\begin{aligned} \overline{U}_1 &= u(g, L) - c(g) - c(L) \\ \overline{V}_1 &= (1 - \xi)v(g, d) - c(d) \end{aligned}$$

We first determine the level of genetic resources g and drug development d chosen by F_S and F_N. Given investment L, F_S and F_N will choose $\hat{g}_1 = g(L)$ and $\hat{d}_1 = d(\hat{g}_1)$ such that:

$$\frac{\partial u}{\partial g}(\hat{g}_1, L) = c'(\hat{g}_1) \tag{6.7}$$

$$(1 - \xi)\frac{\partial v}{\partial d}(\hat{g}_1, \hat{d}_1) = c'(\hat{d}_1) \tag{6.8}$$

Comparing (6.2) with (6.7) suggests that $\hat{g}_1$ is sub-optimal. The supply of g is inefficient, $\hat{g}_1 < g^*$ because like in the autarky regime, F_S fails to internalise the benefit from g that accrues to F_N. Investment in drug development is also sub-optimal, $\hat{d}_1 < d^*$ as F_N discounts the uncertainty about the court's ruling. F_N would like to choose an optimal level of d to fully take advantage of the open access regime (free riding regime) but he refrains from such investment because *ex post* the enforcement of the right would prevent him from marketing a drug derived from g.

Finally, the low level of g also affects investment in d.

Court enforces the right. Once these choices are made, the court's ruling will resolve the uncertainty about the enforceability of the right. If the court enforces the right, i.e. $\xi = 1$, and enjoins F_N to stop its activity, the two parties are free to renegotiate over g. F_N now requires a license from F_S to use the genetic resources. Moreover, the inefficiency of $\hat{g}_1$ makes renegotiation mutually beneficial. The threat point or *status quo* of this renegotiation is determined by the court-induced payoffs defined above. The threat point therefore shifts from the autarky position to the point $\left(-c(\hat{d}_1); u(\hat{g}_1, L) - c(\hat{g}_1) - c(L)\right)$ where F_N's bargaining position is weakened as his payoff decreases while F_S's payoff remains unchanged. The Nash bargaining outcome results in the following division of the benefits:

$$\begin{aligned} U^I &= u(\hat{g}_1, L) - c(\hat{g}_1) - c(L) + \alpha\left[u(g, L) + v(g, \hat{d}_1) - c(g) - u(\hat{g}_1, L) + c(\hat{g}_1)\right] \\ V^I &= -c(\hat{d}_1) + (1-\alpha)\left[u(g, L) + v(g, \hat{d}_1) - c(g) - u(\hat{g}_1, L) + c(\hat{g}_1)\right] \end{aligned}$$

No enforcement of the right. If the Northern court does not enforce the property right granted in the South, i.e. $\xi = 0$, F_S cannot prevent F_N from getting access to her genetic resources and derive a new marketable drug from them. This situation is akin to an open access regime. No license is required from F_N so that he can use g as a free good without compensating F_S. Despite the inefficiency of $\hat{g}_1$, renegotiation over g will not take place. Indeed, with the certainty that F_S is denied her right over g in the North, nothing prevents F_N from reneging on contractual obligations. The division of profits in the open access regime is: $U^{OA} = \Psi_S^{OA}(\hat{g}_1, L) = u(\hat{g}_1, L) - c(\hat{g}_1) - c(L)$ and $V^{OA} = \Psi_N^{OA}(\hat{g}_1, \hat{d}_1) = v(\hat{g}_1, \hat{d}_1) - c(\hat{d}_1)$.

Given these payoffs, F_N decides to engage in drug development if and only if $EV_1 = \xi V^I + (1 - \xi)V^{OA} \geq V^a$, that is:

$$(1-\alpha)\xi\left[u(g, L) + v(g, \hat{d}_1) - c(g) - u(\hat{g}_1, L) + c(\hat{g}_1)\right] + (1-\xi)v(\hat{g}_1, \hat{d}_1) \geq c(\hat{d}_1) \tag{6.9}$$

When this condition is not satisfied (generally when α and ξ are large enough, e.g. if $\alpha = 1$ and $\xi = 1$) the autarky regime will ensue.

F_S's investment decision. Foreseeing these outcomes, at time t_0, F_S unilaterally chooses the level of L that maximises his expected payoff $EU_1 = \xi U^I + (1-\xi)U^{OA}$:

$$EU_1 = u(\hat{g}_1, L) - c(\hat{g}_1) - c(L) + \alpha\xi\left[u(g^*(L), L) + v(g^*(L), \hat{d}_1) - c(g^*(L)) - u(\hat{g}_1, L) + c(\hat{g}_1)\right] \tag{6.10}$$

The first order condition with respect to L yields:

$$\alpha\xi\frac{\partial u}{\partial L}(g^*(\hat{L}_1), \hat{L}_1) + (1-\alpha\xi)\frac{\partial u}{\partial L}(\hat{g}(\hat{L}_1), \hat{L}_1) = c'(\hat{L}_1) \tag{6.11}$$

Full efficiency of L requires F_S to appropriate the marginal social benefit generated by the investment. Equation (6.11) indicates that F_S's marginal private benefit differs from the marginal social benefit as characterised in (6.3) so the investment level $\hat{L}_1$ is not efficient ($\hat{L}_1 < L^*$). This implies that $g^*(\hat{L}_1)$ is not socially optimal either, even though the genetic resources g are supplied efficiently given L. The first term on the LHS in equation (6.11) indicates the expected share of the marginal social benefit from investment captured by F_S through renegotiation. The second term suggests that F_S also weighs the effect of his investment on the noncooperative outcome although this outcome does not actually arise in the renegotiation equilibrium. (Grossman and Hart 1986) In other words, F_S cares about how her investment in L affects the court-induced *status quo* $\Psi_S^I(\hat{g}_1, L)$ in addition to the social benefit derived from the cooperative outcome. Unlike the efficient outcome in (6.3), F_S's choice now depends on the the *status quo* before renegotiation, the distribution of bargaining power and the probability of infringement. F_S faces a typical hold up problem: she underinvests because she is unable to appropriate entirely the fruits of her investment while bearing the whole cost. Only when $\alpha = 1$ and $\xi = 1$ can L be socially optimal. However, with these parameter values, condition (6.9) does not hold. Thus, investment in maintaining genetic diversity is sub-optimal ($\hat{L}_1 < L^*$) when the two firms bargain under the shadow of injunction. The lower F_S's bargaining power, the more benefit is captured by F_N, and the lower the investment in conservation. In addition, the more unlikely F_S thinks the court will enforce her right, i.e. the smaller ξ, the less investment will be undertaken.

Proposition 1:

When the court in the North rules under the shadow of an injunction:

1) If (6.9) holds, F_S faces a hold-up problem so that investment in L is sub-optimal $\hat{L}_1 < L^*$. Moreover, F_N will free ride but will underinvest due to the uncertainty ξ about the enforceability of F_S's property right in the North: $\hat{d}_1 < d^*$.

2) *If (6.9) does not hold, the autarky regime prevails as free riding is deterred. We then have: $\hat{L}_1 = L^a$, $\hat{g}_1 = g^a$, and $\hat{d}_1 = 0$.*

6.3.4.2 Outside option 2: Bargaining under the shadow of the damage rule

Choice of g and d before the court's ruling. With probability ξ, the court in the North enforces the right and we now assume that it relies on the damage rule. F_N develops and sells a new product derived from the genetic resources and receives $v(g,d) - c(d)$. However, he is ordered to pay $D(g,d)$ in damages for using g without F_S's prior consent. The payoffs induced by the damage rule are $\Psi_S^D = u(g,L) + D(g,d) - c(g) - c(L)$ and $\Psi_N^D = v(g,d) - D(g,d) - c(d)$. With probability $1-\xi$, the right is not enforced so that F_N and F_S receive the open access payoffs defined in the previous section. The expected payoffs induced by the court's ruling are then given by:

$$\begin{aligned}
\overline{U}_2 &= u(g,L) + \xi D(g,d) - c(g) - c(L) \\
\overline{V}_2 &= v(g,d) - \xi D(g,d) - c(d)
\end{aligned}$$

Assumption:

1) The damage $D(g,d)$ is strictly positive, increasing and concave in g and d.

2) $\Psi_N^D = v(g,d) - D(g,d) - c(d) \geq 0$

The second assumption is a limited liability assumption as the damage cannot exceed F_N's net earning.[4] The rationale is that the court in the North may want F_N to continue his activity while giving F_S enough incentive to invest and provide useful information. Damage payment

[4]This assumption implies that a condition equivalent to (6.9) for the damage rule, i.e. $EV_2 = \xi V^D + (1 - \xi)V^{OA} \geq 0$ is always satisfied.

depends obviously on g but also on d. This is because we assume that F_N is forced to compensate F_S based on the ill-gotten profit that he has made, and not based on F_S's profit loss, which is irrelevant in this model. (see Schankerman and Scotchmer, 2001)

Given investment L, F_S and F_N choose unilaterally $\hat{g}_2 = g(L)$ and $\hat{d}_2 = d(\hat{g}_2)$ that maximise $\overline{U}_2$ and $\overline{V}_2$ such that:

$$\frac{\partial u}{\partial g}(\hat{g}_2, L) + \xi \frac{\partial D}{\partial g}(\hat{g}_2, \hat{d}_2) = c'(\hat{g}_2) \tag{6.12}$$

$$\frac{\partial v}{\partial d}(\hat{g}_2, \hat{d}_2) - \xi \frac{\partial D}{\partial d}(\hat{g}_2, \hat{d}_2) = c'(\hat{d}_2) \tag{6.13}$$

In the equilibrium, investment in d must equalise F_N's net private marginal benefit—consisting of his marginal benefit minus the expected marginal damage payment—with the marginal cost. Investment in drug development $\hat{d}_2$ is generally not set optimally unless $\xi \frac{\partial D}{\partial d}(\hat{g}_2, \hat{d}_2) = 0$. In general, the existence of uncertainty about enforcement combined with the positive effect of d on damages lead F_N to restrict his investment.

Besides, the equilibrium level of genetic resources $\hat{g}_2$ must balance at the margin, the sum of F_S's benefit and expected damage, with the cost of supply. The choice of a particular damage scheme by the court has a major effect on F_S's incentives to supply genetic resources. A necessary and sufficient condition for $\hat{g}_2$ to be unilaterally optimal given L is that $\xi \frac{\partial D}{\partial g}(\hat{g}_2, \hat{d}_2) = \frac{\partial v}{\partial g}(\hat{g}_2, \hat{d}_2)$, i.e. the expected marginal damage is equal to F_N's marginal benefit from g. When this condition holds, F_S can fully internalise the external effect of g on F_N. The information required for the court to set the right damage scheme may however be considerable. So, in general, it is most likely that $\xi \frac{\partial D}{\partial g}(\hat{g}_2, \hat{d}_2) \neq \frac{\partial v}{\partial g}(\hat{g}_2, \hat{d}_2)$, which implies a sub-optimal level of g. If $\xi \frac{\partial D}{\partial g}(\hat{g}_2, \hat{d}_2) \lesseqgtr \frac{\partial v}{\partial g}(\hat{g}_2, \hat{d}_2)$ then $\hat{g}_2 \lesseqgtr g^*$. The smaller ξ, the smaller the expected marginal damage and therefore the more likely access will be restricted.

Case 1 – General Case: $\xi \frac{\partial D}{\partial g}(\hat{g}_2, \hat{d}_2) \neq \frac{\partial v}{\partial g}(\hat{g}_2, \hat{d}_2)$

Court enforces the right. Uncertainty over the enforcement of the right is resolved once the court has enjoined F_N to pay damages to F_S ($\xi = 1$). As $\hat{g}_2$ is not set at the efficient level, the two parties are free to renegotiate a licensing contract that allows F_N to benefit from an optimal supply of genetic resources given L. The threat point or *status quo* in this renegotiation shifts from the autarky position to the court-induced payoffs determined above $\Big(v(\hat{g}_2, \hat{d}_2) - D(\hat{g}_2, \hat{d}_2) - c(\hat{d}_2); u(\hat{g}_2, L) + D(\hat{g}_2, \hat{d}_2) - c(\hat{g}_2)\Big)$. Relative to autarky, both F_S's and F_N's payoffs increase in this new threat point. The renegotiation outcome will then be given by:

$$\begin{aligned}
U^D &= u(\hat{g}_2, L) + D(\hat{g}_2, \hat{d}_2) - c(\hat{g}_2) - c(L) + \alpha \left[u(g, L) + v(g, \hat{d}_2) - c(g) - u(\hat{g}_2, L) + c(\hat{g}_2) - v(\hat{g}_2, \hat{d}_2)\right] \\
V^D &= v(\hat{g}_2, \hat{d}_2) - D(\hat{g}_2, \hat{d}_2) - c(\hat{d}_2) + (1-\alpha) \left[u(g, L) + v(g, \hat{d}_2) - c(g) - u(\hat{g}_2, L) + c(\hat{g}_2) - v(\hat{g}_2, \hat{d}_2)\right]
\end{aligned}$$

Court does not enforce the right. If however, no damage payment is ordered to F_N then uncertainty is resolved with $\xi = 0$. That is, the property right is not recognised in the North and open access of g ensues. No renegotiation over g will take place for the reason invoked earlier in the case of injunction. The payoffs of the open access regime are now given by: $U_2^{OA} = \Psi_S^D(\hat{g}_2, L) = u(\hat{g}_2, L) - c(\hat{g}_2) - c(L)$ and $V_2^{OA} = \Psi_S^D(\hat{g}_2, \hat{d}_2) = v(\hat{g}_2, \hat{d}_2) - c(\hat{d}_2)$.

F_S's investment decision. Anticipating these possible outcomes, at time t_0, F_S will choose L to maximise her expected payoff:

$$\begin{aligned}
EU_2 &= u(\hat{g}_2, L) + \xi D(\hat{g}_2, \hat{d}_2) - c(\hat{g}_2) - c(L) \\
&+ \alpha\xi \left[u(g^*(L), L) + v(g^*(L), \hat{d}_2) - c(g^*(L)) - u(\hat{g}_2, L) + c(\hat{g}_2) - v(\hat{g}_2, \hat{d}_2)\right]
\end{aligned} \tag{6.14}$$

Investment in conservation L is derived from the first order condition:

$$\alpha\xi \frac{\partial u}{\partial L}(g^*(\hat{L}_2), \hat{L}_2) + (1 - \alpha\xi) \frac{\partial u}{\partial L}(\hat{g}_2, \hat{L}_2) = c'(\hat{L}_2) \tag{6.15}$$

When $\xi \dfrac{\partial D}{\partial g}(\hat{g}_2, \hat{d}_2) < \dfrac{\partial v}{\partial g}(\hat{g}_2, \hat{d}_2)$, the analysis is very similar to the one we made earlier under the injunction rule and F_S faces the same incentive problem. For the reasons invoked earlier, F_S faces a hold-up problem and underinvests in maintaining genetic diversity, $\hat{L}_2 < L^*$.

When $\xi \dfrac{\partial D}{\partial g}(\hat{g}_2, \hat{d}_2) > \dfrac{\partial v}{\partial g}(\hat{g}_2, \hat{d}_2)$, F_S will overinvest in L, i.e. $\hat{L}_2 > L^*$. The fact that F_S values the effect of L on the threat point causes her to overinvest as $\hat{g}_2 > g^*$. This case may be unlikely as the court in the North may be unwilling to grant such favourable compensation to F_S.

Alternatively, this may suggest that F_S preserves land that is not rich in biodiversity. This is inefficient as such land could be put to better use, for example for farming. Finally, the lower the common belief ξ about the infringement ruling, the less likely it is that this condition will hold.

Case 2 – Special Case: $\xi \dfrac{\partial D}{\partial g}(\hat{g}_2, \hat{d}_2) = \dfrac{\partial v}{\partial g}(\hat{g}_2, \hat{d}_2)$

A sufficient condition for this equality to hold is for example $\xi D(g,d) = v(g,d) - K(d)$, i.e. F_N is expected to disgorge part of his benefits but retains the amount $K(d) - c(d)$—where $K(d)$ is increasing and concave in d. In this case, the payoffs are: $U^D = u(\hat{g}_2, L) + v(\hat{g}_2, \hat{d}_2) - c(\hat{g}_2) - K(\hat{d}_2) - c(L)$ and $V^D = K(\hat{d}_2) - c(\hat{d}_2)$. The supply of genetic resources is then efficient given L so that $\hat{g}_2 = g^*(L)$. Therefore, no renegotiation will take place. Expecting this outcome, at time t_0, S will choose L to maximise her expected payoff:

$$EU_2 = U^D = u(g^*(L), L) - c(g^*(L)) - c(L) + v(g^*(L), \hat{d}_2) - K(\hat{d}_2) \tag{6.16}$$

The first order condition then yields the optimal investment $L_2 = L^*$.

When $\xi \dfrac{\partial D}{\partial g}(\hat{g}_2, \hat{d}_2) = \dfrac{\partial v}{\partial g}(\hat{g}_2, \hat{d}_2)$, the damage payment gives F_S the proper incentive to fully internalise the externality of g. In fact, the court makes F_S the residual claimant of the surplus created by her investment by allowing F_N to retain $K(\hat{d}_2) - c(\hat{d}_2)$ and allowing F_S to receive the residual benefit. As a result, F_S will appropriate the entire return on her investment. If the optimality of F_S's investment is the objective for the Northern court, the careful design of the damage scheme is of particular importance. However, given the considerable information required to achieve this goal, this outcome may prove a difficult target.

Proposition 2:

The choice of the damage scheme affects both parties' incentive to invest:

1) If $\xi \frac{\partial D}{\partial g}(\hat{g}_2, \hat{d}_2) < \frac{\partial v}{\partial g}(\hat{g}_2, \hat{d}_2)$, F_S *underinvests in the maintainance of genetic diversity,* $\hat{L}_2 < L^*$.

2) If $\xi \frac{\partial D}{\partial g}(\hat{g}_2, \hat{d}_2) = \frac{\partial v}{\partial g}(\hat{g}_2, \hat{d}_2)$, F_S *optimally invests in the maintainance of genetic diversity,* $\hat{L}_2 = L^*$.

3) If $\xi \frac{\partial D}{\partial g}(\hat{g}_2, \hat{d}_2) > \frac{\partial v}{\partial g}(\hat{g}_2, \hat{d}_2)$, F_S *overinvests in the maintainance of genetic diversity,* $\hat{L}_2 > L^*$.

4) Moreover, in all these cases, drug development is sub-optimal $\hat{d}_2 < d^*$ *because the payment of the damage prevents* F_N *to appropriate the whole return on his investment.*

6.3.5 Discussion

If F_S's right in g was recognised *ex ante* in the North and enforced, the optimal solution would be achieved despite the non contractibility of investment L. This is because the contract over g would channel all the benefit generated by F_S via a transfer payment, providing F_S enough incentive to invest optimally in L. The problem here comes from the uncertainty about the *ex ante* enforceability of the property right in the informational good g. The IPR system in the North does not generally confer exclusive rights in *products of nature* unless they are distinct enough from their forms in the wilderness. Invention rather than discovery is the basis for appropriation in that system.[5] This excludes much of the South own innovations or knowledge because they are often hard to distinguish from the genetic resources as such. Absent the *ex ante* enforceability of the right in g, F_S may suspect that F_N will free ride on her contribution and use g as a free good to develop new drugs without any compensation. By rejecting F_N's offer, F_S has the power to hold up F_N's innovation. This allows her to establish a stronger bargaining position in the negotiation and seek *ex post* recognition and enforcement of her right in Northern courts. By doing so, F_S faces the hold-up problem as the renegotiation after

[5] In Diamond vs. Chakrabarty (1980), the case that first allowed the patenting of microorganisms, the court held that the microorganism in question, a human-made genetically engineered bacterium capable of breaking down components of crude oil, which could not be done by any naturally occurring bacteria, was patentable. (Rodriguez-Stevenson, 2000)

uncertainty is resolved by the court's decision allows F_N to capture some of the benefits created by her investment in L.[6] This problem of appropriation causes F_S to restrict her investment in maintaining genetic diversity.

The court in the North plays a key role both in inducing efficiency and shaping the division of the profit by altering the bargaining position of the two parties through its ruling. Enforcement of the property right shifts the threat point away from the autarky position to a new *status quo* induced by the court's decision and dependent upon the chosen remedy. The choice of the remedy—injunction rule or damage rule—matters as it leads to different incentives to invest in preserving biodiversity and developing drugs.

The damage rule induces both a higher unilateral genetic resource supply and more investment in the maintenance of genetic diversity. This is because unlike injunctions, damages allow F_S to partly internalise the benefit from g accruing to F_N. The use of damages thus mitigates the hold-up problem since the award of a compensation provides incentives for increased investment compared to the award of an injunction, i.e. $\hat{L}_2 \geq \hat{L}_1$. Under specific conditions, damages can lead to a socially optimal investment in genetic diversity. This is the case when the court makes F_S the residual claimant of the surplus created by her investment. Overinvestment in L can even occur if the expected marginal damage is greater than F_N's marginal benefit from g. This is inefficient and suggests that non-biodiverse land is being conserved at the expense of more beneficial uses. The potentially high uncertainty about enforcement makes however this outcome unlikely: the lower ξ, the less likely overinvestment in L is.

Drug development is not optimal because of the *ex ante* uncertainty over enforcement. Given this uncertainty, investment in drug development d depends on the choice of the remedy. When the court seeks to encourage drug development, the choice of the remedy should depend on the relative magnitude of the marginal benefit under the injunction rule $(1-\xi)\dfrac{\partial v}{\partial d}(\hat{g}_1, \hat{d}_1)$ and the marginal benefit under the damage rule $\dfrac{\partial v}{\partial d}(\hat{g}_2, \hat{d}_2) - \xi \dfrac{\partial D}{\partial d}(\hat{g}_2, \hat{d}_2)$. The choice of the remedy then hinges upon the *ex ante* common belief about infringement ξ and the effect of drug development on the damage.

Our model suggests that despite the introduction of a property right in the genetic resources, investment in maintaining biological diversity may be sub-optimal given the uncertainty about

[6] Both parties have incentive to renegotiate: F_N, because 1) g is not unilaterally set efficiently by F_S; and 2) he can no longer sell the new drug without a license under injunction; and F_S, because she can increase her payoff relative to autarky.

the enforcement of the right across jurisdictions. Once investment costs are sunk and genetic information diffused, F_N might opportunistically capture this information without F_S's consent and exploit it for his own private benefit. This situation may eventually lead to renegotiation in which F_S's rent is dissipated causing her to underinvest. The court can however under certain conditions restore optimality by imposing a liability rule that makes F_S the residual claimant of the benefits generated by her investment.

6.4 Conclusion

The literature on the use of biodiversity for the purpose of R&D and bioprospecting often focuses on the issue of access to genetic materials and traditional knowledge. In this chapter, our analysis insists primarily on the incentive problem for land conservation in the context of sequential R&D. We believe that investment in environmental stewardship to maintain biodiversity is a fundamental issue in this area. As genetic material and traditional knowledge (TK) are derived from the observation and knowledge about biodiversity, the irreversible loss of biodiversity would make discussion on access to genetic resources and TK meaningless. In this sense, investment in maintaining diversity is a necessary condition for information to flow across the sequential R&D process in the life sciences.

In this respect, the main issue is the hold-up problem stemming from the absence of coordination of the North and South legal systems to recognise and enforce property rights on informational goods across jurisdictions. Legal institutions—in particular the court in the Northern region—play a crucial role in this paper. The decision of the court—injunction, damage or open access—has an impact both for the efficiency of investment and the distribution of the benefits. In the face of the uncertainty about the enforcement, by Northern courts, of the rights conferred in the South, Southern firms are likely to underinvest in maintaining genetic diversity as they will bear all investment costs but will receive only part of the return. As a result, the genetic information flowing from the primary to the secondary stage of the sequential R&D process is generally inefficient. Uncertainty also prevents firms in the North to undertake socially optimal drug development.

Thus, in this paper we point to the necessity of coordinating the legal systems of the two regions to create the basis for socially optimal investment in land conservation and efficient exchange of information between North and South. Under such system, efficiency need not come from court's intervention but rather from cooperation between the parties. Next chapter will investigate this possibility and analyse the implications of the presence of traditional knowledge.

Bibliography

[1] Binmore, K., A. Rubinstein and A. Wolinsky (1986): The Nash Bargaining Solution in Economic Modelling, *RAND Journal of Economics*, 17(2): 176–188.

[2] Binmore, K., A. Shaked and J. Sutton (1989): An Outside Option Experiment, *Quarterly Journal of Economics*, 104(4): 753–770.

[3] Bullard, L. (2005): *A Briefing Paper on the First Legal Defeat of a Biopiracy Patent: The Neem Case.* Brussels: Research Foundation for Science, Technology and Ecology, International Federation of Organic Agriculture Movements (IFOAM) & The Greens/ European Free Alliance in the European Parliament: page 6. Available at http://www.ifoam.org/press/press/pdfs/Briefing_Neem.pdf [Accessed 5 May 2006].

[4] Farnsworth, N.R. (1988): Screening Plants for New Medicines. In E.O. Wilson (Ed.): *Biodiversity*. Washington DC: National Academy Press.

[5] Gatti, R., T. Goeschl, B. Groom, and T. Swanson (2004): The Biodiversity Bargaining Game, *Cambridge Working Papers in Economics* No. 0447, Sept. 2004 (recent version 2007).

[6] Goeschl, T. and T. Swanson (2002): The Social Value of Biodiversity for R&D, *Environmental and Resource Economics* 22(4): 477–504.

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

[8] Grossman, S. and O. Hart (1986): The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration, *Journal of Political Economy*, 94(4): 691–719.

[9] Klein, B., R.G. Crawford and A. Alchian (1978): Vertical Integration, Appropriable Rents, and the Competitive Contracting Process, *Journal of Law and Economics*, 21: 297–326.

[10] Pitchford, R. and C. Snyder (2003): Coming to the Nuisance: An Economic Analysis from an Incomplete Contracts Perspective, *Journal of Law, Economics & Organization*, 19(2): 491–516.

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

[12] Schankerman, M. and S. Scotchmer (2001): Damages and Injunctions in Protecting Intellectual Property, *RAND Journal of Economics*, 32(1): 199-220.

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

[14] Swanson, T. (1996): The Reliance of Northern Economies on Southern Biodiversity: Biodiversity as Information, *Ecological Economics*, 17(1): 1–8.

[15] Swanson, T. and T. Goeschl (2000): Property Rights Issues Involving Plant Genetic Resources: Implications of Ownership for Economic Efficiency, *Ecological Economics* 32(1): 75–92.

[16] Williamson, O.E. (1979): Transaction-Cost Economics: The Governance of Contractual Relations, *Journal of Law and Economics*, 22(2): 233–261.

Chapter 7

Economics of Traditional Knowledge as Private Information[1]

7.1 Introduction

Bioprospecting is the purposeful search for natural compounds undertaken by pharmaceutical or biotechnology firms to find leads necessary for the development of new drugs. It requires cooperation between the bio-prospecting firm—the North—and the country hosting the genetic resources and/or traditional knowledge—the South. The host country provides basic or pure information on potential solution concepts, while the R&D firm supplies the practical capabilities for developing these solution concepts into marketable compounds and products. In this manner primary biological information is generated and channelled through a secondary R&D sector to become commercial products capable of addressing consumer needs.

Despite the South's contribution in providing necessary primary information as inputs in the R&D process, genetic information and traditional knowledge generally do not meet patentability requirements—novelty and non-obviousness—and receive little or no compensation. The failure to protect these contributions may result in a lack of investment in genetic diversity and traditional human capital, and in inefficient flow of information across the sector. This sub-optimal situation may end up in a permanent loss of both genetic diversity and traditional knowledge and therefore a loss of valuable source of improvement of human health. Thus, to address this problem, Gehl Sampath (2005) suggests that the South's information should be protected in a similar way as the basic information provided by small and medium sized biotechnology firms

[1]This chapter is a joint work with Tim Swanson of University College London

to larger firms which use these inputs to process a final product. It is thought that in the face of this incentive problem, the creation of 'informational property rights' (Swanson, 1995) could provide the South enough incentive to maintain genetic diversity and traditional knowledge, and grant access to her genetic resources. However, unless the property rights assigned domestically in the South are recognised across jurisdictions, the hold-up problem analysed in chapter 6 is likely to persist. The real challenge is for North and South to coordinate their legal systems in a way that allows the South to be properly compensated for investing in genetic diversity and associated human capital, and in supplying genetic material.

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

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

This chapter is structured as follows: Section 7.2 provides a detailed presentation of the model. In section 7.3, we solve the contracting problem under symmetric information when genetic information is afforded property right protection and derive the efficient solution. In section 7.4, we investigate how the contractual outcomes are altered in the presence of traditional knowledge defined as the South's private information about the usefulness of the genetic resources. Finally section 7.5 concludes the analysis.

7.2 The Model

7.2.1 Stylised Facts

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

Separate R&D Contributions. Firms from the North and the South, F_N and F_S, can cooperate for mutual benefit through coordination in the supply of inputs within a process of sequential R&D. If they cooperate successfully, then a higher quality of health services is available to consumers. The South is gene rich and technology poor. The firms in the South F_S are specialised in the provision of genetic material g and traditional knowledge (TK). The North is technology rich and biodiversity poor. The firms in the North F_N use information contained in the genetic resources g and may combine them with traditional knowledge and technology in the North to search for new leads and develop new drugs d.

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

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

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

Table 7.1: Stylised Facts: North/South interaction in the presence of TK

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

7.2.2 Description of the sequential innovation

We model the R&D industry (in the biological sector) as a non-integrated vertical industry of two stages as described in chapter 5. In the primary stage of the process, the firms from the South F_S generate a flow of information originating from nature and accumulated human capital. This information is collected by firms from the North F_N to produce some innovation designed to meet consumers needs in the North.

Through observation of natural diversity, F_S may identify some biological activity in a plant variety and then use this knowledge to produce and market herbal medicines. Thus, by application of her traditional human capital h_S to the genetic capital endowment g, F_S identifies essential information e embodied within herbal medicines H. The genetic material g is assumed to be present only in the South and, for purposes of this analysis, we assume that all innovations in this industry are derived from the capital stock g. F_N, as the second innovator in this industry, is endowed with scientific capital h_N which he is able to combine with g (and e) to produce a flow of innovations d (disembodied information, e.g. identification and isolation of active principles). This innovation d is then embodied within a pharmaceutical drug, which is then amenable to IPR. This industry is depicted in Figure 5.1 and Figure 5.2.

7.2.3 The Fundamentals of the Model

As in chapter 6, we assume that F_N and F_S are two risk neutral agents that bargain over the access to genetic resources g. In this paper, we assume that courts in the North Ct_N recognise any property right granted in the South to protect genetic information and traditional knowledge.

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

$$\Pi_S = t - c_S^a(g) \tag{7.1}$$

$$\Pi_N = \pi_S(g) + \pi_N(g,d) - c_N(d) - t \tag{7.2}$$

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

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

The noncooperative expected payoffs are therefore:

$$\Pi_S^{nc} = \xi(\pi_S(\hat{g}) + \beta\pi_N(\hat{g}, \hat{d})) + (1-\xi)\pi_S^c(\hat{g}) - c_S(\hat{g}) \tag{7.3}$$

$$\Pi_N^{nc} = \xi(1-\beta)\pi_N(\hat{g}, \hat{d}) + (1-\xi)\pi_N^c(\hat{g}, \hat{d}) - c_N(\hat{d}) \tag{7.4}$$

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

The sequence of the decisions is summarised as follows:

1. F_S devotes resources to find genetic materials (e.g. plants) g containing useful information protected by a property right.

2. F_N offers F_S to grant her access to g and develop a new pharmaceutical in return for a transfer payment t.

3. F_S accepts or rejects the offer.

4. In case of rejection, F_N may (or may not) decide to develop a new drug based on g.

5. If a drug is developed, the Court in the North decides whether F_S's exclusive right has been violated.

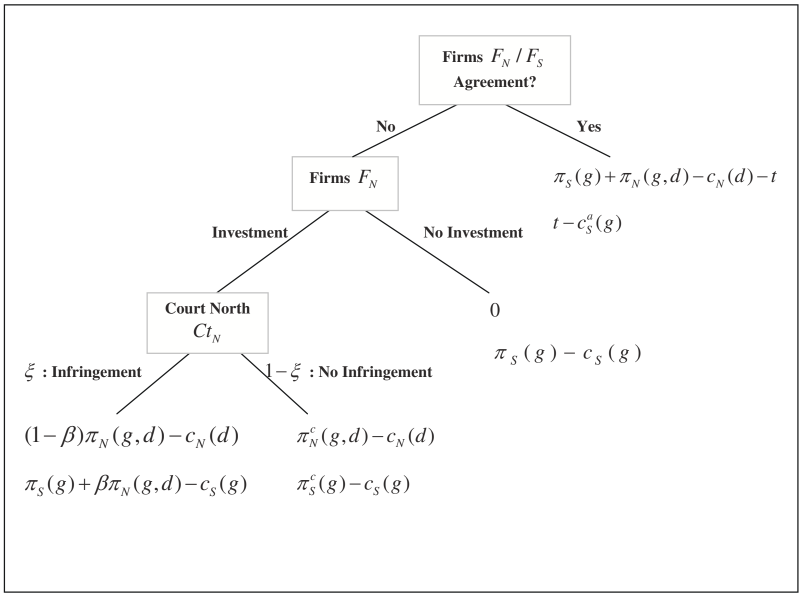


Figure 7.1: Decision tree

7.2.4 Efficiency condition

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

$$\max_{g,d} \Pi_S + \Pi_N = \pi_S(g) + \pi_N(g,d) - c_S^a(g) - c_N(d) \tag{7.5}$$

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

$$\pi_S'(g^*) + \frac{\partial \pi_N}{\partial g}(g^*, d^*) = c_S^{a\prime}(g^*) \tag{7.6}$$

$$\frac{\partial \pi_N}{\partial d}(g^*, d^*) = c_N'(d^*) \tag{7.7}$$

In equation (7.6), the genetic resource level satisfies Bowen-Lindhal-Samuelson condition of optimal public good provision. Drug development is also undertaken optimally by F_N at marginal cost.

We now establish the means by which the establishment of a *property right protecting genetic information and/or associated traditional knowledge* together with a *procedure for its enforcement* determines the prospects for efficient contracting. The main idea is that affording a property right in the information produced by F_S—unlike the current IPR regime—may trigger cooperation and lead to an efficient outcome.[2] Paradoxically, the property right may not be used by F_S, but may serve to determine her outside option when an agreement is being discussed. The very existence of the property right ensures F_S a stream of income that will be accounted for in any negotiation.

7.3 Contracting genetic resources in the absence of traditional knowledge

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

7.3.1 Contract offered by F_N

We assume that F_N has the ability to make a take-it or leave-it offer. This implies that F_S has no bargaining power. The problem faced by F_N is to offer contractual terms to F_S that will cause her to accept the offer to grant access to g. We first characterise the contract offered by F_N when the usefulness of g for R&D purposes is common knowledge. Later in section 7.4, we analyse how asymmetric information about the usefulness of g—interpreted as traditional knowledge—will affect the contractual outcome.

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

[2]Unlike in chapter 6 where F_N and F_S must rely on the court's decision and renegotiation to reach an efficient allocation of g, here the existence of an enforceable property right in the genetic resource-based information enables the parties to reach efficiency without the court's intervention. As we will discuss below, the court sole contribution in this paper is to shape the division of profits.

$$\max_{g,d,t} \quad \pi_S(g) + \pi_N(g,d) - c_N(d) - t$$
$$\text{s.t.} \quad t - c_S^a(g) \geq \xi(\pi_S(\hat{g}) + \beta\pi_N(\hat{g},\hat{d})) + (1-\xi)\pi_S^c(\hat{g}) - c_S(\hat{g})$$

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

1) If the usefulness of g is common knowledge, then there is a unique (subgame perfect) equilibrium contract (g^*, t^*) offered by F_N. This contract is characterised by the efficient allocation of genetic resources g^* and a transfer payment t^* as defined in (7.6) and (7.8).

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

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

Plugging t into the objective function and deriving the first order conditions yields the efficient outcomes obtained in (7.6) and (7.7).

So the optimal transfer payment is given by:

$$t^* = \xi(\pi_S(\hat{g}) + \beta\pi_N(\hat{g},\hat{d})) + (1-\xi)\pi_S^c(\hat{g}) - c_S(\hat{g}) + c_S^a(g^*) \tag{7.8}$$

Moreover it is straight forward to derive the comparative statics:

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

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

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

7.3.2 Contract offered by F_S

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

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

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

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

Replacing t into F_S's objective function and deriving the first order conditions, we obtain the same results as in section 7.3.1. In addition, the optimal transfer becomes:

$$t^* = \pi_S(g^*) + \pi_N(g^*,d^*) - c_N(d^*) - \xi(1-\beta)\pi_N(\hat{g},\hat{d}) - (1-\xi)\pi_N^c(\hat{g},\hat{d}) + c_N(\hat{d}) \tag{7.9}$$

The results obtained here are an application of the Coase theorem. Efficiency is attained independently of the identity of the proposer. Only distribution changes via different transfer payments: compare Equation (7.8) to Equation (7.9).

7.4 Contracting genetic resources in the presence of traditional knowledge

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

We say that F_S holds traditional knowledge when she possesses information on the prospects of heterogeneous genetic resources in regard to their usefulness for R&D. For purposes of exposition, suppose F_S has two types of information on the prospect that the genetic resources deliver a promising lead. There is a "high prospect" type $\overline{\theta}$ with probability p and a "low prospect" type $\underline{\theta}$ with probability $1 - p$. High types are of higher value for two reasons: 1) they have a higher average value for producing information within the R&D process; and 2) they have a lower average cost when supplying information within the R&D process.[3] Thus, the usefulness of the genetic resources for purposes of information generation is F_S's *private information.* Together these assumptions constitute our definition of the economic meaning of TK.

As we did in section 7.3, we first analyse the case where F_N makes the offer and then proceed to the case where F_S has this ability.

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

We now specify the ways in which the existence of this private information will impact upon the contracting process examined in section 7.3.1. F_N specifies the offered contract enabling direct

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

access to F_S's genetic resources. A contract consists of access to F_S's resource g in return for monetary payment t. It is specified in terms of the different types of genetic resources available. A direct revelation mechanism is a menu of two contracts $\{(\overline{g}, \bar{t}), (\underline{g}, \underline{t})\}$, one for each type of resource.

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

$$\begin{aligned}
\overline{V} &= \bar{t} - c_S(\overline{g}) \geq \overline{\Pi}_S^{nc} && (7.10)\\
\underline{V} &= \underline{t} - c_S(\underline{g}) \geq \underline{\Pi}_S^{nc} && (7.11)
\end{aligned}$$

This is equivalent to

$$\begin{aligned}
\overline{V} &\geq \underline{\Pi}_S^{nc} + V_0 && (7.12)\\
\underline{V} &\geq \underline{\Pi}_S^{nc} && (7.13)
\end{aligned}$$

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

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

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

$$\begin{aligned}
\bar{t} - c_S^a(\overline{g}, \overline{\theta}) &\geq \underline{t} - c_S^a(\underline{g}, \overline{\theta}) && (7.14)\\
\underline{t} - c_S^a(\underline{g}, \underline{\theta}) &\geq \bar{t} - c_S^a(\overline{g}, \underline{\theta}) && (7.15)
\end{aligned}$$

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

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

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

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

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

$$\overline{V} \geq \underline{V} + \Phi(\underline{g}) \tag{7.16}$$

$$\underline{V} \geq \overline{V} - \Phi(\overline{g}) \tag{7.17}$$

F_N's problem is then:

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

$$\text{subject to} \quad (7.10), \quad (7.11), (7.14), (7.15)$$

The problem can be re-written as follows:

$$\max_{\{(\overline{g},\overline{V}),(\underline{g},\underline{V})\}} \quad p\left(\pi_S(\overline{g}) + \pi_N(\overline{g},\overline{d}) - c_S^a(\overline{g}) - c_N(\overline{d})\right) + (1-p)\left(\pi_S(\underline{g}) + \pi_N(\underline{g},\underline{d}) - c_S^a(\underline{g}) - c_N(\underline{d})\right)$$
$$-[p\overline{V} + (1-p)\underline{V}] \tag{7.18}$$

$$\text{subject to} \quad (7.12), \quad (7.13), (7.16), (7.17)$$

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

Proposition 2:

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

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

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

$$\pi_S'(\underline{g}^{SB}) + \frac{\partial \pi_N}{\partial \overline{g}}(\underline{g}^{SB},\underline{d}^{SB}) = c_S'^a(\underline{g}^{SB}) + \frac{p}{1-p}\Phi'(\underline{g}^{SB}) \tag{7.19}$$

$$\overline{t}^{SB} = \xi(\pi_S(\hat{\overline{g}}) + \beta\pi_N(\hat{\overline{g}},\hat{\overline{d}})) + (1-\xi)\pi_S^c(\hat{\overline{g}}) - c_S(\hat{\overline{g}}) + c_S^a(\overline{g}^*) + \Phi(\underline{g}^{SB}) \tag{7.20}$$
$$\underline{t}^{SB} = \xi(\pi_S(\hat{\underline{g}}) + \beta\pi_N(\hat{\underline{g}},\hat{\underline{d}})) + (1-\xi)\pi_S^c(\hat{\underline{g}}) - c_S(\hat{\underline{g}}) + c_S^a(\underline{g}^{SB}) \tag{7.21}$$

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

$$\bar{t}^{SB} = \xi(\pi_S(\hat{\bar{g}}) + \beta\pi_N(\hat{\bar{g}}, \hat{\bar{d}})) + (1-\xi)\pi_S^c(\hat{\bar{g}}) - c(\hat{\bar{g}}) + c_S^a(\bar{g}^*) = \bar{t}^* \tag{7.22}$$

$$\underline{t}^{SB} = \xi(\pi_S(\hat{\underline{g}}) + \beta\pi_N(\hat{\underline{g}}, \hat{\underline{d}})) + (1-\xi)\pi_S^c(\hat{\underline{g}}) - c(\hat{\underline{g}}) + c_S^a(\underline{g}^*) = \underline{t}^* \tag{7.23}$$

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

$$\pi_S'(\bar{g}^{CI}) + \frac{\partial \pi_N}{\partial \bar{g}}(\bar{g}^{CI}, \bar{d}^{CI}) = c_S'^a(\bar{g}^{CI}) - \frac{1-p}{p}\Phi'(\bar{g}^{CI}) \tag{7.24}$$

$$\bar{t}^{CI} = \xi(\pi_S(\hat{\bar{g}}) + \beta\pi_N(\hat{\bar{g}}, \hat{\bar{d}})) + (1-\xi)\pi_S^c(\hat{\bar{g}}) - c_S(\hat{\bar{g}}) + c_S^a(\bar{g}^{CI}) \tag{7.25}$$

$$\underline{t}^{CI} = \xi(\pi_S(\hat{\bar{g}}) + \beta\pi_N(\hat{\bar{g}}, \hat{\bar{d}})) + (1-\xi)\pi_S^c(\hat{\bar{g}}) - c_S(\hat{\bar{g}}) + c_S^a(\bar{g}^{CI}) - \Phi(\bar{g}^{CI}) \tag{7.26}$$

Proof 2: See Appendix A.1.■

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

7.4.2 Discussion: TK and Information Rents

The importance of private information is that it might confer an information rent upon its holder. Our model departs from the standard prediction (that informational advantage confers a rent upon the promising type only) because the participation constraints are type-dependent. Whether F_N gives up information rent and to which type depends instead upon the value of V_0, i.e. the difference between the outside option of the high type and that of the low type. When the high type enjoys a highly profitable outside opportunity relative to the low type, the contract must offer her a large transfer. This contract must also reward the low type to prevent her from misrepresenting the quality of her information since the additional cost she incurs by lying, i.e. $\Phi(\overline{g})$ is smaller than the profit differential V_0. To ensure that incentive compatibility is satisfied, F_N will give her an information rent $\underline{V} = \overline{V} - \Phi(\overline{g})$.[4] In this case F_S's informational advantage works more effectively in competition with F_N than it does in cooperation, and therefore her threat not to cooperate is credible (as in case 2.4). Thus, F_S's private information creates a bargaining advantage: the existence of TK confers a clear-cut increase in F_S's share of the production surplus.

If F_S's primary informational advantage lies in her supply costs rather than in her outside option—that is, the differential in reservation profit V_0 does not exceed the cost differential between the high type and the low type—then the benefit conferred by private information comes from the high type's ability to mimic the low type, taking advantage of the supply costs differential (as in case 2.2). In this case, the high type is able to appropriate some informational rent by reason of the asymmetric information whereas the low type is excluded from the sharing of the surplus.[5]

If, however, F_S's informational advantage lies above the cost advantage for the high type resources but below the cost of lying for the low type, then F_N is able to screen effectively between the two types and eliminate all informational advantages (as in case 2.3). Indeed, the cost differentials are sufficiently different to enable screening between them. For intermediate values of V_0, F_N can impose incentive compatible contracts where both types of genetic resources receive their expected reservation profit. This is because no agent has an incentive to misrepresent her type so that the symmetric information outcome (see section 7.3.1) can be implemented.

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

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

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

additional incentives for investment in the provision of these resources to the R&D process, enhancing the efficiency of the R&D process.[6]

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

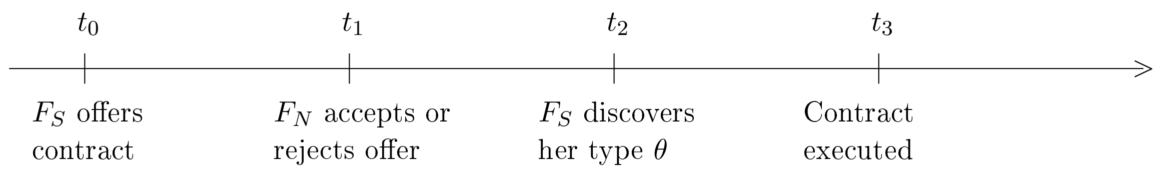
When the high type's advantage derives from the cost of access, then she has strong incentive to invest in human capital to keep her edge and continue to capture informational rent. At the same time, if the low type wants to improve her position by narrowing her cost disadvantage, she too has to invest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

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

We now assume that F_S, the informed agent, has the ability to make an offer to F_N, the uninformed agent. Both high and low types would like to be seen as possessing valuable information. To be convincing, the high type should signal herself to induce F_N to accept the offer granting him access to the genetic resources and traditional knowledge against a sizable payment. We assume that F_S offers an *ex ante* contract (Laffont and Martimort, 2002). In such a contract, F_S is uncertain about the prospect of her genetic resources to be useful for the purpose of F_N's specific R&D, when she makes an offer. She only knows the probability distribution p that her information is useful to truncate the search (high type). With probability $1-p$, her information

[6] Informational rents may contribute to their own types of inefficiencies, however, as efficiency is lost whenever F_S has an incentive to misrepresent herself to capture some information rent and appropriate some of the cooperative surplus. This places F_N in the situation in which he will move away from productive efficiency in order to minimise rent-sharing. That is, to minimise rent-sharing, F_N has to decrease $\underline{g}$ (in case of low V_0), and increase $\overline{g}$ (in case of large V_0) away from the productively efficient levels, respectively $\underline{g}^*$ and $\overline{g}^*$.

is of little use to F_N (low type). There are two reasons for the assumption of *ex ante* contracting. First, F_S may simply be unfamiliar with some diseases common in the North, when the contract is offered, so that there is no certainty about how useful her information. Second, this assumption simplifies the treatment of the signalling problem by yielding only a separating equilibrium—i.e. no pooling equilibrium will result from this contract. The timing is described as follows:



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

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

The incentive constraints require that whatever her type, F_S is always better off revealing her type after she learns it. Formally this translates into: $\overline{t} - c_S^a(\overline{g},\overline{\theta}) \geq \underline{t} - c_S^a(\underline{g},\overline{\theta})$ and $\underline{t} - c_S^a(\underline{g},\underline{\theta}) \geq \overline{t} - c_S^a(\overline{g},\underline{\theta})$. This can be re-written as in (7.16) and (7.17). Note that Assumptions A1 and A2 still hold. Because participation is voluntary, the contract must induce F_N to participate. In other words, the payoff earned by accepting the offer should be greater than or equal to his reservation profit. By rejecting the offer, F_N will receive the following expected reservation payoff:

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

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

F_N's participation constraint is therefore given by:

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

Or equivalently:

$$p\left(\pi_S(\overline{g}) + \pi_N(\overline{g},\overline{d}) - c_S^a(\overline{g}) - c_N(\overline{d}) - \overline{V}\right) + (1-p)\left(\pi_S(\underline{g}) + \pi_N(\underline{g},\underline{d}) - c_S^a(\underline{g}) - c_N(\underline{d}) - \underline{V}\right) \geq \Pi_N^0 \tag{7.27}$$

F_S's problem is then written as:

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

$$\text{subject to} \quad (7.16), \quad (7.17), \ (7.27)$$

Proposition 3:

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

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

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

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

$$\begin{aligned} \overline{t}^* &= p\left(\pi_S(\overline{g}^*) + \pi_N(\overline{g}^*,\overline{d}^*) - c_S^a(\overline{g}^*) - c_N(\overline{d}^*)\right) + (1-p)\left(\pi_S(\underline{g}^*) + \pi_N(\underline{g}^*,\underline{d}^*) - c_S^a(\underline{g}^*) - c_N(\underline{d}^*)\right) - \Pi_N^0 \\ &+ (1-p)\Phi(\overline{g}^*) + c_S^a(\overline{g}^*) \end{aligned} \tag{7.28}$$

$$\begin{aligned} \underline{t}^* &= p\left(\pi_S(\overline{g}^*) + \pi_N(\overline{g}^*,\overline{d}^*) - c_S^a(\overline{g}^*) - c_N(\overline{d}^*)\right) + (1-p)\left(\pi_S(\underline{g}^*) + \pi_N(\underline{g}^*,\underline{d}^*) - c_S^a(\underline{g}^*) - c_N(\underline{d}^*)\right) - \Pi_N^0 \\ &- p\Phi(\overline{g}^*) + c_S^a(\underline{g}^*) \end{aligned} \tag{7.29}$$

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

Proof: See Appendix A.2.■

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

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

7.4.4 Role of Property Rights in TK

No property right in TK was necessary to achieve the results described in this section. The fact that TK is private information is sufficient to confer advantages upon F_S, and alter the bargaining environment which determines the level of F_S's share of the surplus. The existence of a property right in genetic resource-based information retains its importance as the value of the outside option remains dependent upon the enforcement of the right in the Northern market. If the court holds that F_N has not infringed F_S's right—i.e. if the drug is distinctive enough from the herbal medicine marketed in the Northern market—then F_S will receive little compensation under cooperation. If however, the court rules that F_N has infringed the right, then F_S will receive a substantial payoff based on her ability to license her right after the court's decision.[7]

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

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

recognised, F_S's other contributions may be able to be channelled through the existing right in terms of its impacts upon the outside option.

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

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

7.5 Conclusion

This paper has analysed a simple model of the interaction between North and South in relation to the establishment of property rights to protect genetic resources and traditional knowledge. We have stylised the North as rich in human capital but in need of essential genetic resources and traditional knowledge only available in the South to make innovations in the life sciences industries. We examine the impacts upon the cumulative research setting of assigning a second property right to the resources held by the firms in South. In doing so, we investigate how this can achieve efficiency and discuss the implications for the division of the profit.

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

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

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

Bibliography

[1] Artuso, A. (1997): *Drugs of Natural Origin - Economic and Policy Aspects of Discovery, Development and Marketing*, The Pharmaceutical Products Press.

[2] Balick, M.J. (1990): Ethnobotany and the Identification of Therapeutic Agents from the Rainforest. In: D.J. Chadwick, and J. Marsh (Eds.): *Bioactive Compounds from Plants.* Ciba-Geigy Symposium No. 154, Bangkok 20-22 February. New York: John Wiley, 22–39.

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

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

[5] Cox, P.A. (1990): Ethnopharmacology and the Search for New Drugs. In: D.J. Chadwick, and J. Marsh (Eds.): *Bioactive Compounds from Plants.* Ciba-Geigy Symposium No. 154, Bangkok 20–22 February. New York: John Wiley, 50–55.

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

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

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

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

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

[11] Farnsworth, N.R. (1988): Screening Plants for New Medicines. In E.O. Wilson (Ed.): *Biodiversity*. Washington DC: National Academy Press.

[12] Farnsworth, N.R. (1990): The Role of Ethnopharmacology in Drug Development. In: D.J. Chadwick, and J. Marsh (Eds.): *Bioactive Compounds from Plants*. Ciba-Geigy Symposium No. 154, Bangkok 20–22 February. New York: John Wiley, 2–21.

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

[14] Gatti, R., T. Goeschl, B. Groom, and T. Swanson (2004): The Biodiversity Bargaining Game, *Cambridge Working Papers in Economics* No. 0447, Sept. 2004 (recent version 2007).

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

[16] Goeschl, T. and T. Swanson (2002a): The Social Value of Biodiversity for R&D. *Environmental and Resource Economics*, 22: 477–504.

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

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

[19] Hunter, C. (1997): Sustainable bioprospecting: Using private contracts and international legal principles and policies to conserve raw medicinal materials, *Boston College Environmental Affairs Law Review*, 25: 129–174.

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

[21] King, S.R. (1992): Pharmaceutical Discovery, Ethnobotany, Tropical Forests and Reciprocity: Integrating Indigenous Knowledge, Conservation and Sustainable Development.

In: M. Plotkin and L. Famolare (Eds.): *Sustainable Harvest and Marketing of Rain Forest Products*. Washington D.C.: Island Press.

[22] Kloppenburg, J. (1991): No Hunting! Biodiversity, indigenous rights, and scientific poaching, *Cultural Survival Quarterly*, Issue 15.3.

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

[24] Legros, P. and A. Newman (2002): Courts, Contracts, and Interference. *European Economic Review*, 46: 734–744.

[25] Rausser, G.C. and A. Small (2000): Valuing Research Leads: Bioprospecting and the Conservation of Genetic Resources. *Journal of Political Economy*, 108(1): 173–206.

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

[27] Roht-Arriaza, N. (1996): On Seeds and Shamans: The Appropriation of the Scientific and Technical Knowledge of Indigenous and Local Communities, *Michigan Journal of International Law*, 17: 919–965.

[28] Scotchmer, S. and J. Green (1990): Novelty and Disclosure in Patent Law, *RAND Journal of Economics*, 21: 131–146.

[29] Scotchmer, S. (1991): Standing on the Shoulders of Giants: Cumulative Research and the Patent Law, *Journal of Economic Perspectives*, 5: 29–41.

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

[31] Sheldon, J.W. and M.J. Balick (1995): Ethnobotany and the search for balance between use and conservation. In: T. Swanson (ed.): *Intellectual Property Rights and Biodiversity Conservation: an Interdisciplinary Analysis of the Values of Medicinal Plants.* Cambridge: Cambridge University Press, 45–64.

[32] Simpson, D., R. and A. Craft (1996): The Social Value of Using Biodiversity in New Pharmaceutical Product Research. *Discussion Paper 96–33*. Washington D.C.: Resources for the Future.

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

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

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

[36] Weitzman, M. (1998): The Noah's ark problem. *Econometrica*, 66(6): 1279–1298.

7.6 A.1 Proof of Proposition 2

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

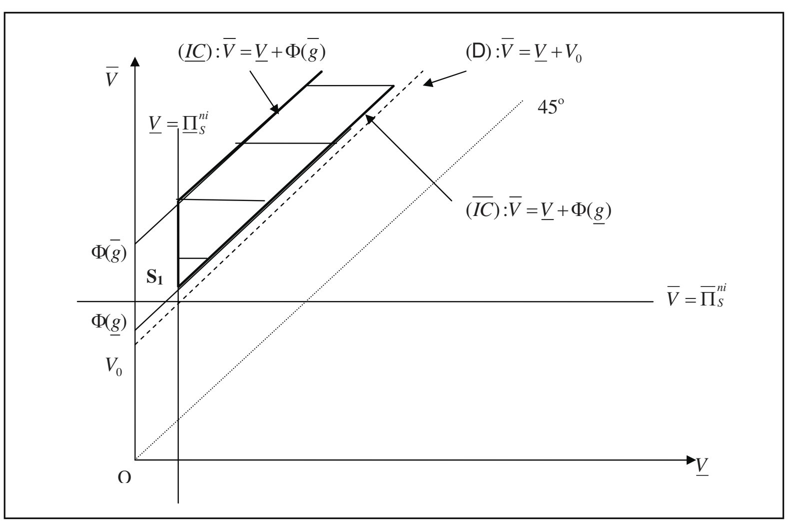
Because the participation constraints are type dependent, the search for equilibrium requires to consider several cases. Let us first represent the four constraints (7.12), (7.13), (7.16), and (7.17) in the space $(\underline{V}, \overline{V})$.

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

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

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

Figure 7.2: Case 1: Low V_0



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

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

Plugging $\overline{V}$ and $\underline{V}$ in (7.18) and deriving the first order conditions yields:

$$\begin{aligned}\max_{\{(\overline{g},\bar{V}),(\underline{g},\underline{\mathrm{V}})\}} \quad & p\left(\pi_S(\overline{g}) + \pi_N(\overline{g},\overline{d}) - c_S^a(\overline{g}) - c_N(\overline{d})\right) + (1-p)\left(\pi_S(\underline{g}) + \pi_N(\underline{g},\underline{d}) - c_S^a(\underline{g}) - c_N(\underline{d})\right) \\ & -[p(\underline{V} + \Phi(\underline{g})) + (1-p)\underline{\Pi}_S^{nc}]\end{aligned} \tag{7.30}$$

$$\frac{\partial \pi_{N+S}}{\partial \overline{g}}(\overline{g}^{SB},\overline{d}^{SB}) = \pi_S'(\overline{g}^{SB}) + \frac{\partial \pi_N}{\partial \overline{g}}(\overline{g}^{SB},\overline{d}^{SB}) = c_S'^a(\overline{g}^{SB}) = \frac{\partial \pi_{N+S}}{\partial \overline{g}}(\overline{g}^*,\overline{d}^*) \tag{7.31}$$

$$\frac{\partial \pi_{N+S}}{\partial \overline{g}}(\underline{g}^{SB},\underline{d}^{SB}) = \pi_S'(\underline{g}^{SB}) + \frac{\partial \pi_N}{\partial \overline{g}}(\underline{g}^{SB},\underline{d}^{SB}) = c_S'^a(\underline{g}^{SB}) + \frac{p}{1-p}\Phi'(\underline{g}^{SB}) > \frac{\partial \pi_{N+S}}{\partial \overline{g}}(\underline{g}^*,\underline{d}^*) \tag{7.32}$$

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

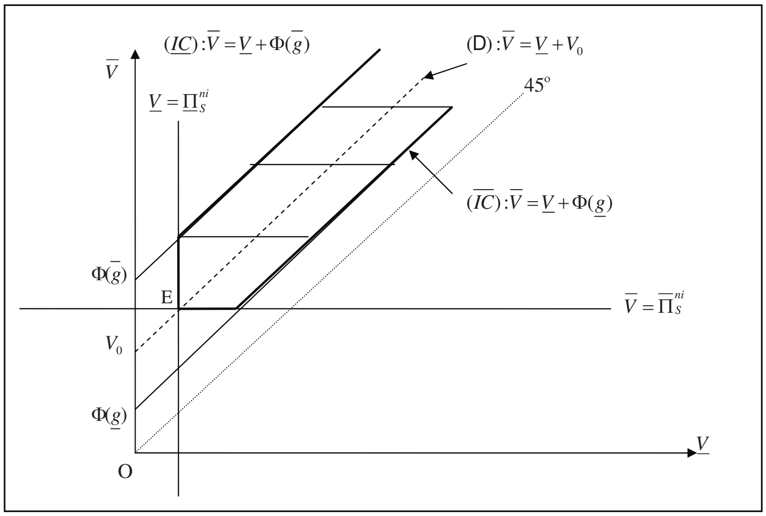
$$\bar{t}^{SB} = \xi(\pi_S(\hat{\overline{g}}) + \beta\pi_N(\hat{\overline{g}},\hat{\overline{d}})) + (1-\xi)\pi_S^c(\hat{\overline{g}}) - c_S(\hat{\overline{g}}) + c_S^a(\overline{g}^*) + \Phi(\underline{g}^{SB}) > \bar{t}^* \tag{7.33}$$

$$\underline{t}^{SB} = \xi(\pi_S(\hat{\underline{g}}) + \beta\pi_N(\hat{\underline{g}},\hat{\underline{d}})) + (1-\xi)\pi_S^c(\hat{\underline{g}}) - c_S(\hat{\underline{g}}) + c_S^a(\underline{g}^{SB}) \tag{7.34}$$

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

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

Figure 7.3: Case 2: Intermediate V_0



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

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

Plugging $\bar{V}$ and $\underline{\mathrm{V}}$ in (7.18) and deriving the first order conditions yields:

$$\frac{\partial \pi_{N+S}}{\partial \overline{g}}(\overline{g}^{SB}, \overline{d}^{SB}) = \pi_S'(\overline{g}^{SB}) + \frac{\partial \pi_N}{\partial \overline{g}}(\overline{g}^{SB}, \overline{d}^{SB}) = c_S'^a(\overline{g}^{SB}) = \frac{\partial \pi_{N+S}}{\partial \overline{g}}(\overline{g}^*, \overline{d}^*) \tag{7.35}$$

$$\frac{\partial \pi_{N+S}}{\partial \overline{g}}(\underline{g}^{SB}, \underline{d}^{SB}) = \pi_S'(\underline{g}^{SB}) + \frac{\partial \pi_N}{\partial \overline{g}}(\underline{g}^{SB}, \underline{d}^{SB}) = c_S'^a(\underline{g}^{SB}) = \frac{\partial \pi_{N+S}}{\partial \overline{g}}(\underline{g}^*, \underline{d}^*) \tag{7.36}$$

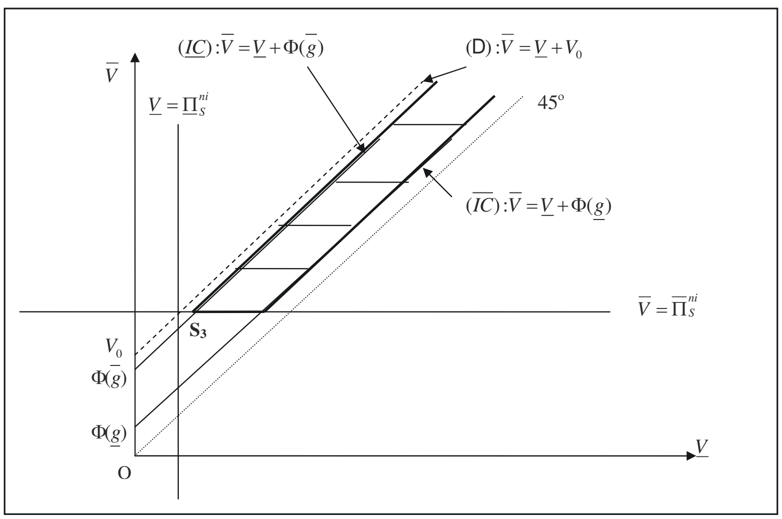
By continuity of $\pi^i_{N+S}(.)$ it follows that: $\overline{g}^{SB} = \overline{g}^*$, $\underline{g}^{SB} = \underline{g}^*$, and monotonicity ensures that $\underline{g}^* \leq \overline{g}^*$. Allocative efficiency is reached for both types: F_N will have an optimal access to the genetic resources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

$$\overline{t}^{SB} = \xi(\pi_S(\hat{\overline{g}}) + \beta\pi_N(\hat{\overline{g}}, \hat{\overline{d}})) + (1-\xi)\pi^c_S(\hat{\overline{g}}) - c(\hat{\overline{g}}) + c^a_S(\overline{g}^*) = \overline{t}^* \tag{7.37}$$

$$\underline{t}^{SB} = \xi(\pi_S(\hat{\underline{g}}) + \beta\pi_N(\hat{\underline{g}}, \hat{\underline{d}})) + (1-\xi)\pi^c_S(\hat{\underline{g}}) - c(\hat{\underline{g}}) + c^a_S(\underline{g}^*) = \underline{t}^* \tag{7.38}$$

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

Figure 7.4: Case 3: High V_0



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

Plugging $\bar{V}$ and $\underline{\mathrm{V}}$ in (7.18) and deriving the first order conditions yields:

$$\frac{\partial \pi_{N+S}}{\partial \overline{g}}(\overline{g}^{CI}, \overline{d}^{CI}) = \pi_S'(\overline{g}^{CI}) + \frac{\partial \pi_N}{\partial \overline{g}}(\overline{g}^{CI}, \overline{d}^{CI}) = c_S'^{a}(\overline{g}^{CI}) - \frac{1-p}{p}\Phi'(\overline{g}^{CI}) < \frac{\partial \pi_{N+S}}{\partial \overline{g}}(\overline{g}^{*}, \overline{d}^{*}) \tag{7.39}$$

$$\frac{\partial \pi_{N+S}}{\partial \overline{g}}(\underline{g}^{CI}, \underline{d}^{CI}) = \pi_S'(\underline{g}^{CI}) + \frac{\partial \pi_N}{\partial \overline{g}}(\underline{g}^{CI}, \underline{d}^{CI}) = c_S'^{a}(\underline{g}^{CI}) = \frac{\partial \pi_{N+S}}{\partial \overline{g}}(\underline{g}^{*}, \underline{d}^{*}) \tag{7.40}$$

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

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

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

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

7.7 A.2 Proof of Proposition 3

As in the case of screening, the combination of (7.16), (7.17) and $\Phi' > 0$ implies that $\overline{g} \geq \underline{g}$.

The Lagrangian of the programme is given by:

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

where λ and μ are the Lagrange multipliers for (7.17), and (7.27). The first order conditions are:

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

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

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

$$p\overline{V} + (1-p)\underline{V} = p\left(\pi_S(\overline{g}) + \pi_N(\overline{g}, \overline{d}) - c_S^a(\overline{g}) - c_N(\overline{d})\right) + (1-p)\left(\pi_S(\underline{g}) + \pi_N(\underline{g}, \underline{d}) - c_S^a(\underline{g}) - c_N(\underline{d})\right) - \Pi_N^0 \quad (7.41)$$

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

Given that $\overline{V} > \underline{V}$ from the high type incentive constraint (7.16), F_S can structure her payoff so that:

$$\overline{V}^* = p\left(\pi_S(\overline{g}^*) + \pi_N(\overline{g}^*, \overline{d}^*) - c_S^a(\overline{g}^*) - c_N(\overline{d}^*)\right) + (1-p)\left(\pi_S(\underline{g}^*) + \pi_N(\underline{g}^*, \underline{d}^*) - c_S^a(\underline{g}^*) - c_N(\underline{d}^*)\right) - \Pi_N^0 + (1-p)\Phi(\overline{g}^*) \quad (7.42)$$

$$\underline{V}^* = p\left(\pi_S(\overline{g}^*) + \pi_N(\overline{g}^*, \overline{d}^*) - c_S^a(\overline{g}^*) - c_N(\overline{d}^*)\right) + (1-p)\left(\pi_S(\underline{g}^*) + \pi_N(\underline{g}^*, \underline{d}^*) - c_S^a(\underline{g}^*) - c_N(\underline{d}^*)\right) - \Pi_N^0 - p\Phi(\overline{g}^*) \quad (7.43)$$

It can be easily verified that $\overline{V}^*$ and $\underline{V}^*$ satisfy the incentive compatibility constraints (7.16) and (7.17) as well as the *ex ante* participation constraint (7.27).[8]

We can therefore determine the optimal transfer payments:

$$\overline{t}^* = \overline{V}^* + c_S^a(\overline{g}^*) \quad (7.44)$$

and

$$\underline{t}^* = \underline{V}^* + c_S^a(\underline{g}^*) \quad (7.45)$$

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

[8] Subtracting (7.42) and (7.43) gives $\overline{V}^* - \underline{V}^* = \Phi(\overline{g}^*) \geq \Phi(\underline{g}^*)$ which satisfies both incentive compatibility constraints (7.16) and (7.17). Subtracting (7.42) to $p\overline{V}^* + (1-p)\underline{V}^* + (1-p)\Phi(\overline{g}^*)$ and combining it with $\overline{V}^* - \underline{V}^* = \Phi(\overline{g}^*)$, we show that the *ex ante* participation constraint (7.27) is also satisfied.