Department of Economics

Forests and Development:
Local, national and global issues

Philippe Delacote

Thesis submitted for assessment with a view to obtaining the degree of Doctor of Economics of the European University Institute

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CONTENTS

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1. FORESTS AND DEVELOPMENT: LOCAL, NATIONAL AND GLOBAL ISSUES

1.1 The world forests and deforestation

Forests cover about 4 billion hectares worldwide which represents 30.3 percent of total land area. Deforestation is defined as a radical removal of vegetation, to less than 10 % crown cover (FAO). This definition refers to a change in the land use and long term removal of tree cover (Angelsen and Kaimowitz, 1998). Annual loss of tropical forests was estimated at 15.4 million hectares per year in the 1980's (FAO, 1992), and at 12.7 million hectares per year in the 1990's (FAO, 1997). Net annual loss was estimated at 7.3 million hectares per year in the Global Environment Outlook (UNEP, 2006). Latin America and Caribbean region, with the largest proportion of forest area, had a decrease in the forest cover from 49.2 per cent cover in 1990 to 45.8 per cent in 2005. Africa also shows a continued net loss of forest area with 21.4 per cent in 2005, compared to 23.6 per cent in 1990. Forest areas in Europe, North America, Asia and Pacific regions remained stable and even increased slightly during this period. Overall countries where deforestation is the most severe are developing countries (Argentina, Brazil, Democratic Republic of Congo, Indonesia, Myanmar, Mexico, Nigeria, Sudan (Smouts, 2002)).

Deforestation represents a major environmental concern. Indeed, forests provide many environmental services both at local and global levels. Locally, forests provide important hydrological benefits, as they prevent soil erosion and flood hazard. Globally, forests sequester carbon, and are therefore important to limit global climate change. For instance, it is estimated that deforestation accounts for up to 20 percent of the global greenhouse gas emissions (www.FAO.org). Moreover, tropical forests are the most valuable ecosystem in the world: between 50 and 90 per cent of the earth species live in tropical forests (WCED, 1987). Finally, forests are not only an environmental indicator, but also an exploitable resource, which can create wealth and local development.

Overall deforestation is at the frontier of development and the environment, and forests constitute both an environmental concern and a renewable resource. Deforestation and forest issues are therefore a very interesting and challenging research object. Forests are a perfect illustration of the poverty-environment nexus, but are also concerned by important and broader development issues, such as corruption, rent-seeking behaviors, and economic and environmental management. They also constitute a global environmental concern, which implies continental and global interactions, and even individual citizens interventions. The aim of this thesis is therefore to consider those three types of interactions involving forest issues: forest's local characteristics in a poverty context, national forest management and corruption, international environmental concerns.

1.2 Forests and people

Among all the deforestation causes, agricultural expansion appears to be the most important one. Indeed, the share of deforestation related to agricultural expansion has been estimated at at least 50 per cent (Myers, 1992; UNEP, 1992) and to 70 per cent in the 1990's (UNEP, 2003). In Africa, which is the area with the highest deforestation rates in the world, more than 50 per cent of the deforested zones were switched into small firms. Deforestation is therefore mostly unplanned and beyond the direct control of governments. It is therefore crucial to understand which links exist between people and forests.

Poverty and environmental degradation are often said to constitute a vicious circle (SARDC, IUCN and SADC 1994 in GEO 2000, Chapter 2). Poor people are dependent on the environment, and thus overuse it, which makes them even poorer. The Brundtland report (1987), the first to underline the importance of poverty in environmental degradation, was followed by the 1992 Rio conference. The implicit conclusion of this link is a win-win potential of helping poor countries to develop and to protect the environment at the same time. Concerning the deforestation process, this vicious circle analysis appears to be appropriate, given that poor households are the main agents of deforestation. In Africa, this link appears to be related to the low productivity and input use of smallholder agriculture, which leads to land degradation and agricultural expansion (Reardon et al., 1999).

More than 1.6 billion people depend to varying degrees on forests for their livelihood. About 60 million indigenous people are almost wholly dependent on forests. Some 350 million people who live within or adjacent to dense forests depend on them to a high degree for subsistence and income. In developing countries, about 1.2 billion people rely on agroforestry farming systems that help to sustain agricultural productivity and generate income. Worldwide, forest industry provides employment for 60 million people. Some 1 billion people depend on drugs derived from forest plants for their medical needs (World Bank, 2001). Disregarding the problem of having defined precisely the concept of forest dependency (see Wollenberg and Ingles, 1998), it appears that forest-dependent people, who are poor for the most important part, constitute a real challenge for development and the environment. A crucial issue is thus to state which are the conditions upon which forest conservation and development can be reconciled. An important factor to consider here is whether agricultural development tend to use land on the intensive or the extensive margin.

Different types of forest use can be elaborated by the households, depending essentially on their market integration. A typology of these strategies is provided by Angelsen and Wunder (2002). First, the *specialized strategy*, related to a high integration into markets, is related to a high contribution of forest products to the households income - this strategy fits with the Asia case. Second, the *diversification strategy*, also related to a high integration into markets, only gives a marginal share of income to the forest products - this is the case for Latin America. Third, the *coping strategy* is associated to a low share of income from forest products and a low integration into markets. This last strategy does not imply, however, that households do not depend on forest, since they may use forest resources for direct consumption. The coping strategy is often seen in Africa. The first strategy allows an explicit important contribution of forest products to income, with extraction being a main activity of the household. In contrast, the last two strategies give forest product extraction a risk-management role: a relatively low importance in terms of income, but a useful tool to smooth household consumption.

Chapter 2 analyzes this insurance use of Non-Timber Forest Products (NTFP) by poor households and its potential impact on deforestation. In the first part of the chapter, I apply a simple model of land use by agricultural households. The representative agricultural household chooses how the land will be used, between agricultural land and forests. It faces a simple trade-off: agriculture is more profitable, but riskier, while NTFP extraction is safer but less productive. The variables influencing the land use are therefore agricultural profitability, NTFP quantities, agricultural risk and risk aversion. This first part thus consider the extensive use of the land.

Overall, it appears in this context that risk reduction tends to increase deforestation. Indeed, if agricultural risk reduces, the household will naturally increase the agricultural area and reduce the forest area. For example, the introduction of an insurance or micro-credit mechanism would increase deforestation. In the same manner, if the household becomes less risk-averse, it will decrease its NTFP extraction to focus more on agriculture, and thus will deforest more. Finally, if forests provide a lot of NTFP, the household tend to keep more land into forests.

In the second part of the chapter, I consider the fact that risk may impact labor allocation and not only land use choices. In this section, I show that in the case where only labor is allocated in order to cope with risk, the use of commonly-held forests as insurance may lead to a poverty-trap situation if the population in need of insurance is too large, and if the resource has a too small capacity. In these circumstances, the introduction of insurance schemes may lead to win-win situations, of alleviating poverty and relaxing pressure on the resource.

However, even if poor people are important agents of deforestation and forest degradation, it appears that larger landholders and richer economic agents, such as logging firms, have also an important role in forest concerns (World Bank, 2006).

1.3 Forest management, corruption and illegal logging

Forests do not only constitute a crucial resource for poor households, but are also an exploitable resource at a macro-level. Forestry sectors generally represent a small share of the countries GDP. In 2000, forestry sectors contributed for about 3% to 5% of GDP in Brazil, Guyana, Suriname, Paraguay, Chile, Latvia, Estonia and some African countries. Overall, forestry sectors contributed to 1.5% of GDP in Africa, 1.1% in Western Europe, 1.7%

in Latin America and 1.2% worldwide (FAO, 2004). Nevertheless forests employ about 13 million people worldwide and forestry may be the main activity in less developed regions.

Forests can therefore be a part of a country's long term development, but also a source of voracity, rent-seeking behaviors, and even crime. As any other resources, forests need good institutions, sustainable policies and effective enforcement to participate in countries development without jeopardizing environmental quality.

Corruption constitutes in this context a very important issue. Indeed, corruption is a major problem in many developing countries. For instance, the World Bank targets corruption indicators as one of the main target conditioning international aid. Concerning forest issues, corruption and poor institutions are very important patterns of unsustainable exploitation. It has been estimated that illegal logging induces losses of 10 billion dollars a year in assets and revenue and 5 billion dollars in revenue through tax evasion (World Bank-IMF meetings, Singapore, 2006). Moreover, illegal logging has important environmental consequences, since it leads to forest over-exploitation, forest degradation and deforestation.

Chapter 3 therefore analyzes the relationship between bureaucratic and governmental corruptions, forestry sectors and forest over-exploitation. Indeed, two kinds of corruption are distinguished in a two-stages model. In the first stage, the forest policy is given, which the logging firm has an incentive not to respect. Thus the firm may bribe the bureaucratic agents in charge of controlling logging practices. Moreover, both the inspected firm and the bureaucrat may be audited by an independent corrupt authority. Unsurprisingly, punishing harder the firm and the bureaucrat when convicted of irregular behavior reduces forest over-exploitation. Moreover, a larger area of exploited forest and less stringent harvest rules reduce over-exploitation. Finally, a larger number of firms exploiting forest resources tends to increase exploitation intensity.

In the second stage, the choice of the forest policy is considered. Logging firms may lobby the government so that it set less stringent forest policy (i.e. harvest rules and the size of exploited forest). If the lobby is well organized, i.e. with low coordination costs, a larger number of exploiting firms leads to larger area of exploited forests and less stringent harvest quotas. Moreover, a cascade effect seems to define this type of relationship: the corrupt government tends to set a larger number of exploiting firms, which increases the lobby's influence and bureaucratic corruption. Thus it appears that more corrupted countries are likely to have larger number of firms exploiting their resource, less stringent harvesting rules and more important bureaucratic corruption.

Chapter 4 investigates empirically the links between natural resource endowments, growth, deforestation and institutions. Indeed, the resource curse literature highlights a negative relationship between resource endowments and growth. An important transmission channel of this resource curse is determined by corruption and poor institutions: resource wealth may lead to sloth in institutions development and greed in resource appropriation. These sins are in turn likely to slow economic growth. The paper considers two kinds of resource curses. First, a classic resource curse is considered, focusing on forest endowments. It appears here that forests do not represent enough economic influence to constitute a resource curse. Second, the fact the the corruption transmission channel may also lead to poor environmental management is considered. The hypothesis of an environmental resource curse is thus tested. Focusing on deforestation, it appears that countries with important timber exploitation tend to deforest more than countries with smaller forest exploitation. This result supports the idea that forest exploitation is mainly unsustainable worldwide. Moreover, this tendency is robust to the addition of corruption and institutions indicators.

1.4 Forests as a global public good: international action and citizens interventions

Forests do not only constitute a local resource and environmental indicator, but also have global properties that put the issue on the international agenda. Indeed, as already mentioned, carbon sequestration by forests is an important tool against global warming. Moreover, primary forests is the main biodiversity reservoir. UNESCO lists several forest site, because of their wildlife wealth, in its World Heritage list (Australia, Brazil, Central African Republic, Democratic Republic of Congo, Indonesia, Kenya, Russia; see whc.unesco.org).

Overall, international organizations appear to be quite involved in forest issues. FAO has an important forestry department and focuses its work on the economic side of forest issues. UNEP considers the environmental side of forest issues. CIFOR is an international research center on forest issues, such as poverty and illegal logging. Nevertheless, even if international organizations get involved in forest conservation and sustainable development, forest issues and deforestation remains an important and alarming environmental concern. Thus many Non Governmental Organizations, such as Greenpeace and Friends of the earth, act to protect forests and denunciate illegal logging and corruption. Moreover individual citizens make a role for themselves, using their economic power to induce more responsible environmental practices. Indeed, consumers are more and more informed of environmental concerns and of marketing and economic practices. Thus they do feel involved and concerned by the international environment. Two related political consumption practices have emerged for the past few years. First, consumer boycotts are a commonly and frequently tool used to induce better firm's environmental practices. Second, ecological certification is now an important signal to consumers sensitive to their environment.

Concerning forest issues, in 2004, WALHI, the Indonesia's largest environmental group, and several other environmental groups, have called for a boycott of timber from Indonesia, Malaysia, Singapore and China, countries where illegal logging plagues local development and environmental indicators. Moreover, several eco-labels (SmartWood, Scientific Certification Systems, Certified Wood Products Council, Good Wood) certifies that timber has been harvested in a sustainable way.

Chapter 5 aims therefore at analyzing the impact of consumer boycotts on firms' practices. Consumer boycotts are considered as a war of attrition between a group of consumers and a targeted firm. Environmentalist consumers refuse to consume the firm's good as long as it is produced with a polluting technology. The boycott is successful if the group of consumers is able to remain longer in the conflict than the firm. Two kinds of characteristics determine the outcome of the game. First, market structure is important. If the market is competitive, it may be open to eco-labeling and certification. Any firm may enter and provide the good with a clean production. In this case, boycotting is less costly and the boycott success is more likely. In contrast, if the firm is in a monopoly position, a good substitute is difficult to find, the boycott is more costly and therefore less likely.

Second, demand structure and consumer preferences are important. The boycotting group, i.e. the population concerned by the quality of the environment, needs to be quite important, and composed of important consumers. Indeed, the aim of the boycott is to hurt the firms profit, which means that it should represent an important part of the firm demand. A simple tradeoff therefore describes the problem to which consumers are confronted: boycott by important consumers is very costly for the firm, but boycotting is very costly for those consumers. Finally, coordination failures and free riding are important issues that may jeopardize boycott successes. Overall, consumer boycotts are likely to be quite ineffective.

1.5 Future research

The contributions of this thesis open opportunities for future research. Two main orientations are to be distinguished.

First, as mentioned quickly before, political consumption has become an important phenomenon over the past few years, which completely changes the way citizens act and defend their environmental and social convictions. Focusing on consumer boycotts, the last paper of this thesis is a first attempt to analyze this *"new way to save the world"* (Mc Laughlin, 2004). However, several important issues of political consumption remain to be investigated. First, consumer boycotts may be an important way to signal important issues to politicians. Investigating which type of boycott offers the best signalling window of opportunity seems to be a crucial and interesting topic. Second, certification and eco-labeling constitute another important pattern of political consumption. Analyzing the patterns of eco-labels settings is an important research gap. Indeed, considering how the label requisites are chosen and the impact of this choice process on the environment and the market structure is a crucial element to be understood. Finally, the two kinds of political consumption mentioned (consumer boycotts and certification) are closely related. Investigating more precisely the relationships between consumer boycotts and the emergence of eco-labeling is crucial to understand more precisely the global impact of political consumption.

Second, the first paper of this thesis analyzes the land use choice process of poor agricultural households when using forest products as insurance. This paper is applied theoretic, and would benefit a lot of being tested empirically. Indeed, while some papers investigate empirically the choice process of the land use in developing countries, the analyze of the insurance use of forest products, and more broadly the impact of risk on the land use choice are still research to be undertaken.

Several environmental and forest issues are only mentioned and considered quickly in this thesis, but would benefit from a deeper and more precise analysis, such as the links between election processes, economic power and forest allocation, or communities land-use management. Finally, deforestation is responsible of about 20 % of total Co^2 emissions. Payment for forest conservation to mitigate climate change may therefore constitute an interesting option to combine environmental protection with direct livelihood improvement for communities living near tropical forests. This issue is therefore an important topic to be considered for future research.

2. AGRICULTURAL EXPANSION, FOREST PRODUCTS AS SAFETY NETS, AND DEFORESTATION

Abstract

Incompleteness of insurance markets is a crucial weakness of developing countries. In this context, the poor households of rural regions often exploit common property resources, such as forests, as insurance in case of economics stress. The aim of this paper is to derive the implications of this insurance use on the forest cover, and thus on deforestation. The land-use choice between agricultural land and forest therefore resembles a portfolio diversification. However, I also show that this insurance strategy may lead to resource over-exploitation and constitute a poverty trap.

Keywords: deforestation; household model; risk aversion; agricultural expansion; forest products.

JEL classification: D13; O12; O13; Q12; Q15; Q23.

2.1 Introduction

Insurance markets of rural regions in developing countries are often incomplete, if not non-existent. This situation gives non-conventional insurance systems an important role. Among these systems, common property resources (CPR) appear to have an important insurance role. Several case studies have studied the insurance role of commonly held resources, such as forests, commonly held lands or even fisheries.

A particular activity is often used as a safety net [1]: Non-Timber Forest Products (NTFP) extraction[2]. Populations of interest here are farming communities that rely on forest as a

[1] Among other insurance mechanisms: inter-household solidarity, livestock...

[2] The term "non-timber forest product" encompasses all biological materials other than timber which are extracted from forests for human use.

supplementary source of income (Byron and Arnold, 1999). In case of bad agricultural crops, the households extract NTFP from the forest in order to smooth their consumption.

The aim of this paper is to understand the impact of this insurance use of forest products on the land-use choice. Indeed, agricultural expansion appears to be the most important cause of deforestation. The share of deforestation related to agricultural expansion has been estimated at at least 50 per cent (Myers, 1992; UNEP, 1992) and at 70 per cent in the 1990's (UNEP, 2003). In Africa, which is the area with the highest deforestation rates in the world, more than 50 per cent of the deforested zones were switched into small exploitations. Simultaneously, agricultural development is an important tool for poverty alleviation and long term development (World Bank; 2000). The consequences of this insurance role of NTFP extraction on deforestation is thus an interesting issue and can be investigated with farm household models - a priority for future research (Angelsen and Kaimowitz, 1998).

Some papers have studied the safety-net role of common property resources, such as forests (Agarwal, 1991 ; Baland and Francois, 2004 ; Pattanayak and Sills, 2001), but they do not consider the impact of this role on the land-use decision. However the households face a trade-off between forest and agriculture. Agriculture can be a way to alleviate poverty, but is a risky activity, while NTFP extraction has low poverty alleviation potential, but is a useful tool to compensate for agricultural risk. This paper investigates therefore the impact of the use of NTFP as safety nets on the household's decision to increase their agricultural land, and thus, to clear forests.

The safety-net use of NTFP extraction may take two forms, corresponding to two kinds of risk-management strategies. First, the *diversification strategy* is equivalent to a portfolio analysis, because the households use NTFP extraction as a risk-free asset (Aldermann and Paxson, 1994). Second, the *coping strategy* consists of extracting NTFP only when agricultural output is too low, working as a "natural" insurance mechanism. Therefore, the problem for the local communities has both the characteristics of portfolio analysis and economics of insurance. The paper focuses on the diversification strategy. The household chooses *ex ante* the share of land dedicated to agriculture and the share of land dedicated to NTFP extraction. The analysis of a coping strategy would induce a different timing of the land-use choice and the allocation of labor.

To investigate the impact of the use of NTFP as a risk-management strategy, we build on Angelsen (1999). Our extension allows for agricultural crops uncertainty and for NTFP extraction, neither of which is considered in Angelsen (1999). Thus the model is an expected utility maximization process of a risk-averse household which uses forest products to face agricultural crops uncertainty. We assume a community that does not have access to insurance nor credit market, so that the risk-management use of forest products is the only way to deal with crop risks.

In this context, the comparative statics show that risk reduction, lower risk aversion and larger population may be important factors of deforestation. Moreover, forest profitability is unambiguously positively correlated with the forest cover.

Angelsen and Wunder (2003) notes that this activity can constitute a poverty trap for poorer households. Azariadis and Stachuski (in Aghion and Durlauf, 2006) define a poverty trap as a *"self reinforcing mechanism which causes poverty to persist"*. Thus determining the conditions under which a CPR constitutes both a safety net and a poverty trap is also an important issue. I define a poverty trap as a situation in which households cannot get more than their subsistence requirement from their activities. In the case considered here, households are "trapped" in CPR extraction activity because of their need of insurance, which keeps them away from other development opportunities. CPR extraction can constitute a poverty trap as a result of a tragedy-of-the-commons process. Too much households are in need of insurance and the resource cannot provide enough to properly insure all the population. They face thus the classic poverty-environment nexus, where poor people depend too much of their environment and overuse it.

Section 2 gives a brief review of the literature, emphasizing the use of NTFP for poor agricultural households, describing the economics of land-use in agricultural areas and the insurance properties of common property resources. Section 3 presents a household model of land-use choice with risk on agricultural output and NTFP extraction used as safety net. Section 4 shows how a CPR may constitute both a safety net and a poverty trap. Finally section 5 concludes and discusses the policy implications.

2.2 *Review of the literature*

2.2.1 *The safety-net use of non-timber forest products*

In developing countries, about 1.2 billion people rely on agroforestry farming systems that help to sustain agricultural productivity and generate income (World Bank, 2001). The risk-management role of forest products is particularly important in the rural regions of developing countries, given that agricultural crops face many types of risk, such as price shocks, seasonal flooding, unpredictable soil quality, pests, crop diseases or illnesses. NTFP can be used directly in consumption or sold to fill cash gaps. Formally, rural households, which have limited credit and insurance options, choose a diversification of their activities (thus of the land use), in order to reduce aggregate risk (Morduch, 1995; Godoy et al., 1998). Some studies analyze this use of NTFP (Baland and Francois, 2004; Pattanayak and Sills, 2001). One of the results is that any individual is more likely to visit the forest if the crops are more risky or if he faces a negative shock. Godoy et al. (2000), in a study in Honduras, argue that although NTFP extraction has a low annual value, it can provide insurance in the case of unexpected losses. This risk-management role can be particularly important in the case of common risk, because intra-village credit or insurance systems are more difficult to implement (Dercon, 2002).

Two risk-management strategies may be implemented (Angelsen and Wunder, 2002). The diversification strategy (usually observed in Latin America) is a classic risk-management tool (Aldermann and Paxson, 1994). The household raises *ex ante* the number of its activities, choosing if possible activities that have low covariance. In contrast, the coping strategy (observed in Africa) consists of extracting NTFP only in the case of bad agricultural crops. The use of NTFP can here be considered as an *ex post* gap filling use. Forest products are extracted in order to smooth the household's consumption in case of low crop returns.

In these two risk-management approaches, NTFP extraction appears to be efficient for poor rural households. First, a large variety of NTFP can be extracted, thus raising the diversification of activities. Several studies mention fuel, fodder, fibres, oil seeds, edible fruits, staple foods, vegetables, spices, rope, leaf-plates, medicinal plants, vines, honey, sap, Brazilian nuts, fruits bark and rubber (Kumar (2002), for rural India; Pattanayak and Sills (2001), for the Tapajos National Forest, Brazilian Amazon). Second, many NTFP do not have strong positive correlation among themselves or with agricultural output (Pattayanak and Sills, 2001), so that they can be efficient risk-management instruments. A bad agricultural output is not necessarily linked to bad forest product quantities.

Two characteristics of NTFP are important to note. First, there are low capital and skills requirements to NTFP extraction as well as open or semi-open access to the resource, so that poor households can easily extract the resource. Neumann and Hirsch (2000) argue that the poorest people are those who are the most engaged in NTFP extraction. Second, NTFP habitually have low return to labor, so that they have poor potential to alleviate poverty (Wunder, 2001; Angelsen and Wunder, 2002). Studying Bagyeli and Bantu communities in South Cameroon, Van Dijk (in Ros-Tonen and Wiersum (2003)) gives an illustration of the relatively low share of NTFP in total income -which argues for the risk-management strategies- and of the link between poverty and NTFP use.

Hence, forests are competing for the land-use, with agriculture representing the most important alternative. Indeed, forest products have a low potential of poverty alleviation, but can be used to compensate shortfalls in agricultural yields. Conversely, agricultural crops is a potential way out of poverty for households, but may represent a high levels of risk, especially if the households have low access to insurance or credit markets. The trade-off between these two land-uses is a major choice for poor rural households, and is a potentially driving force of deforestation. An interesting topic is thus to analyze the land-use choice process of the households.

2.2.2 The land-use choice literature and NTFP extraction

Among the papers studying the land-use choice by rural communities, only few take into account the forest products use, and none study the risk-management use described here. Lopez (1998) notes the coexistence in most developing countries of private lands, intended for agricultural crops, and common property lands, namely forests, used for their products. In his paper, the two land-uses compete with each other, but forest products extraction is not a risk-management strategy. Specifically, Lopez analyzes the consequences of agricultural intensification and farm productivity improvement programs on the pressures on the common resource. The main factor determining the programs' impact on pressure on the common resource is the factor-intensity of the crops. If crops are labor-intensive, then a rise in their prices is likely to diminish the pressure on the common resource. However, if crops are land-intensive, the pressure is likely to rise with the commodity prices.

Parks et al. (1998) study the competing land-uses, mainly agriculture, timber and non-timber forest products. The paper distinguishes four cases, depending on the relative productivity of the different activities: joint management of forests, forest preservation, conversion to non-forest use, and forest abandonment. These four cases depend mainly on the impact of the age of the trees and the management effort on a profit maximization function.

2.2.3 Common property resources as safety net

The literature on land-use choice discussed above ignores the safety-net role that forests have when they are commonly held. Another part of the literature does, however, argue the importance of common property resources (CPR) as safety net. Baland and Francois (2005) analyze the insurance property of CPR, and compare it with the increased efficiency if this resource is privatized. In their paper, each household has the choice between two activities: CPR extraction and a private project. CPR extraction requires low skilled labor, which implies homogenous returns to labor. The private projects provide heterogenous returns, depending on the households skills. Therefore, CPR extraction represents for low skilled households an outside option to private project, while the most skilled households allocate their labor to the private projects. The authors found a potential negative impact of the privatization of the resource on the welfare of the community's poorest members.

Pattanayak and Sills (2001) find that NTFP collection is positively correlated with agricultural shortfall and expected agricultural risk. According to Bromley and Chavas (1989), non-exclusive property rights can be seen as an integral part of risk sharing. In this case, the common forest can be considered as an asset of last resort (Baland and Francois, 2005). A strong link between poor people and CPR is often underlined. Dasgupta and Maler (1993) argue that local commons provide the rural poor with partial protection in time of unusual economic stress. A study of tribal groups in rural Bihar qualifies communally-held forests as the only means of survival for poorer members in lean seasons (Agrawal, 1991). Reddy and Chahravaty (1999) observe in India a more intensive use of the CPR by poor households. Dasgupta (1987) notes a higher level of CPR products in low labor productivity regions. Johda (1986) finds a negative relationship between CPR income and rural inequalities.

Although some papers study the competing land-use relationship between agriculture and forests, none of them investigate the safety-net use of forest products to insure against crops risk. In contrast, papers studying the safety-net role of CPR treat the share private/common land as exogenous. The aim of this paper is thus to reconcile these two sides of the literature, investigating the role of the safety-net use of NTFP on the land-use choice.

2.3 Diversification strategy, risk-aversion and household's optimal land-use

The model presented is an adaptation from Angelsen (1999). In contrast to Angelsen's set-up, agricultural output is uncertain and forest provides NTFP that are used to smooth the household's consumption when the agricultural output is bad.

The set-up for the land: The model represents a village economy. The total area of the village is normalized to 1. We assume here only two possible uses for the land: agriculture and forests. Both agricultural and forested areas are assumed to have the same quality. In contrast to Angelsen (1999), we assume that forests provide Non-Timber Forest Products (NTFP). We assume for simplicity an egalitarian repartition of the land across the households in the village. Therefore, we consider a representative household, which has a share $\frac{1}{N}$ of the total area of the village (N is the number of households in the village and is our indicator of population pressure), which is equivalent to a share $\frac{1}{N}$ of total forest product extraction. We avoid thus the tragedy of the commons problem, i.e competition between households for the forest products. We also assume that both the agricultural good and the forest product are homogenous. For both goods, land and labor are the only inputs. We assume that the household uses an optimal combination of labor in the production process. Thus the labor side is not explicitly considered here. The implicit assumption is that the household's labor force is entirely used and that the household may eventually hire outside labor [3].

R is the share of agricultural land in the village area ($0 \leq R \leq 1$). Agricultural land area used by the household is thus defined as $\frac{R}{N}$ and forest land area for the representative household use is $\frac{1-R}{N}$. R is an indicator of the agricultural land cover and the choice variable of the household. At the beginning of the period, the household chooses the share of the

[3] For an analysis of the interactions between labor market and deforestation, see Bluffstone (1995).

land it will cultivate. If $R = 1$, all the land around the village is converted to agriculture and deforestation is maximized in the village area. If $R = 0$, forest conservation is maximized and there is no agriculture. Between these two extreme cases, there is a trade-off between the two possible uses of the land.

The safety-net use of forest products: We focus here on the diversification strategy, i.e. the land-use choice (inducing the labor allocation) is made *ex ante*. We assume that agricultural land is, on average, more profitable than forest land, but agricultural production is more volatile than NTFP. Thus, there is a trade-off between a relatively more profitable but riskier activity - agriculture - and a relatively less profitable but safer activity - NTFP extraction. In contrast to Angelsen (1999), the agricultural output is not certain. The risk on agricultural crops is supposed to be systemic. Therefore every household in the village lives in the same state of the world. Thus there cannot be inter-household insurance.

There are two states of the world. In the good state, which occurs with probability δ, the agricultural output per hectare (or per unit of land, as the area is normalized to 1) is high.

$$\overline{C}(R) \equiv \frac{1}{N}[R\overline{x} + (1 - R)f] \tag{2.1}$$

where $\overline{x}$ is the optimal agricultural output (net of costs) per hectare in the good state of the world. f is the quantity of forest products extracted per hectare, net of extraction costs. In contrast to the agricultural output, f is assumed to be certain.

In the bad state, with probability $(1 - \delta)$, agricultural output is low.

$$\underline{C}(R) \equiv \frac{1}{N}[R\underline{x} + (1 - R)f] \tag{2.2}$$

$\underline{x}$ is the optimal agricultural output in the bad state of the world. Clearly $\underline{x} < \overline{x}$ must hold. Expected agricultural output per hectare is therefore:

$$E(x) = \delta\overline{x} + (1 - \delta)\underline{x} \tag{2.3}$$

Clearly, by assumption $f < E(x)$, for otherwise there is no trade-off between the two land-uses and all the land is used for forest product extraction.

2.3.1 Expected utility maximization

The objective of the household is to maximize its expected utility. The household's utility function only depends on consumption: $U = U(C)$, with $\frac{\partial U}{\partial C} > 0$. A quick mean-variance analysis may be done before considering the household's optimal trade-off.

Mean-variance analysis: Both the expected level of consumption and its variance depend on the share of agricultural land, R, to be chosen by the household.

The household can either consume directly what it produces or sell it to purchase other goods. Thus we consider the equality between consumption and production as a budget constraint. The expected level of consumption is therefore:

$$E_c(R) = \frac{1}{N}[R(E(x) - f) + f]; \qquad \frac{\partial E_c(R)}{\partial R} > 0 \tag{2.4}$$

Expected consumption rises with the share of agricultural land, R, since expected agricultural production is more efficient than forest product extraction. Therefore, a risk-neutral household would convert all the land into fields ($R = 1$) in order to maximize its expected consumption. The variance of consumption is:

$$\sigma_c^2 \;=\; \frac{1}{N^2}\sigma_x^2 R^2$$

Clearly the variance of consumption is strictly increasing in R. Thus the choice in the land-use is a trade-off between expected consumption and variance of consumption. The relative weight given to the expected consumption and the variance will depend on its risk-aversion: a risk-averse household gives more importance to the variance of consumption, than a risk-neutral household.

Household's objective and the optimal trade-off: We introduce a Constant Absolute Risk Aversion (CARA) function, with α being the Arrow-Pratt Absolute Risk Aversion coefficient:

$$U(C) = -\exp[-\alpha C] \tag{2.5}$$

Expected utility is then:

$$E_U(R) = -\delta \; \exp[-\alpha \overline{C}(R)] - (1 - \delta) \; \exp[-\alpha \underline{C}(R)] \tag{2.6}$$

The objective of the household is to choose R in order to maximize expected utility:

$$\max_{R}\ E_U(R) \tag{2.7}$$

Note that $\frac{\partial E_U}{\partial R} > 0$ if $f \leq \underline{x}$. Therefore, we have a corner solution ($R = 1$) if the forest profitability is lower than or equal to the agricultural profitability in the bad state of the world. In this framework, the safety-net use of the forest products only exists if the risk on agricultural output is so high that NTFP extraction becomes the main activity of the household in the bad state of the world. This condition is consistent with a portfolio analysis, where the risk-free asset needs to be more profitable than the risky asset in some states of the world to have a positive share in the portfolio (Gollier, 2001). We now characterize the agricultural frontier that maximizes expected utility. The first-order condition gives the optimal agricultural frontier:

$$R^* = \left(\frac{N[\ln \frac{\delta(\overline{x}-f)}{(1-\delta)(f-\underline{x})}]}{\alpha(\overline{x}-\underline{x})}\right) \tag{2.8}$$

2.3.2 Comparative statics

In this framework of risk on agricultural output, we define risk reduction as a rise in $\underline{x}$ and a fall in $\overline{x}$, with a constant expected output $E(x)$. This kind of risk reduction can be viewed as the introduction of an insurance system. On the one hand, the household pays a risk premium $d\overline{x}$ per hectare in the good state of the world. On the other hand, if the bad state of the world occurs, the household receives as insurance $d\underline{x}$ per hectare. This risk reduction definition implies $(1-\delta)d\underline{x} = -\delta d\overline{x}$, with $d\underline{x} > 0$.

Proposition 1 : *When NTFP extraction is used as a diversification strategy, risk reduction, lower risk aversion and larger population decrease the forest cover. Moreover, the forest profitability is positively correlated with the forest cover.*

Proof : sign of the first derivatives of R^* (see appendix A): $\left(\frac{\partial R^*}{\partial \underline{x}} - \frac{(1-\delta)}{\delta}\frac{\partial R^*}{\partial \overline{x}}\right) > 0$, $\frac{\partial R^*}{\partial \alpha} < 0$, $\frac{\partial R^*}{\partial N} > 0$ and $\frac{\partial R^*}{\partial f} < 0$.

Risk reduction has a positive impact on R. Hence, if the agricultural risk is reduced, the safety-net use of NTFP is less important, agricultural land increases and forest cover declines.

Intuitively, if the more profitable activity becomes less risky - with the same expected profitability -, its share in the agent's portfolio raises. In our example, the introduction of an insurance mechanism thus leads to more deforestation.

The Arrow-Pratt Absolute Risk Aversion coefficient has a positive impact on the forest cover. Intuitively, if the household is risk averse, it keeps more land as forest in order to insure itself against crop risks, even if this is done at the expense of lower expected consumption.

The village population has a negative impact on the forest cover (positive impact on R). Indeed, a larger population reduces the size allowed to each household. Each household therefore raises the share of the most profitable activity.

Consistently with a portfolio analysis, the portfolio share of the risk-free asset, i.e. NTFP extraction, is positively correlated with its profitability. A rise in forest profitability could come, for example, from a rise in the NTFP prices. A policy frequently advocated to reduce tropical deforestation is the introduction of green labeling for NTFP in order to raise the profitability of the forests. Appendix C provides a numerical example of the coping and diversification strategies.

The precedent proposition ignores the fact that NTFP extraction from a common property or free access forest can constitute a poverty trap, as an extreme case of a tragedy-of-the-commons process. This case is studied in the next section.

2.4 Safety-net or poverty trap?

In this section, we build on Baland and Francois (2005). The share of agricultural land (R) is now supposed to be fixed, and not a choice variable anymore. The choice variable is now the allocation of labor between the two activities. Moreover, the households are supposed to have different productivity on the agricultural land. We distinguish therefore skilled and unskilled households. In contrast to the precedent section and because of household heterogeneity, only unskilled households allocate some labor to CPR extraction.

The N households of the community allocate their unit of labor ($L_i = 1$) between two activities. First, labor can be allocated to a private project (e.g: private agriculture). Second, it can be allocated to CPR extraction (e.g: NTFP extraction). In Baland and Francois, the household allocate all its labor to one activity. In contrast, in the following model, each household can divide its labor supply and allocate a share to both activities.

Baland and Francois consider successively a risk-free private project with heterogeneous returns, and a risky private project with homogeneous returns. Conversely, we consider here a risky private project with heterogeneous returns, while the CPR provides safe and homogeneous returns. Therefore, CPR extraction may have two motivations. First, households have different expected returns on their private project and the less skilled households allocate all their labor to CPR extraction, and the CPR returns represent the minimum income of the community. Second, the households face also different levels of risk on their private projects and allocate thus a share of their labor supply to CPR extraction in order to insure themselves (note here that we assume the extreme case of no outside insurance possibilities). Whereas Baland and Francois consider separately those two kinds of heterogeneity, the model presented here study the possible poverty-trap implications of the coexistence of these two role of the CPR: minimum income and insurance.

2.4.1 NTFP extraction as insurance and households heterogeneity

As in Baland and Francois (2005), we assume that all labor allocated to the CPR is equivalently productive and receives the average product: $\frac{f(L).l_i}{L}$, with $l_i \in [0,1]$ the amount of labor allocated to the CPR by household i and $L = \int_N^1 l_i \, di$ the aggregate amount of labor allocated to the commons [4]. The commons production function, $f(L)$, is strictly increasing and concave in L. Therefore, the average product is decreasing in L, which constitutes a tragedy-of-the-commons effect: labor allocated by one household has a negative externality on the other households. Moreover, total labor allocated to the commons can be an indicator of environmental damages. Indeed, the overuse of a resource coincides with the degradation of the ecosystem. Note here that we assume that the CPR is *de facto* open access, and that no joint management strategy is implemented to induce sustainable use.

As already said, the private projects provide uncertain returns [5]. The expected private project return of household i is $E(x_i).(1-l_i)$. In the worst case, the private project provides

[4] Note here that the size of the CPR is fixed, and therefore not a choice variable.

[5] A first-best outcome would therefore come from the introduction of an efficient insurance market that eliminate risk on the private project.

$\underline{x_i}.(1 - l_i)$. Note here that only $E(x_i)$ and $\underline{x_i}$ (and not the whole distribution of the private project returns) are needed to describe the households characteristics. We restrict ourselves to the case of common risk, i.e. we define: $\underline{x_i} = E(x_i) - C$. Where C is the same across households. Expected returns, $E(x)$, and minimum returns, $\underline{x}$, constitute a representation of the households heterogeneity in terms of skills and risk, respectively.

The households are sorted according to the expected return on their private project. Household *1* has the lowest expected return and household N has the highest one.

Household's objective: At the beginning of the period, each household chooses its labor allocation between the two activities to maximize its expected return $\Pi(l_i)$:

$$\max_{l_i} \ \Pi(l_i) = (1 - l_i).E(x_i) + l_i.\frac{f(L)}{L} \tag{2.9}$$

Moreover, the households need to insure a minimum consumption requirement C_{min} in the worst state of the world (i.e if $\underline{x_i}$ occurs). We assume here that the minimum requirement is the same across the population. We consider basic needs to survive, such as nutrition. If this requirement is not met, concerned households cannot stay in the community and have therefore to migrate. Migration is therefore considered here as an action of last resort if the environment cannot insure their livelihood to some households. An important concern here is whether migration provides the minimum requirement to migrating households. Indeed, migrating is by itself a risky behavior. This concern is not explicitly considered here. The important point is that some households have to migrate simply because their livelihood is threatened.

The choice of any household i to migrate ($M_i = 1$) or not ($M_i = 0$), is therefore:

$$\begin{cases} M_i = 1 \ if \ (1 - l_i).\underline{x_i} + l_i \frac{f(L)}{L} < C_{min} \\ M_i = 0 \ if \ (1 - l_i).\underline{x_i} + l_i \frac{f(L)}{L} \geq C_{min} \end{cases} \tag{2.10}$$

Thus households are risk neutral, as long as they get their minimum requirement, and are infinitely risk averse under that point. We define as poor a household not getting more than its subsistence requirement: it cannot get more from its activities than what it needs to survive. This set up is somehow unfamiliar, but seems to fit with the reality of many poor communities of developing countries. Indeed, the main objective of poor households is likely to insure livelihood. Thus, it seems fair to assume that, in very poor communities, households first insure their livelihood, and then try to maximize their expected payoff.

Two kinds of households decide not to migrate. First, private projects may be profitable enough for some households, even in the worst state of the world: $\underline{x_i} \geq C_{min}$. These households are naturally insured. Second, households properly insured by CPR extraction also decide not to migrate. Thus CPR extraction needs to be profitable enough to insure the households properly, and the households need to allocate a minimum amount of labor to the CPR. The conditions for these households to stay in the community are as follow.

$$\begin{cases} \frac{f(L)}{L} \geq C_{min} \\ \underline{l_i} = \frac{C_{min} - \underline{x_i}}{\frac{f(L)}{L} - \underline{x_i}} \end{cases} \tag{2.11}$$

Return to CPR extraction is decreasing in total labor allocated. Thus, if too much labor is allocated to the CPR, the average product goes down to its bottom value C_{min}. Therefore, a maximum possible amount of labor allocated to the CPR can be defined:

$$L_{max} : \quad \frac{f(L_{max})}{L_{max}} = C_{min} \tag{2.12}$$

If too many households are in need of insurance, the insurance capacity of the resource, L_{max}, may be too small. At this point, some households have to migrate and migration occurs until the point at which every remaining household is insured, with the average return being equal to the minimum requirement. Migration is considered here as an action of last resort: the environment cannot provide to the households their livelihood, thus they have to leave. Households are therefore assumed to migrate from the area if and only if they cannot get their minimum requirement from their livelihood. The number of households having to migrate is therefore:

$$M = \int_0^N M_i di = S - L_{max} \tag{2.13}$$

with S the population in need of insurance:

$$S \ : \ \underline{x}_S = C_{min} \tag{2.14}$$

At equilibrium, three classes of households can be distinguished, related to their labor allocation.

2.4.2 Classes of households at equilibrium

The equilibrium is a combination of a total amount of labor allocated to the commons, L_c, a share of labor allocated to the commons by each household, l_i, and a number of households that have to migrate, M.

At equilibrium, 3 classes of households can be distinguished according to the households allocation of labor. Two classes are in need of insurance and therefore allocate a share of their labor to CPR extraction, while the third one is "naturally" insured.

Unskilled households: The less skilled households have an expected return on the private project smaller or equal to the average product on the CPR. These households allocate all their labor to the CPR. Therefore they get the average product.

$$For \quad i \in [0;U] : \begin{cases} E(x_i) \leq \frac{f(L_c)}{L_c} \\ \underline{x_i} < C_{min} \\ l_i = 1 \\ \Pi(l_i) = \frac{f(L_c)}{L_c} \end{cases} \tag{2.15}$$

The motivation for CPR extraction here is a lack of better opportunity. Less skilled households rely on this activity because it requires low skilled labor and provides higher returns than their private projects.

Skilled households: The most skilled households are those who get at least their minimum requirement from their private project. Moreover, the expected return on their private project must be greater than the average product on the CPR. Thus they allocate all their labor to the private project. Their expected income is the expected private return.

$$For \quad i \in [S;N] : \begin{cases} E(x_i) > \frac{f(L_c)}{L_c} \\ \underline{x_i} \geq C_{min} \\ l_i = 0 \\ \Pi(l_i) = E(x_i) \end{cases} \tag{2.16}$$

This class of household can be considered as "naturally" insured: they always get enough returns from their private project to satisfy their basic needs.

Middle class: This last class of household does not appear in Baland and Francois. For this class, the private project is in expectation more profitable than CPR extraction. However, there are some states of the world in which this private project does not provide their minimum requirement. Therefore they put some labor in CPR extraction in order to insure themselves. Because the expected private project return is greater than the return on CPR extraction, these households allocate labor on the CPR in order to get exactly their minimum requirement in the worst state of the world.

$$For \quad i \in [U; S] : \begin{cases} E(x_i) > \frac{f(L_c)}{L_c} \\ \underline{x_i} < C_{min} \\ \underline{l_i} = \frac{C_{min} - \underline{x_i}}{\frac{f(L_c)}{L_c} - \underline{x_i}} \\ \Pi(\underline{l_i}) = \underline{l_i}.\frac{f(L_c)}{L_c} + (1 - \underline{l_i}).E(x_i) \end{cases} \tag{2.17}$$

While in a world with perfect insurance, these middle-class households would allocate all their labor to the private project and get its expected return, they need here to extract from the CPR in order to insure themselves, at the expense of reducing their expected return. Note here that S represents the population in need of insurance (unskilled and middle class). The following table synthesizes the patterns of the different classes in equilibrium.

	Unskilled	Middle	Skilled
Households	$[0; U]$	$[U; S]$	$[S; N]$
$E(\theta_i)$	$\leq \frac{f(L_c)}{L_c}$	$> \frac{f(L_c)}{L_c}$	
$\underline{\theta_i}$	$< C_{min}$		$\geq C_{min}$
l_i	1	$\underline{l_i}$	0
$\Pi(l_i)$	$\frac{f(L_c)}{L_c}$	$\underline{l_i}.\frac{f(L_c)}{L_c} + (1 - \underline{l_i}).E(x_i)$	$E(x_i)$

In order to show how CPR extraction becomes a poverty trap, we need to determine what is the total amount of labor in the CPR.

2.4.3 Total amount of labor in the CPR

Only two classes of household allocate labor to CPR extraction: the unskilled and the middle class. First, the unskilled households allocate all their labor to the CPR. Note here that the number of households classified in the unskilled class depends on the total amount of labor allocated to the CPR.

$$\begin{cases} L_c^U(L_c) = \int_1^{U(L_c)} 1di = U(L_c) \\ U(L_c) \ : \ E(x_U) = \frac{f(L_c)}{L_c} \end{cases} \quad (2.18)$$

Second, the middle-class households allocate only a share of their labor supply to the CPR.

$$\begin{cases} L_c^M(L_c) = \int_{U(L_c)}^{S} [\frac{C_{min} - \underline{\theta}_i}{\frac{f(L_c)}{L_c} - \underline{x}_i}] di \\ S \ : \ \underline{x}_S = C_{min} \end{cases} \quad (2.19)$$

S therefore represents the population in need of insurance. The size of the population in need of insurance is independent of the total amount of labor allocated to the CPR. However, the total amount L_c influences the repartition between unskilled and middle-class households.

CPR extraction constitutes a poverty trap if the average product of CPR extraction go below the minimum requirement. In this case, CPR extraction cannot properly insure the households. This situation occurs if too much labor is allocated to the CPR: $L > L_{max}$. In that case, both poor and middle-class households cannot get more than their minimum requirement and allocate all their labor to CPR extraction. Moreover, M households have to migrate until the average return $\frac{f(L_c)}{L_c}$ equals the minimum requirement C_{min}.

Thus, if CPR extraction does not constitute a poverty trap, the equilibrium amount of labor allocated to the CPR is:

$$\begin{cases} L_c = L_c^U + L_c^M \\ \frac{f(L_c)}{L_c} > C_{min} \\ M = 0 \end{cases} \quad (2.20)$$

Note here that the total amount of labor allocated to the CPR in the non-poverty-trap case is a fixed point of which the existence needs to be proven (see appendix C).

The equilibrium amount of labor allocated to the CPR in the poverty trap case is:

$$\begin{cases} L_c = L_{max} \\ \frac{f(L_c)}{L_c} = C_{min} \\ M = S - L_{max} \end{cases} \quad (2.21)$$

At this point, it is possible to describe the two types of situation.

2.4.4 Tragedy of the commons and poverty trap

It is well known that an open-access resource suffers of a tragedy of the commons: individuals do not take into account the negative externality of their actions on the others. In the case studied here, with CPR used as insurance, this phenomenon may lead to a poverty trap: the population in need of insurance (unskilled and middle class households) is trapped in CPR extraction and cannot get more than their minimum requirement. Moreover, some households have to migrate.

Insurance without poverty trap: We consider here the case where: $L_c \geq L_{max}$. Therefore, the insurance use of the CPR does not lead to a poverty trap. Nevertheless, CPR extraction is characterized by a tragedy-of-the-commons process. Note for example that both unskilled and middle class households would be better off with an insurance scheme. Indeed, middle class households could allocate all their labor to their private project, which is more profitable in expectation. Moreover, the unskilled households would be better off too, because the labor supply allocated to the commons and thus the tragedy-of-the-commons effect would be lower. Therefore, the average product of CPR extraction would be bigger. Figure 1 illustrate this case.

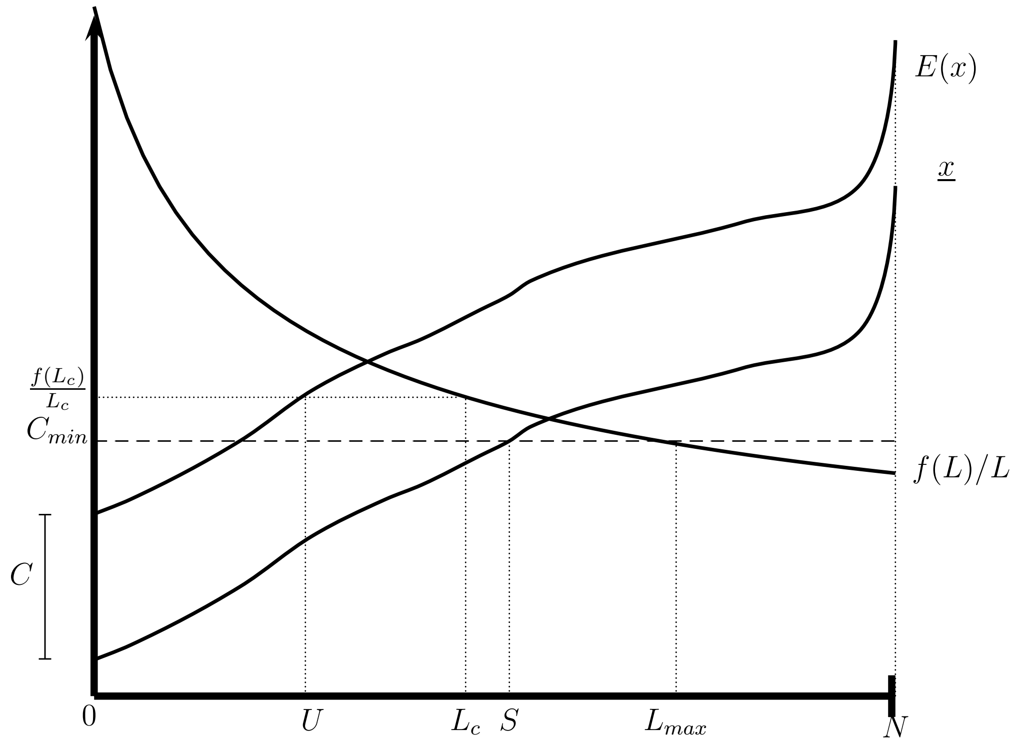


Fig. 2.1: Insurance with no poverty trap and common risk

Insurance with poverty trap The poverty-trap case is a result of: $S > L_c = L_{max}$. More precisely, it is essentially an extreme consequence of the tragedy of the commons described before. As already showed, M households have to migrate until the point at which the average product of CPR extraction reach the minimum requirement. At this point, middle class households have to allocate all their labor to the CPR in order to insure themselves. Therefore, both unskilled and middle class households are perfectly insured but cannot get more than their minimum requirement, which constitute a poverty trap (as defined in introduction). Figure 2 describes the poverty trap case. Note here that skilled households get the same outcome whatever is the type of situation.

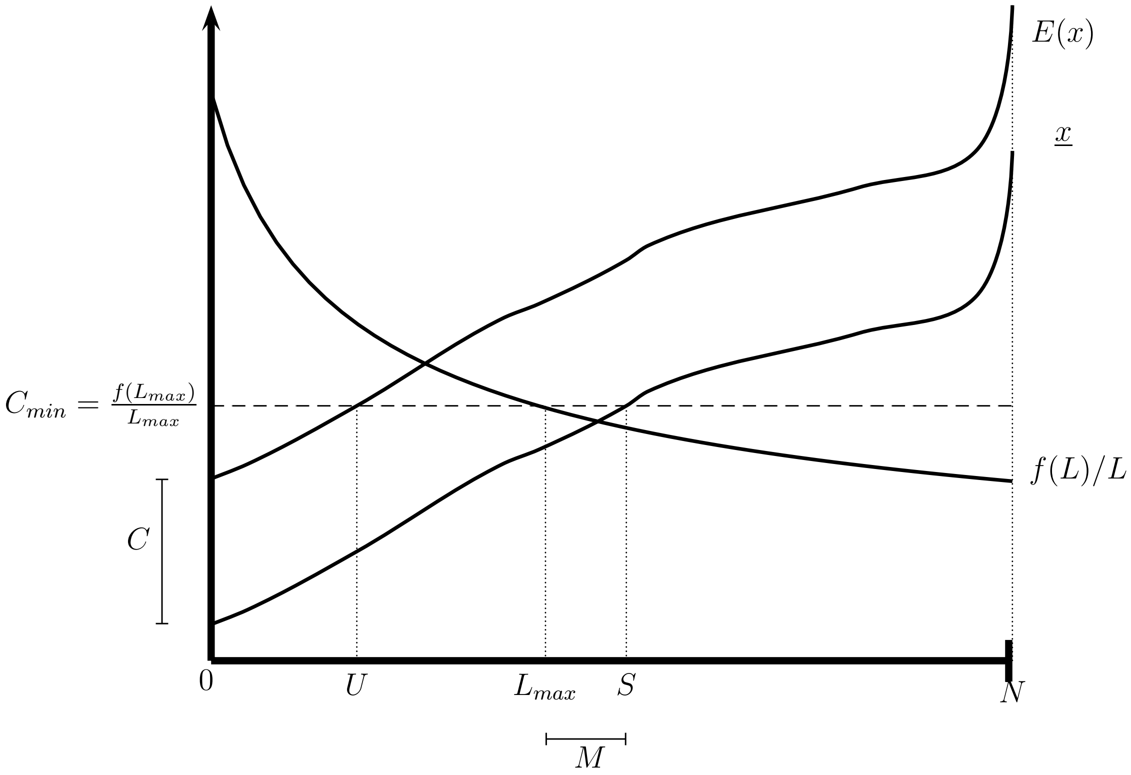


Fig. 2.2: Insurance with poverty trap and common risk

The causes of the poverty trap: A poverty trap is therefore the result of two main factors. First, population factors are important. If the population in need of insurance (S) is big, the poverty trap case is more likely. The size of this population is a consequence of two components: distribution of skills ($E(x)$) and distribution of risk ($\underline{x}$). Firstly, the bigger is the population with relatively high expected return on the private profit, the smaller is the unskilled population. Secondly, the smaller is the risk at which the households are exposed, the bigger is the population that does not depend on the resource.

Second, the production function of the CPR determines the threshold of population (L_{max}) that could exploit it. If the environment is fragile, it is quickly saturated and the threshold is low.

Proposition 2: *In a context of risk on the private projects, such as agriculture, the use of CPR extraction as insurance can lead to a poverty trap if the population in need of insurance is too large and the resource has small capacity. Then, both unskilled and middle* *class households are trapped in CPR extraction and cannot get more than their basic needs in return.*

Proof: A poverty trap situation is characterized by: $L_c = L_{max}$. S determine the equilibrium amount of labor allocated to the CPR (L_c), while the capacity of the resource determine the production function, and thus the maximum amount of labor allocated to the CPR (L_{max}).

As already mentioned, the poverty-trap situation is an extreme case of a tragedy of the commons. The only difference in terms of welfare between those two cases is the fact that the middle class *de facto* disappears when CPR extraction becomes a poverty trap. Indeed, middle class households can insure themselves only at the cost of allocating all their labor to the CPR. They lose therefore all the extra return they could get from their private project. Only two classes of households remain in the society: the unskilled and the skilled households.

Moreover, as shown in Baland and Francois (2005), privatization may not be a good solution in terms of welfare, since the improved efficiency may not compensate for the reduction of the insurance properties of the CPR.

2.5 Conclusion

The aim of this paper is to investigate the safety-net function of forest products in the economics of land-use change and deforestation. We analyze the trade-off between two land-uses. Agriculture is more profitable but is risky. In contrast, NTFP extraction is less profitable but is used to smooth consumption or to fill some consumption gaps when agricultural crops are bad.

The first model presented ignores some important features of poor agricultural households, which open opportunities for future research. First, households may compete for NTFP extraction if the forest is open access. The potential poverty-trap implications that NTFP extraction may create must then be taken into account. Indeed, if the population in need of safety net is large, and if the forest capacity is small, a tragedy-of-the-commons process may trap the less skilled households into NTFP extraction and deprive them of other development opportunities. The second model of the paper highlight this potential implication.

Second, considering more explicitly labor market integration could point outside opportunities for households, that would reduce the safety-net role of NTFP extraction and thus increase deforestation. Third, other types of risk-management could have several implications on the land use. For example, agricultural households could use livestock as a risk-management strategy, which could increase land clearing and deforestation. Fourth, the statement of risk-free NTFP extraction should be moderated, because of the existence of risk such as animal migration or price volatility. Finally, the two models presented are static, while dynamic modeling could allow for accumulation as insurance.

However, although quite simple and not considering some important factors such as dynamic effects or labor outside options, the model presented here stresses some important implications. We predict that a reduction in crop risk may have a negative impact on forest cover. Development policies often consider agricultural development as a priority. Moreover, an important objective is to reduce risk on poor agricultural households' income. Therefore, to reduce this impact, risk reduction policies should be combined with environmental and forest management policies. For example, payment for environmental services provided by forests may be an interesting tool. Indeed this kind of payment may enhance forest preservation and raise the "profitability" of forests.

Risk aversion of the household is positively correlated with forest cover. This result is quite intuitive, since forest products are a tool to reduce risk. In the economic analysis, households are typically more risk averse than entrepreneurs, generally risk neutral. Economic development may raise through market integration the separability between the utility and profit maximizing process. Households may become less risk averse, which could have a negative impact on forest cover. Moreover, market integration should provide to households new insurance and credit mechanisms, reducing the safety-net use of forest products described in this paper. This kind of market integration can thus indirectly lead to more deforestation.

Agricultural risk and the safety-net use of NTFP extraction is therefore an crucial issue with important economic and environmental implications such as deforestation, poverty-trap and degradation of commonly-held forests. Some empirical analysis of the relationships that link agricultural risk, poverty and deforestation could give interesting indications. Moreover, a natural extension of this paper would be to allow for land-use and labor allocation to be choice variables at the same time.

Finally a related issue is the study of potential conflicts of interest between local communities using the resource and forest loggers. In this context, corruption and lobbying powers have an important role, that could lead, for the local communities, to the deprivation of the resource.

Appendix A: comparative statics

Proof of proposition 1: we take the first derivatives of the optimal share of agricultural land R^* with respect to our variables of interest. We define a risk reduction as a rise in $\underline{x}$ and a fall in $\overline{x}$, with a constant expected output $E(x)$: $(1-\delta)d\underline{x} + \delta d\overline{x} = 0$; $d\underline{x} > 0$; $d\overline{x} < 0$.

$$\left(\frac{\partial R^*}{\partial \underline{x}} - \frac{(1-\delta)}{\delta}\frac{\partial R^*}{\partial \overline{x}}\right).d\underline{x} = N\frac{[\ln(\frac{\delta(\overline{x}-f)}{(1-\delta)(f-\underline{x})}) + \frac{(\overline{x}-\underline{x})(E(x)-f)}{(\overline{x}-f)(f-\underline{x})}]}{\delta\alpha(\overline{x}-\underline{x})^2}.d\underline{x} > 0 \qquad (2.22)$$

$$\frac{\partial R^*}{\partial \alpha} = \frac{-N\ln[\frac{\delta(\overline{x}-f)}{(1-\delta)(f-\underline{x})}]}{\alpha^2[\overline{x}-\underline{x}]} < 0 \qquad (2.23)$$

$$\frac{\partial R^*}{\partial N} = \frac{\ln[\frac{\delta(\overline{x}-f)}{(1-\delta)(f-\underline{x})}]}{\alpha[\overline{x}-\underline{x}]} > 0 \qquad (2.24)$$

$$\frac{\partial R^*}{\partial f} = \frac{N}{\alpha(\overline{x}-\underline{x})}\left[\frac{-1}{(\overline{x}-f)} - \frac{1}{(f-\underline{x})}\right] < 0 \qquad (2.25)$$

Appendix B: a numerical illustration

The values of the variables (table 1) are adapted from Angelsen (1995, 1999). They correspond as far as possible to a household survey done in the Seberida district, Riau, Sumatra. For the variables not corresponding to the survey (i.e δ, $\overline{x}$, $\underline{x}$, f and α), we use values corresponding to the basic conditions of the model ((2.3), (2.2)).

Tab. 2.1: **Parameter values of the numerical simulation**

Variable	Symbol	Initial value	Adapted value
Total land area	H	1932	1
Number of households	N	82	0.042
Expected output in agriculture	$E(x)$	500	0.26
Low level of output	$\underline{x}$	n.a	0.15
High level of output	$\overline{x}$	n.a	0.37
Forest products intensity	f	n.a	0.22
Probability of $\overline{x}$	δ	n.a	0.5
Absolute Risk Aversion coefficient	α	n.a	0.5

n.a : not available

Source: Angelsen (1995, 1999)

Tab. 2.2: **Results of the numerical simulation**

	Change in parameters	Diversification
Initial situation	Cf Table 2	0.29
Risk reduction	$\overline{x} = 0.36$; $\underline{x} = 0.16$	0.36
Forest profitability	$f = 0.2$	0.47
	$f = 0.24$	0.14
Risk aversion	$\alpha = 0.3$	0.48
	$\alpha = 0.7$	0.21

Appendix C: L_c as a fixed point

The total amount of labor allocated to the CPR in the non-poverty-trap case is a fixed point. First, we need to prove that $U(L_c) + L_c^M(L_c)$ is decreasing in L_c.

Note that $U(L_c)$ is decreasing in L_c. Indeed the number of unskilled people is defined as: $E(x_U) \leq Y(L_c)/L_c$, which is decreasing in L_c by assumption.

Therefore, if L_c increases, some households pass from the unskilled class to the middle class. Those households reduce the amount of labor allocated to the CPR. Indeed, the unskilled households allocate all their labor to the CPR, while middle-class households allocate only a share of it.

Overall, an increase of L_c induces a reduction in labor allocated by the unskilled class, which over-compensate the raise in labor allocated by the middle-class households. It follows that the total amount of labor allocated to the CPR decreases.

Second, $U(L_c)+L_c^M(L_c)$ is positive, as the amount of labor allocated by insurance-seeking households is necessarily positive. It follows that $L_c = U(L_c) + L_c^M(L_c)$ is a fixed point.

3. FORESTRY SECTOR CONCENTRATION, CORRUPTION AND FOREST OVER-EXPLOITATION

Abstract

This paper develops the analysis of the relationship between concentration of the forestry sector, corruption and forest over-exploitation. Policy maker and bureaucratic corruption are considered sequentially. Overall, the corrupt policy maker chooses a larger share of forest to exploit and sets less stringent harvest quotas. Moreover, if the forestry sector is a well-organized lobby, the policy maker sets a larger number of firms harvesting the forest and smaller concessions, which increases the impact of bureaucratic corruption.

Keywords: corruption, concentration, forest exploitation.

JEL classification: D73, Q23.

3.1 Introduction

Corruption is one of the main features behind deforestation and over-exploitation of natural resources, especially in developing countries. Illegal logging represents more than 90 per cent of logging in Indonesia (Dudley et al., 1995), 80 per cent in Brazil and 90 per cent in Cambodia (Winbourne, 2002). However, several forms of corruption can be distinguished. An important distinction is between policy maker and bureaucratic corruption (Rose-Ackerman, 1978; World Bank, 2000; Wilson and Damania, 2005). First, policy maker or "grand" corruption consists of offering bribes to the policy maker in order to influence his policy choices. Second, bureaucratic or "petty" corruption consists of paying bribes to bureaucrats to avoid the consequences of a particular rule.

Wilson and Damania (2005) first consider this two-scales corruption and analyze the impact of political competition and corruption on environmental policy stringency. They show that political competition increases the stringency of environmental policy, but that its impact is limited. Indeed, if judicial institutions are weak, an increase in political competition may increase bureaucratic corruption, which limits the enforcement of environmental policy. Moreover, political competition does not necessarily deter bureaucratic corruption.

We build on Wilson and Damania (2005) and study the occurrence of corruption at different levels of governments and its effects on forest exploitation in developing countries. We extend from Wilson and Damania in two directions. First, we allow for bureaucratic and policy maker corruption to have different objectives. Indeed, policy maker corruption may take the form of logging companies paying bribes to the policy maker to increase the size of the forest to exploit. For example, in Indonesia, logging concessions covering more than half the country's total forest area were awarded by former President Suharto, many of them to his relatives and political allies (Global Forest Watch, World Resource Institute). In 1995, in Cambodia, the two prime ministers in power at that time gave concessions, contrary to the law, for the remaining parts of tropical forest (Harris White, 1996). Conversely, bureaucratic corruption may take the form of a logging firm bribing a bureaucrat so that he underreports the logging volumes. We take the corruption objectives as given without exploring their motivations[1]. In contrast, Wilson and Damania consider that both policy maker and bureaucratic corruption have the same objective (namely reducing the impact of an environmental tax).

Second, we study an incumbent government and analyze the impact of the forestry sector concentration on corruption and the forest policy. In contrast, Wilson and Damania consider the impact of corruption on the environmental policy in the context of political parties competing for power.

An important pattern of forest management is the allocation of forest concessions to logging companies. The policy maker is supposed to decide both the size of the forest to exploit, the number of firms exploiting it and thus the concessions size. We consider that the firms are price takers. Therefore, we take the number of firms exploiting the forest as an indicator of the forestry sector concentration. An interesting question that has not been addressed in the literature is thus to wonder which relationships may link the concentration of the forestry sector with corruption and over-exploitation of the forest resources. Indeed,

[1] For an overview of the corrupt and illegal activities in the forestry sector, see Contreras-Hermosilla (2001) and Callister (1999)

developing countries usually have limited means to fight corruption. An increased knowledge of the links between forestry sector's concentration and corruption may provide some tool to reduce the impact of corruption, or at least give an indication of the source and impact of corruption on forests over-exploitation.

As mentioned before, addressing rigorously this relationship requires to precise which type of corruption is considered. Of course, the two types of corruption are rarely observed separately. Corruption is generally a systemic phenomenon. A corrupted policy maker often coexists with a corrupted bureaucracy, and *vice versa*. Moreover, both kinds of corruption may interact. In this paper, policy maker and bureaucratic corruption are analyzed sequentially, proceeding backward.

The first part of the paper investigates the impact of the forestry sector concentration on bureaucratic corruption and on forest over-exploitation, taking the forest policy as given. The logging firms may be inspected by a bureaucrat they might be willing to bribe. Moreover, an uncorrupt authority may audit both the firm and the bureaucrat to verify the enforcement of the forest policy. Intuitively, two factors influence the link between concentration and the impact of bureaucratic corruption. First, a large number of firms reduces the probability for the firm to be inspected by the bureaucrat and audited by the authority. Therefore, a large number of firms on the market decreases the expected penalty and is an incentive not to respect the logging rules and to over-exploit the forest resources. Second, if the marginal productivity of harvest decreases with the size of concessions, small concessions also represent an incentive to over-exploit the forest. Considering previous studies, it appears that smaller concessions may incite the logger to intensify its logging efforts, and thus exceed the logging limits. Overall it appears that a larger number of firms tends to increase forest over-exploitation.

The second part presents a model of policy maker corruption, following Grossman and Helpman (1994). The policy maker chooses the forest policy, which consists of the number of harvesting firms, the size of the forest to exploit and the maximum harvest intensity. It maximizes a weighted sum of social welfare and received bribes. The firms act as one lobby, bribing the policy maker to increase the size of the forest to exploit. In this context, the policy maker tends to increase the size of the exploited forest. Moreover, if the lobby has small coordination costs, the policy maker chooses a larger number of firms to exploit the forest and sets less stringent maximum harvest intensity, in order to indirectly increase the received bribe. The model presented supports therefore the concept of systemic corruption: the corrupt policy maker sets a large number of firms, which increases the impact of bureaucratic corruption.

3.2 Bureaucratic corruption and forestry sector concentration

The policy maker is assumed to have chosen the forest policy, which consists of the size of the forest to exploit $\overline{F}$, the number of firms exploiting the forest, $\overline{N}$, and the maximum harvest intensity, $\overline{e}$. This last policy instrument can be considered as a quota [2]. For example, it can be the minimum rotation age, or a maximum amount of timber to log per hectare. We proceed backward. $\overline{F}$, $\overline{N}$ and $\overline{e}$ are considered as given by the firm. In the next section, the choice process of the forest policy is described.

We assume that the logging firms have an interest not to respect the quota and to set $e > \overline{e}$, i.e a positive level of non-compliance $v = (e - \overline{e}) > 0$. To verify that the quota is respected, bureaucrats may inspect the logging firm. However, the means being limited, only a number N^c of firms can be inspected. Moreover, if the inspected firm does not respect the harvest limit, it may offer a bribe B to the bureaucrat, in order for him to declare that the quota has been respected.

Finally, an independent uncorrupt authority is in charge of auditing both the bureaucrat and the firm, to verify the enforcement of the forest policy. If both parties are convicted of over-exploitation and corruption, the authority imposes some penalties (proportional to the level of non-compliance) $h^f(v)$ and $h^b(v)$ to the firm and the bureaucrat, respectively. It is assumed that: $\partial h^i/\partial v > 0$ and $\partial^2 h^i/\partial v^2 > 0$, for i = f, b. The authority audits a share σ of the inspected firms. Assuming such a kind of authority allows to consider different cases of anti-corruption policies. As an extreme case, the authority has no mean to audit firms: $\sigma = 0$. As another extreme, the authority has full mean to fight against corruption, and audit every inspected firm: $\sigma = 1$.

[2] The case of an environmental tax is addressed in Damania and Wilson (2005). The level of non-compliance would then reduce the tax basis.

Following the political economy literature, we assume that the parameters related to the enforcement of forest policy (N^c, σ, $h^f(v)$ and $h^b(v)$) are exogenous. Indeed, these variables depend on the country's resources, which are heavily constrained in developing countries. Thus, although crucial in fighting against corruption, these policy instruments are assumed to be exogenous, mainly because of budget constraint. However, one could argue that fines collected may finance the fight against corruption. A next step to the analysis could therefore be to make the corruption policy endogenous.

3.2.1 The firm-bureaucrat interaction

The Firm

Each of the $\overline{N}$ identical firms[3] receives the right to exploit a concession of size $s = \frac{\overline{F}}{N}$. Harvest and land-holding costs are integrated in the harvest function. Timber price is also integrated in the net harvest function. Therefore, concentration does not represent here market power, as the firms are price takers. Concentration is only addressed trough the impact of the number of logging firms and the concessions size on corruption.

The net harvest function takes the form $H(s; e)$, with standard properties[4]: $H_e > 0, H_{ee} < 0, H_s > 0, H_{ss} < 0$. The number of firms and the size of the exploited forest determine the concessions size, which implies: $H(s; e) = H(\frac{\overline{F}}{N}, e)$, $H_F = \frac{H_s}{N} > 0, H_N = \frac{-FH_s}{N^2} < 0, H_{FF} = \frac{H_{ss}}{N^2} < 0, H_{NN} = \frac{FH_{ss}}{N^4} < 0$.

It appears difficult to have a clear idea of the link between the size of the concessions and the marginal productivity of harvest (H_{se}). On one side, transport costs and the costs of opening access (mainly the creation of roads) to the forest are probably positively correlated with the size of the concession, which tend to decrease the marginal productivity of harvest. On the other side, congestion should be more important in the case of small firms, which would have the opposite impact on the marginal productivity of harvest.

Only few studies treat this issue. Ruiz Perez et al. (2005) find a negative relationship between the size of concessions and logging ratio in the Congo Basin. This suggests a higher pressure on small concessions (and thus $H_{se} < 0$). Gray (2002) also describes small concessions as an incentive for unsustainable logging. Although empirical evidence is rather

[3] In reality, the coexistence of large and small firms exploiting the forest is usually observed.

[4] The subscripts refer to first and second derivatives.

meagre, it seems that marginal productivity of harvest is negatively correlated with the size of concessions: $H_{se} < 0$. Consequently, the number of logging firms increases the harvest marginal productivity, while the size of the exploited forest decreases it: $H_{Ne} = \frac{-FH_{se}}{N^2} > 0$, $H_{Fe} = \frac{H_{se}}{N} < 0$.

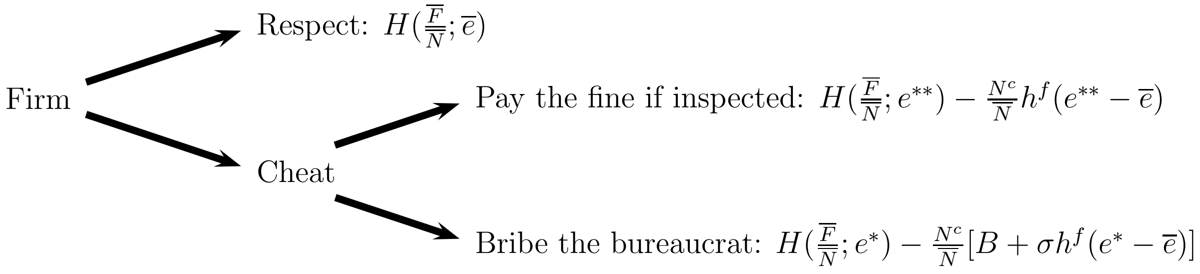
The firms have interest to exceed the cutting quota (i.e the maximum harvest intensity) imposed by the policy maker. We do not consider explicitly the incentive to over-exploit the forest. Short-term horizons (e.g: short-term concessions or political instability) or non-internalization of externalities could represent incentives to exceed the logging limit. Indeed, an inter-temporal profit maximization would suggest that a firm would not over-exploit the resource because of expected future lost. Unsustainable forest exploitation is nevertheless frequently observed. We take these incentives as given and focus the analysis on their consequences.

The firm may be inspected (with probability $(\frac{N^c}{N})$), and possibly pay the bureaucrat a bribe B. Moreover, with probability $(\sigma\frac{N^c}{N})$, the authority audits and the firm has to pay a penalty $h^f(v)$.

Overall, the firm has to make two choices. First, it chooses whether to respect the quota (set $e = \overline{e}$) or not. Second, if the choice of cheating has been made and if the firm is inspected, it has to choose whether to bribe the bureaucrat (and set $e^* > \overline{e}$) or to accept to pay the fine (and set $e^{**} > \overline{e}$). If choosing to pay a bribe, the firm still risks to be audited by the independent authority (with probability σ) and pay the fine anyway. The following table summarizes the different strategies and payoffs.

	Not inspected	Inspected Not audited	Inspected by the bureaucrat Audited by the authority
Probability	$(1-\frac{N^c}{N})$	$(1-\sigma)\frac{N^c}{N}$	$\sigma\frac{N^c}{N}$
Respect	$H(\frac{\overline{F}}{N};\overline{e})$	$H(\frac{\overline{F}}{N};\overline{e})$	$H(\frac{\overline{F}}{N};\overline{e})$
Cheat/Pay the fine	$H(\frac{\overline{F}}{N};e^{**})$	$H(\frac{\overline{F}}{N};e^{**}) - h^f(e^{**}-\overline{e})$	$H(\frac{\overline{F}}{N};e^{**}) - h^f(e^{**}-\overline{e})$
Cheat/ Bribe	$H(\frac{\overline{F}}{N};e^{*})$	$H(\frac{\overline{F}}{N};e^{*}) - B$	$H(\frac{\overline{F}}{N};e^{*}) - [B + h^f(e^{*}-\overline{e})]$

Consequently the strategies and their related expected payoffs are presented in the following figure.



The objective of the fine is to enforce the logging quota and therefore deter incentives to cheat. Thus, it seems reasonable to assume that the fine is set such that the *cheat/pay-the-fine* strategy is dominated by the *respect* strategy, which implies that the expected fine should exceed the harvest gains from cheating:

$$\frac{N^c}{\overline{N}}h^f(e^{**}-\overline{e}) > H(\frac{\overline{F}}{\overline{N}};\overline{e}) - H(\frac{\overline{F}}{\overline{N}};e^{**}) \tag{3.1}$$

Moreover, the *cheat/bribe* strategy is assumed to be strictly dominant, which implies:

$$B \;<\; \frac{\overline{N}}{N^c}(H(\frac{\overline{F}}{\overline{N}};e^{*}) - H(\frac{\overline{F}}{\overline{N}};\overline{e})) - \sigma h^f(e^{*}-\overline{e}) \equiv \overline{B} \tag{3.2}$$

The *cheat/bribe* strategy is chosen if the expected bribe is cheap enough to compensate for the potential fine involved by the audit. $\overline{B}$ therefore represents the reservation value of the bribe for the firm.

The firm's expected net benefit from the bribe is the expected payoff from the *cheat/bribe* strategy, minus the payoff of the *respect* strategy, i.e. the safe strategy:

$$\Psi^f = H(\frac{\overline{F}}{\overline{N}};e) - \frac{N^c}{\overline{N}}[B+\sigma h^f(v)] - H(\frac{\overline{F}}{\overline{N}};\overline{e}) \tag{3.3}$$

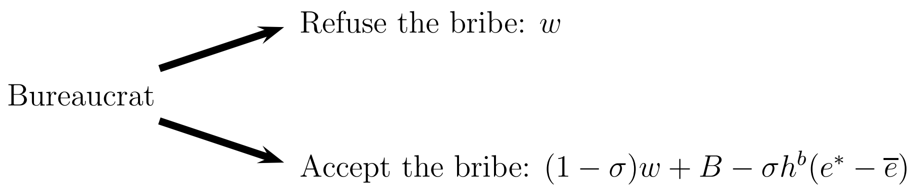
When choosing the *cheat/bribe* strategy, the firm gets a larger net output $H(\frac{\overline{F}}{\overline{N}};e)$. Its is inspected by the bureaucrat with probability $\frac{N^c}{\overline{N}}$ and pay a bribe B. Moreover, it may be convicted by the audit authority with probability $\frac{N^c}{\overline{N}}\sigma$ and pay a fine $h^f(v)$. Finally, the *respect* strategy provides a safe payoff $H(\frac{\overline{F}}{\overline{N}};\overline{e})$.

The bureaucrat

The bureaucrat is risk-neutral and gets a wage w for each firm inspected. Assuming the inspected firm did not respect the harvest quota and offers a bribe, he may accept the offer and be audited with probability σ. If he is convicted, he looses his wage and is imposed a penalty $h^b(v)$. The bureaucrat has therefore to make a choice between two behaviors: to refuse the bribe and to make the firm pay the fine, or to accept it and to take the risk of being punished. The payoffs related to each strategy in each case are given in the following table.

	Not audited	Audited
Probability	$(1-\sigma)$	σ
Refuse the bribe	w	w
Accept the bribe	$w+B$	$B-h^b(v)$

The following figure shows the expected payoffs related to both strategies.



We consider the situation in which accepting the bribe is the dominant strategy, implying:

$$B > \sigma(w + h^b(e^* - \overline{e})) \equiv \underline{B} \tag{3.4}$$

Indeed, the bureaucrat accepts the bribe if it is larger than the expected loss of being audited. $\underline{B}$ is therefore the reservation value of the bribe for the bureaucrat. The bureaucrat's net expected payoff is therefore his expected payoff of accepting the bribe, minus the payoff of refusing it:

$$\Psi^b = (1-\sigma)w + B - \sigma h^b(v) - w \tag{3.5}$$

If he accepts the bribe B, the bureaucrat is audited with probability σ and pays a fine $h^b(v)$. Moreover, he only keeps his wage w with probability $(1-\sigma)$ (i.e. if he is not audited). Finally, the *refuse* strategy generates a safe payoff of w.

3.2.2 Equilibrium harvest intensity and bribe

The process to the equilibrium could be described as a *maximize-then-share-the-pie* process. First, the harvest intensity of the firm is set in order to maximize the joint payoffs of both parties, taking $\overline{N}$, $\overline{F}$ and $\overline{e}$ as given. Second, the firm and the bureaucrat share the surplus through a Nash bargaining process.

Equilibrium harvest intensity

Following Wilson and Damania (2005), the equilibrium harvest intensity is set in order to maximize the joint net payoffs of the firm and the bureaucrat.

$$\max_e \ \Omega(e) = \psi^f + \psi^b = H(\frac{\overline{F}}{\overline{N}}; e) - H(\frac{\overline{F}}{\overline{N}}; \overline{e}) - \sigma w + B(1 - \frac{N^c}{\overline{N}}) - \sigma[\frac{N^c}{\overline{N}} h^f(v) + h^b(v)] \quad (3.6)$$

The first order condition is:

$$\Omega_e = H_e - \sigma[\frac{N^c}{\overline{N}} h_v^f + h_v^b] = 0 \quad (3.7)$$

The firm's optimal harvest intensity is implicitly given by equation (3.7). In equilibrium, the firm's actual intensity of harvest $e^*(\overline{N}, \overline{F}, \overline{e}, N^c, \sigma, h_v^f, h_v^b)$ is set such that the marginal productivity of harvest equals the marginal expected penalty.

Considering the factors influencing the firm's harvest intensity, the parameters related to the control of the harvest volumes, σ, N^c, h_v^f and h_v^b, unsurprisingly induce a smaller harvest intensity in equilibrium: $e_x^* < 0$, for $x = \sigma, N^c, h_v^f, h_v^b$. Controlling more intensively the firm (and the bureaucrat) thus decreases the equilibrium harvest intensity.

The impact of the size of the exploited forest $\overline{F}$ on the equilibrium harvest intensity depends on the impact of the concession size on the marginal productivity of harvest, assumed to be negative. An increase in the size of the exploited forest then leads to a decrease in the equilibrium harvest intensity.

$$e_{\overline{F}}^* = -\frac{\frac{H_{se}}{\overline{N}}}{H_{ee} - \sigma(\frac{N^c}{\overline{N}} h_{vv}^f + h_{vv}^b)} < 0 \quad (3.8)$$

Ceteris paribus, an increase in the size of the exploited forest decreases the harvest intensity of the firms. In this context, it seems that there is a trade off between primary forest preservation (through the size of the exploited forest) and over-exploitation of harvested forest (through harvest intensity).

Finally, the harvest quota $\overline{e}$ has a positive impact on the effective harvest intensity. Indeed, a less stringent harvest quota reduces the extend of the potential fine:

$$e_{\overline{e}}^* = \frac{-\sigma(\frac{N^c}{\overline{N}} h_{vv}^f + h_{vv}^b)}{H_{ee} - \sigma(\frac{N^c}{\overline{N}} h_{vv}^f + h_{vv}^b)} > 0 \quad (3.9)$$

Concentration and harvest intensity: The impact of $\overline{N}$ on the equilibrium harvest level is:

$$e^*_{\overline{N}} = -\frac{\frac{-FH_{se}}{N^2} + \frac{N^c}{\overline{N}^2}\sigma h^f_v}{H_{ee} - \sigma(\frac{N^c}{\overline{N}}h^f_{vv} + h^b_{vv})} > 0 \tag{3.10}$$

The sign of the denominator being unambiguously negative, equation (3.10) has the sign of $[\frac{-FH_{se}}{N^2} + \frac{N^c}{\overline{N}^2}\sigma h^f_v]$. Two components determine this sign. First, a large number of firms reduces the probability of being inspected by the bureaucrat and audited by the authority, and thus reduces the expected marginal fine. This smaller expected fine is an incentive to raise the harvest intensity and over-exploitation of the resource. Second, the impact of $\overline{N}$ on the marginal productivity of harvest is important. Since an increase in the concessions size is assumed to decrease the marginal productivity of harvest ($H_{se} < 0$), a large number of firms tends to increase the harvest intensity ($H_{Ne} > 0$). Overall, a larger number of firms exploiting the forest tends to increase the equilibrium harvest intensity and forest over-exploitation.

Equilibrium bribe

The equilibrium bribe is set trough a Nash bargaining process. Both parties are supposed to have the same bargaining power, so that they share equally the benefit of not respecting the harvest quota. We consider here that the bargaining is successful. It implies that the equilibrium bribe must respect the reservation values described in equations (3.2) and (3.4).

The equilibrium bribe is set maximizing the Nash bargain:

$$\max_B \ \Psi^f\Psi^b = [H(\frac{\overline{F}}{\overline{N}}; e^*) - \frac{N^c}{\overline{N}}(B + \sigma h^f(v)) - H(\frac{\overline{F}}{\overline{N}}; \overline{e})][-\sigma w + B - \sigma h^b(v)] \tag{3.11}$$

The first order condition gives:

$$B = \frac{1}{2}[\frac{\overline{N}}{N^c}(H(\frac{\overline{F}}{\overline{N}}; e^*) - H(\frac{\overline{F}}{\overline{N}}; \overline{e})) + \sigma w - \sigma(h^f(v) - h^b(v))] \tag{3.12}$$

This equilibrium bribe must lie in between the reservation values of both parties $[\underline{B}, \overline{B}]$, which implies that the benefit of not respecting the quota must exceed the global expected loss of being convicted:

$$H(\frac{\overline{F}}{\overline{N}}; e^*) - H(\frac{\overline{F}}{\overline{N}}; \overline{e}) \quad > \quad \frac{N^c}{\overline{N}}\sigma(w + h^f(v) + h^b(v)) \tag{3.13}$$

The equilibrium bribe is consistent with Damania and Wilson (2005). First, in order to insure that higher fines induce a decrease in the equilibrium bribe, we need to assume:

$h^f > h^b$. Indeed, the punishment has to be more severe on the bribe giver. For otherwise, a higher fine on the recipient would incite the giver to raise the bribe to compensate for the recipient's expected fine. This assumption is consistent with the conclusions emerging from the literature (Mookherjee and Png, 1995; Basu et al., 1992). Second, the equilibrium bribe raises with the gain in revenue from not respected the quota, $(H(\frac{\overline{F}}{\overline{N}}; e^*) - H(\frac{\overline{F}}{\overline{N}}; \overline{e}))$. Indeed, if the quota is stringent with respect to the harvest function, the incentive to cheat is high. Finally, the impact of the probability of being audited σ depends on what both agents have to loose: if the bureaucrat has more to loose than the firm $(w + h^b(v) > h^f(v))$, the bribe is increasing in σ and *vice versa*.

In contrast with Damania and Wilson (2005), the equilibrium bribe is positively correlated with the agent's wage. Indeed, the authors do not consider the wage as lost if the agent is convicted. However, it seems reasonable to assume that the bureaucrat is deprived from his wage if he is convicted of not enforcing the quota and being corrupt. Moreover, this assumption provides the insight that a well-paid bureaucrat is more expensive to corrupt, simply because he has more to lose.

Furthermore, the bribe reduces with the number of firms inspected by the bureaucrat N^c. Indeed, N^c raises the probability of being inspected, and thus reduces the expected share of extra-harvest got by the firm, which naturally reduces its incentive to cheat.

Finally, the impact of the number of firms exploiting the forest is not clear:

$$B_{\overline{N}} = \frac{1}{2N^c}[(H(\frac{\overline{F}}{\overline{N}}; e^*) - H(\frac{\overline{F}}{\overline{N}}; \overline{e})) + \frac{\overline{F}}{\overline{N}}(H_s(\frac{\overline{F}}{\overline{N}}, \overline{e}) - H_s(\frac{\overline{F}}{\overline{N}}, e^*))] \tag{3.14}$$

While the first part of the equation, $(H(\frac{\overline{F}}{\overline{N}}; e^*) - H(\frac{\overline{F}}{\overline{N}}; \overline{e}))$, which corresponds to the productive incentive to cheat, is positive, the second part, $(H_s(\frac{\overline{F}}{\overline{N}}, \overline{e}) - H_s(\frac{\overline{F}}{\overline{N}}, e^*))$, depends on the cross derivative of the harvest function H_{se}, assumed to be negative. Overall, even if H_{se} is negative, it seems reasonable to assume that a large firm pays a higher bribe to the bureaucrat.

3.3 Concentration and policy maker corruption

Proceeding backward, we analyze now the choice process of the forest policy ($\overline{N}$, $\overline{F}$ and $\overline{e}$). The policy maker is assumed to choose first the number of firms, and then the harvest quota and the size of the exploited forest. The firms in the forestry sector act as one lobby, the aim of which is to increase the size of the forest to exploit.

Note here that the lobby could also bribe the policy maker to set less stringent harvest quota. Nevertheless, logging quotas (or other harvest limits) in most countries are often set in order to insure sustainability. Indeed, unsustainable logging policy is hardly accepted politically. The major concern in this context is the enforcement of the rules, through the limitation of bureaucratic corruption. In contrast, policy maker corruption appears to be more likely to increase the share of exploited forest (as well as to influence the process of concessions allocation).

The total forest area is set to 1. Thus $\overline{F}$ is the share of the forest to be exploited, while the share $(1-\overline{F})$ represents protected primary forest.

3.3.1 The firm-policy maker interaction

To address this issue, we build on Grossman and Helpman (1994). The policy maker's objective function is a weighted sum of social welfare and bribes.

$$G(e,N,F) = \alpha W(NH(\frac{F}{N};e);(1-F);e) + (1-\alpha)C(F) \tag{3.15}$$

W is the social welfare function. It is increasing in the total harvested volumes. Moreover, the social welfare function is increasing in the size of primary protected forests $(1-F)$ (and thus decreasing in the size of exploited forest), because of the environmental services provided, such as biodiversity conservation or hydrological benefits. Finally the social welfare function is decreasing in the harvest intensity, assimilated to environmental degradation (biodiversity loss, erosion, wildlife habitat degradation): $W_H > 0$, $W_F < 0$ $W_e < 0$, $W_{HH} < 0$, $W_{FF} < 0$ and $W_{ee} < 0$. $(1-\alpha)$ is the degree of corruptibility of the policy maker and $C(F)$ is the bribe schedule offered by the lobby to the policy maker.

The forestry sector acts as a lobby. Its payoff is therefore the total harvested volumes of the sector minus the bribe paid to the policy maker.

$$\Pi(F) = NH(\frac{F}{N};e) - (1+\lambda(N))C(F) \tag{3.16}$$

The effect of N on the lobby coordination is captured by $\lambda(N)$, which corresponds to the coordination costs of the lobby and the costs due to free rider behaviors by the lobby members. This set up follows Laffont and Tirole (1991) and Fredriksson et al. (2004). It is assumed that: $\lambda_N > 0$.

3.3.2 Equilibrium forest policy

The equilibrium consists of the size of exploited forest $\overline{F}$, the harvest quota $\overline{e}$ and the number of firms exploiting the forest $\overline{N}$.

Equilibrium size of exploited forest

The conditions for equilibrium are consistent with the political economy literature: $\overline{F}$ maximizes both (i) G(F) and (ii) $(G(F) + \Pi(F))$. The first order conditions are:

$$(i) \quad \alpha W_H H_s + \alpha W_F + (1-\alpha)C_F = 0 \tag{3.17}$$

$$(ii) \quad \alpha W_H H_s + \alpha W_F + (1-\alpha)C_F + H_s - (1+\lambda(N))C_F = 0 \tag{3.18}$$

Which imply:

$$H_s(\alpha W_H + \frac{1-\alpha}{1+\lambda(N)}) + \alpha W_F = 0 \tag{3.19}$$

Which gives implicitly the equilibrium size of exploited forest $\overline{F}$. Note here that a more corrupt policy maker (with low α) tends unsurprisingly to put more weight on the harvest volumes, which tends to increase the size of the exploited forest.

Impact of the number of firms on the equilibrium size of exploited forest: The impact of $\overline{N}$ on $\overline{F}$ is given by:

$$\overline{F}_N = -\frac{(\frac{2H_s}{N} - \frac{H_{ss}}{N^2})(\alpha W_H + \frac{1-\alpha}{1+\lambda(N)}) - \frac{(1-\alpha)\lambda_N}{(1+\lambda(N))^2}H_s}{\frac{H_{ss}}{N}(\alpha W_H + \frac{1-\alpha}{1+\lambda(N)}) + \alpha W_{FF}} \tag{3.20}$$

The denominator of (3.20) is unambiguously negative. The sign of the equation is thus the sign of the nominator. Two components can be distinguished. First, a larger number of firms increases the coordination costs of the lobby, which tends to decrease the size of the exploited forest. Second, when choosing $\overline{F}$, the policy maker takes into account the impact of the size of concessions on the total harvest. If the number of firm is large, the policy maker tends to increase the size of the forest to exploit in order to increase the size of the concessions. The nominator may thus be negative if the lobby is not well organized and has large coordination costs.

Equilibrium harvest quota and number of firms

Although the lobby only offers a bribe to the policy maker in order to influence the size of the exploited forest, corruption has an indirect impact on the equilibrium harvest quota and number of firms. Indeed, both variables have an influence on the lobby's profit, and therefore an impact on the bribe offered. The first order conditions of the policy maker's objective give:

$$\alpha(W_H H_e + W_e) + (1-\alpha)C_e = 0 \tag{3.21}$$

$$\alpha(H(\frac{F}{N}; e) - \frac{FH_s}{N}) + (1-\alpha)C_N = 0 \tag{3.22}$$

Those two equations give implicitly the equilibrium harvest quota $\overline{e}$ and number of firms $\overline{N}$.

The choice of policies $\overline{e}$ and $\overline{N}$ has indirectly an impact on the equilibrium bribe. The sign of this impact depends on the impact of the policy on the lobby profits. First, an increase in $\overline{e}$ increases unambiguously the lobby's profit, which represents an incentive for the lobby to raise its bribe. Second, an increase in $\overline{N}$ raises the lobby's profit (and thus increases the equilibrium bribe) only if the marginal coordination costs λ_N and the decrease in productivity due to the size reduction H_s are small:

$$\frac{\partial \Pi}{\partial e} = NH_e > 0 \tag{3.23}$$

$$\frac{\partial \Pi}{\partial N} = H(\frac{F}{N}; e) - \frac{F}{N}H_s - \lambda_N C(F) \tag{3.24}$$

Therefore, if the policy maker receives a bribe in order to increase the size of the forest to exploit, it might at the same time set less stringent quota than an uncorrupt policy maker, in order to increase the profitability of the harvested forest, and thus the equilibrium bribe. Moreover, if the lobby is well-organized and if the harvest volumes do not increase too much with the size of the concessions, the policy maker is likely to set a larger number of firm in the forestry sector, in order to increase the equilibrium bribe.

Proposition : *If the lobby is well organized, with small coordination and transaction costs, a larger number of firms exploiting the resource tends to increase the size of the exploited forest $\overline{F}$. Moreover, a* cascade effect *illustrate the impact of corruption in the forestry* *sector: even if the lobby only offers a bribe to the policy maker for an increase in the size of the forest to exploit, the policy maker tends also to set less stringent harvest quota in order to increase the equilibrium bribe. Moreover, the policy maker chooses a larger number of firms to exploit the forest, which tends to increase the lobby's influence and the impact of bureaucratic corruption.*

3.4 Conclusion

This paper analyzes the impact of concentration of the forestry sector and corruption on forest over-exploitation. Concentration is defined here as the number of firms harvesting the forest and the size of the concessions. Corruption may occur at different scales of governments. First, the exploiting firm may bribe the bureaucrat in charge of the harvest inspection, so that he underreports the harvest volume. Second, the exploiting firms may act as a lobby, and bribe the policy maker to increase the size of the forest to exploit.

In the first case of bureaucratic corruption, a forestry sector composed of a large number of small logging firms tends to increase the impact of corruption on forest over-exploitation. Indeed, a large number of firms reduces the control capacity of the civil agency. Moreover, small concessions (i.e a large number of firms) appear to be an incentive for harvest intensification.

In the second case of policy maker corruption, a corrupt policy maker tends to set a larger exploited forest. Moreover, if the lobby is well-organized, the policy maker sets a larger number of firms exploiting the forest in order to increase the equilibrium bribe, which in turn increases the lobby's influence. Finally, less stringent harvest quota is set.

The model presented here supports the argument of systemic corruption. Overall, if the forestry sector is well-organized, a corrupt policy maker chooses a large number of firms exploiting the market, in order to increase the bribe he receives, which in turn increase the impact of bureaucratic corruption. Therefore, the two kinds of corruption are likely to be observed at the same time. Moreover, a *cascade effect* might describe the environmental degradation. First, the size of the harvested forest is larger than the social optimum. Second, the harvest rules are less stringent than the social optimum. Finally, due to bureaucratic corruption, those sub-optimal harvest rules are not even enforced. Overall, the size of the primary protected forest decrease, and the harvested forest is over-exploited.

A crucial limitation of the model presented here is that firms and concessions are assumed to be homogeneous in size. However, in real life, small and large firms often coexist. Thus it could be interesting to consider the difference in corruption patterns between heterogeneous firms. For example, small firms might choose to bribe bureaucrats, while large firms find more profitable to bribe directly policy makers.

Moreover, a restrictive definition of concentration is used. Indeed, firms are assumed to be price-takers whatever is the concentration of the forestry sector. It could be more realistic to assume that firms have some market power in case of a concentrated forestry sector. In that case, market power would increase the firm's potential for bribing, which would compensate for the propositions presented here. However, the fact that logging firms from highly concentrated forestry sector of developing countries have strong market power is not obvious and should be investigated.

Finally, the process of concessions allocation is not modeled explicitly in this paper. Nevertheless, concessions allocation is an important pattern of corruption and forest exploitation in developing countries. Indeed corrupt regimes often use these allocation process to reward their political allies or to increase the wealth of their friends or family. In this context, concessions would be given according to the number of these allies and their ”worthiness”, which would determine the concessions size. Moreover, logging firms may compete for concessions allocations. The links between concentration of the forestry sector and forest exploitation would in that case be different.

4. FORESTS AND THE RESOURCE CURSE HYPOTHESIS

Abstract

The resource curse hypothesis relies on the resource-rich countries tendency to grow slower than resource-poor countries. Focusing on forest issues, this paper extends the resource curse hypothesis to environmental degradation: how do forest and resource endowments affect deforestation? Countries with important forestry sectors seem to have deforested more than countries with small forestry sectors, which supports the hypothesis of an environmental resource curse. We also test whether forests constitute a resource curse, using three different forest indicators. While our stock indicators are not significantly related to growth, our flow indicator is strongly negatively correlated with growth.

Keywords: resource curse, growth, tropical forest, deforestation.

JEL classification: C21; O13; Q33.

4.1 Introduction

A well documented paradox in the economic development literature is the tendency of resource-rich countries to grow slower than countries with less natural resources. Whereas a conventional view would see endowments in oil, diamond, gas and other natural resources as a blessing that gives the country an opportunity to create wealth and contribute to economic development, many observations emphasize this resource curse hypothesis. For instance, Nigeria, Venezuela, Sierra Leone or Angola, all countries with large natural endowments, are among slow growth countries. In contrast, Korea, Hong Kong and Singapore are resource poor, but have experienced fast growth periods.

Researchers (Leite et al., 2002; Mehlun et al., 2006; Papyrakis et al., 2004; Sachs et al., 1997, 1999) usually focus on growth to describe a resource curse. Bulte et al. (2005) find evidence of the resource curse for several human development indicators (Human Development

Indicator, Undernourished population, Percentage of the population with no proper water access, Life expectancy). However, important resource endowments may also constitute a curse for the environment. Among different environmental concerns, deforestation is interesting to analyze. Indeed countries the most concerned by the resource curse are developing countries. Therefore, it is interesting to test this environmental resource curse hypothesis with an important environmental concern in the developing world, and deforestation is one of the major environmental concerns in developing countries. Furthermore, forest endowments constitute both a resource endowment and an environmental indicator. This allows us to test the resource curse hypothesis in two directions. We investigate first for an environmental resource curse for deforestation and then test whether forest endowments constitute a resource curse.

This paper first wonders whether important resource endowments also represent an environmental resource curse. Indeed important resource endowments may lead to poor institutions and policy making. Poorly developed institutions may lead in turn to unsustainable environmental management, and thus more deforestation. Moreover, natural resources exploitation requires space, which creates incentives to land use change and thus deforestation. For example, mining is a major cause of deforestation in many South-American countries. We test for a direct environmental resource curse, considering the importance of the forestry sector to GDP, and an indirect resource curse, using the share of primary products exports in GNP. We find evidence of a direct environmental resource curse, especially when controlling for growth. Contrarily, we find no evidence of an indirect resource curse. When controlling for corruption, we even find that countries rich in natural resources tend to deforest less than countries with small resource endowments.

Second, we wonder whether forests constitute a resource curse. The usual resource curse literature usually focuses on flows (e.g: share of primary export in total export) to investigate the resource curse hypothesis, which is closely related to resource exploitation: countries with large resource endowments may have small resource flows, because of a better diversification of activities. Focusing on forests allows to consider both flows (or exploitation) and stocks (or endowments). Indeed, we use three different forest indicators. Stocks are approximated through the size of the countries forests (or absolute endowment) and the proportion of land area covered by forests (or relative endowment), while flows are approximated through the volume of industrial roundwood produced divided by GDP (or exploitation indicator). While our forest endowment indicators are not significantly related to growth, our proxy for the forestry sector's importance is strongly and negatively related to growth, which gives the insight that the resource curse is a result of bad economic management and over-specialization.

Section 2 surveys the transmission channels of the resource curse, and mentions the potential for an environmental resource curse. Section 3 investigates the existence of a resource curse for deforestation. Section 4 tests the resource curse hypothesis, using three different forest endowment indicators and section 4 concludes.

4.2 Which factors drive the resource curse?

Three main groups of transmission channels are to distinguish: specialization perverse effects, rent-seeking behaviors and institutional development. The first group underlines the fact that large natural endowments may divert a country from activities the most able to conduct to long term growth. This specialization into resource extraction activities is likely to be detrimental to the country in the case of declining terms of trade between primary resources and manufactured goods (Prebisch, 1950). Even if the Prebisch hypothesis finds little empirical support, countries specialized in resource extraction benefit less from manufacturing sector's spillovers (positive externalities and increasing return to scale; Sachs and Warner, 1999; Torvik, 2001). Finally, natural resource prices are usually quite volatile, which increase investors uncertainty.

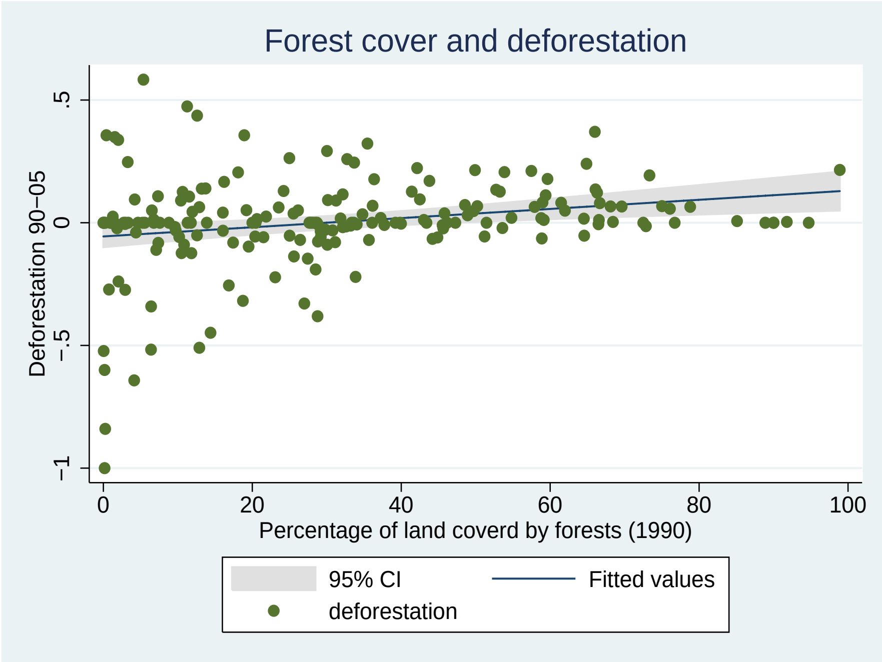
The second group underlines the importance of rent-seeking behaviors in resource-rich countries. Indeed, resources are usually considered as easily appropriable, so that there are large incentives for rent-seeking activities, such as bribes or lobbying. This ”voracity effect” (Mehlun et al., 2006b) constitute a diversion of labor and capital from more productive activities. As an extreme case, natural resource appropriation may be a source of conflicts or political violence. For instance, Olsson (2006) studies diamond exploitation and conflicts between rebel groups and kleptocratic governments. However, all resource-rich countries do not experience high levels of corruption. Most papers conclude that institutional background is an important vector of the resource curse: administrations with low levels of corruption reduce the incentive for rent-seeking activities and thus decrease the importance of this transmission channel. Therefore, countries with well-developed institutions should be less cursed and even blessed by resource endowments (Mehlun et al., 2006a, 2006b).

The third group refers to this institutional quality. Poor institutions may be a consequence of resource wealth (Leite and Weidmann, 2002). Indeed natural resources represent to governments "easy money" that may lead to sloth in the development of institutional quality and economic policies. Then low quality institutions lead to bad economic management, poor decision making, bad or low investment decisions, unsustainable management of the resource and thus jeopardize long term growth. Moreover, as already mentioned, it offers an incentive for corruption and other rent-seeking activities. Overall, large resource endowments may influence institutional quality (Hall and Jone, 1999), which in turn reduces growth and jeopardizes long term development.

In this context, several authors (Auti, 2001a, 2001b; Bulte et al., 2005) note that "point" resources, such as fuel and mineral resources are more easily appropriable than "diffuse" resources, such as agricultural resources or forests. Indeed, spacial concentration makes exclusion from the resource, and thus appropriation, easier. This implies a greater concentration of power, which offers more scale for rent seeking and corrupted behaviors. Point resources are therefore more likely to represent a resource curse than diffuse resources. When forests are considered, rent seeking and institutional quality should therefore be less important factors of the resource curse.

Environmental resource curse: The last two transmission channels considered are likely to have strong relationship with environmental quality and especially deforestation issues. Indeed, corruption and rent-seeking activities are a frequently cited factor of forest over-exploitation in developing countries (Callister, 1999; Contreras-Hermosilla, 2001). More generally, poor institutional quality is likely to induce poor policy making, which generates unsustainable forest management. Overall, many empirical analysis find that better institutions reduce deforestation (Bhattarai and Hammig, 2001; Culas, 2006; Deacon, 1994; Nguyen Van and Azomahou, 2006). Moreover, resource extraction and exploitation need space and infrastructures, which may imply more deforestation.

Fig. 4.1:



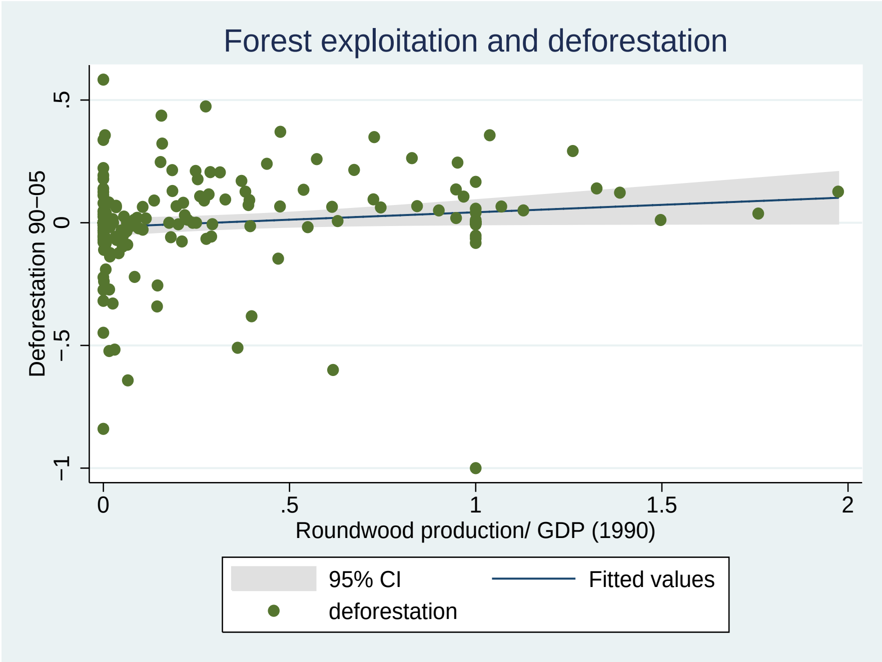
Two types of environmental resource curse may be distinguished. First, a direct environmental resource curse describes the negative impact of forests endowments and exploitation on deforestation. Second, an indirect environmental resource curse would be the impact of global resource endowments on the forest cover.

4.3 Is there a resource curse for deforestation?

4.3.1 Data and regressions

This section wonders whether deforestation may be a special type of resource curse. Indeed, when looking at stylized facts, countries with important forest cover seem to deforest more than countries with small forest cover. Figure 5.1 illustrate this relationship between percentage of land covered by forests and deforestation. Indeed, the value given to standing forest is likely to be negatively correlated with the quantity of forest available. Deforestation is therefore cheaper for a country with large forest endowments. Moreover, it appears that countries with large forest exploitation also seem to deforest more (figure 5.2).

Fig. 4.2:



We regress therefore our deforestation proxy (*Deforestation*) on two indicators of natural resource endowments (*Ressource*) and a vector of potential explanatory variables (H):

$$Deforestation^i = \beta_0 + \beta_1 Ressource^i + \beta_2 H^i + u^i \tag{4.1}$$

Our deforestation indicator is the forest cover change for the period 1990-2005: $Deforestation^i = \frac{AFD^i_{90} - AFD^i_{05}}{AFD^i_{90}}$. We test for two types of environmental resource curse. First, a direct resource curse is estimated, using industrial roundwood production (m^3) divided by GDP, which is a proxy for the share of GDP provided by the forestry sector (*Forest Sector*). This proxy is somehow tricky, but the FAO only provides roundwood production data in volumes. The sign depends on the quality of forest exploitation. Sustainable forest exploitation should have no or small impact on the forest cover, while unsustainable forest exploitation should increase deforestation. Indeed, the FAO definition of the forest cover is: *Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent.* Forest exploitation leads to deforestation only if the cover decreases to less than 10%. A direct environmental resource curse would therefore come from unsustainable forest exploitation. Second, an indirect resource curse is estimated using the share of primary products exports in National GNP for the year 1970 (*PrimaryExports*). Here, the environmental resource curse would come from road creation and bad environmental management due to poor institutions.

Our first control variable is a relative forest endowment indicator i.e. the proportion of land area covered by forests (*Forest Cover*). Indeed, the relative value of standing forests is likely to be smaller for countries with large forests endowments. Thus, a country with an important forest cover is likely to deforest more than a country with small forest cover. The second type of control variables approximate institutional quality. We use sequentially the IRIS corruption (*Corruption*, low score means high corruption) and rule of law index (*Rule of Law*). We expect a negative impact of corruption (positive impact of the index) and a positive impact of the rule of law on the forest cover: rent-seeking behaviors and poor institutions to appropriate forest resources are likely to increase deforestation. Third, we consider the annual growth rate of GDP as a potential explanatory variable (*growth*).

4.3.2 Results

Results are presented in table 4.1. As expected, a negative robust correlation is established between the forest cover and deforestation. Overall, countries with relatively important forest cover have deforested more over the period considered than countries with small forest cover. Deforestation also appears to be more important in countries with poorer institutions. Unsurprisingly, corruption, rent-seeking behaviors and poor economic and environmental management facilitate resource appropriation, limits law enforcement and thus favors land appropriation and unsustainable forest use.

Considering our variable of interest, two main relationships need to be distinguished. First, the regressions give some evidence of a direct environmental resource curse: countries relying heavily on forest exploitation seem to have deforested more than countries with small forestry sectors. Moreover, introducing the growth rate of GDP reinforces the negative relationship between forestry sector's importance and forest cover change. This result gives the insight that forest exploitation is mainly non sustainable, since it leads to increased deforestation. Second, we do not find evidence of an indirect environmental resource curse. Indeed, the coefficients related to natural resource exports are at first not significant and become strongly positive, when the corruption index is introduced in the regressions. [1]

[1] The results are robust to the addition of distance to the tropics.

Tab. 4.1: **Deforestation regressions as in Equation (1)**

Dependent Variable: $Deforestation^i$	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Forest Cover	0.02***	0.003***	0.003***	0.004***	0.005***	0.004***	0.003***
	(3.02)	*(3.37)*	*(2.98)*	*(4.46)*	*(4.72)*	*(3.63)*	*(3.64)*
Forest Sector	0.05*	-	0.10**	0.11*	0.07	0.22***	0.25***
	(1.44)		*(1.66)*	*(1.51)*	*(0.98)*	*(2.96)*	*(3.43)*
Primary Export	-	-0.12	-0.14	-0.46***	-0.54***	-0.67***	-0.67***
		(0.9)	*(1.05)*	*(-2.94)*	*(-3.29)*	*(-2.57)*	*(-2.62)*
Corruption	-	-	-	- 0.04***	-	-	-0.03**
				(-3.59)			*(-2.28)*
Rule Of Law	-	-	-	-	-0.04***	-0.03**	-
					(-3.65)	*(-2.22)*	
Growth	-	-	-	-	-	- 0.03**	-0.03**
						(-1.9)	*(-1.86)*
Constant	-0.07***	-0.07**	-0.09**	0.04	0.04	0.04	0.04
	(-2.84)	*(-1.79)*	*(2.09)*	*(0.61)*	*(0.61)*	*(0.61)*	*(0.64)*
Adjusted R^2	0.06	0.09	0.1	0.33	0.33	0.36	0.37
N	189	110	108	80	80	73	73

Notes: The t-statistics are in parentheses.

* 10% level of significance

** 5% level of significance

*** 1% level of significance

Corruption index: low score means high corruption

4.4 *Are forests a resource curse?*

4.4.1 *Data description*

The resource curse literature usually considers the impact of resource exploitation on growth and development (e.g: primary export intensity, share of mineral production in GDP, mineral production). The analysis therefore focuses on the resource curse for countries exploiting intensively their resources. In contrast, countries may have important resource endowments, but give priority to the diversification of their activities. Focusing on forest resources allows to distinguished the impacts of both endowments (or stocks) and exploitation (or flows) on growth. Indeed we use three different forest indicators. Dotations are approximated through the size (hectare) of the countries forests, or absolute endowments (*Forest Area*), and the percentage of land covered by forests, or relative endowment (*Forest Cover*). Exploitation is approximated through a proxy for the forests economic importance, using industrial roundwood production (m^3) divided by GDP (*Forest Sector*).

These three indicators (source: FAO) allow for considering forest endowments in different manners. Absolute forest endowments seem to be the most evident indicator, but is closely related to the country's total area, which is likely to have an impact on development. Relative forest endowments are not directly related to the total area. Nevertheless, a large share of land covered by forests may be a consequence of underdevelopment, and not a direct cause. Finally, industrial roundwood production per unit of GDP is not a direct indicator of forest endowments, but it indicates to what extend the country relies on this resource. Unfortunately, there is no indicator giving information of forest biodiversity, which would be an important factor to be considered in the analysis. Rapid graphical analysis tends to show that forest cover and our proxy for the forestry sector's importance are negatively correlated with growth (figure (4.3) and (4.4)).

The other variables used in this section are those of Sachs and Warner (1997, 1999) and are described in appendix A. The resource curse hypothesis assumes a negative relationship between natural resource endowments and development. The development indicator we use is the average annual per-capita growth in real GDP for the period 1979-90. Of course, the growth of GDP is an imperfect estimator of development. Several other indicators could be considered, that could catch other dimensions of human development. Bulte et al.

Fig. 4.3:

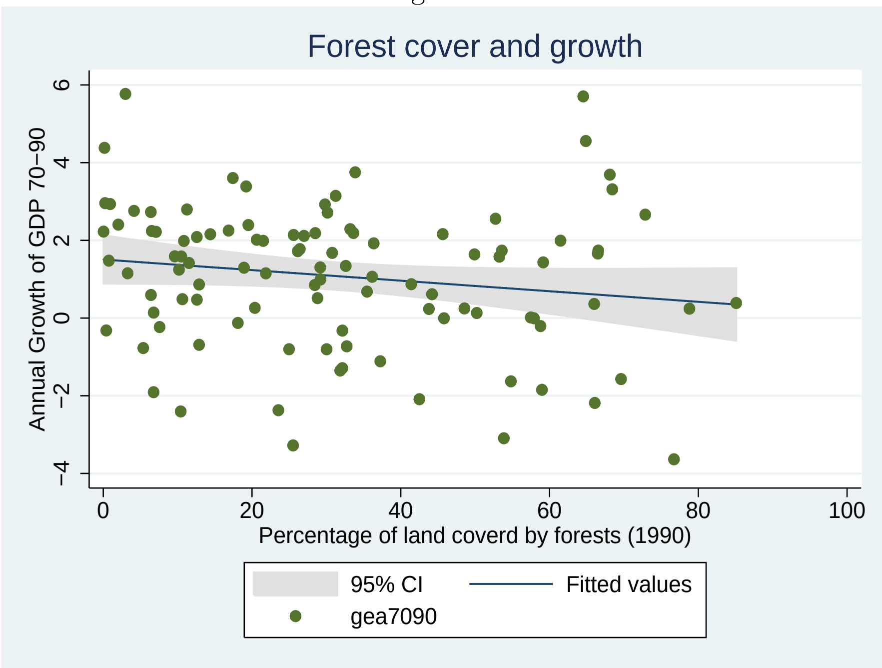
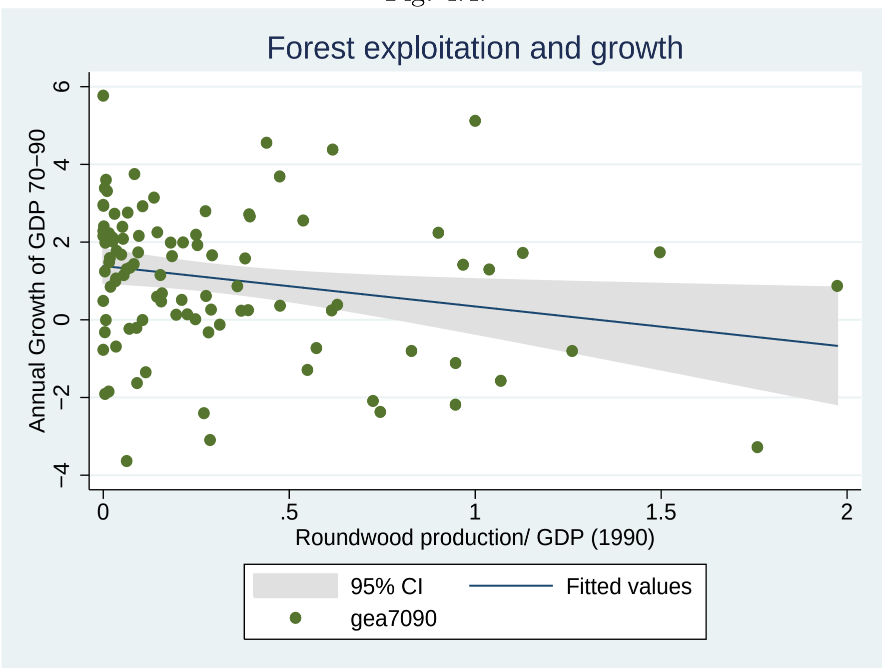

Forest cover and growth
Annual Growth of GDP 70−90
−4
−2
0
2
4
6
0
20
40
60
80
100
Percentage of land coverd by forests (1990)
95% CI
Fitted values
gea7090

Fig. 4.4:


Forest exploitation and growth
Annual Growth of GDP 70−90
−4
−2
0
2
4
6
0
.5
1
1.5
2
Roundwood production/ GDP (1990)
95% CI
Fitted values
gea7090

(2005) test the resource curse hypothesis using different indicators of human welfare: HDI, undernourished population, access to water, life expectancy. Nevertheless, growth of GDP is a commonly used indicator of economic development, which is in itself an important part of human development.

Our estimations are based on the convergence hypothesis, i.e among several variables, high-income countries tend to have lower growth rates than low-income countries. Therefore, country i's average annual growth rate of GDP per capita, g_i, is assumed to be negatively correlated with the log of its 1970 GDP per capita, $\ln(Y_{70}^i)$. However, the use of the convergence hypothesis has been criticized when applied to cross-country estimations. Indeed, because it does not consider initial level of productivity, the coefficient of lagged income is likely to be overestimated (Islam, 1995). Panel data would be a solution to this problem.

Moreover, the resource curse hypothesis assumes a negative relationship between the growth rate and forest indicators F^i. Finally, a vector of other explanatory variables Z^i is considered. Those explanatory variables are the potential transmission channels of the resource curse presented earlier. Perverse effects of specialization are captured by the share of manufacturing exports in total export (*Manufacturing Sector*). Rent-seeking activities, corruption and more broadly institutions are captured by the corruption index (*Corruption*) and the rule of law index (*Rule of Law*) presented before (source: IRIS). Finally, institutional development is considered through economic openness (*Openness*), usually considered as a profitable economic policy, and the ratio of domestic investment to real GDP (*Investment*), which is the result of profitable policies.

Thus, for our three forest endowments indicators, we proceed to the estimation of (ε is the usual error term):

$$g^i = \alpha_0 + \alpha_1 \ln(Y_{70}^i) + \alpha_2 F^i + \alpha_3 Z^i + \varepsilon^i \quad (4.2)$$

4.4.2 Results of the cross country regressions

The results can be found in table 4.2, 4.3 and 4.4. For the three forest indicators, all the habitual potential sources of growth have the expected sign and are highly significative: the convergence hypothesis is confirmed; openness, manufacturing sector development, institutions and investment are positively correlated with growth, while corruption is negatively correlated with growth.

Considering absolute forest endowment (table 4.2), the sign of the coefficient is not the one expected, but is not significative. Indeed, while the resource curse hypothesis implies a negative relationship between resource endowments and growth of GDP, the coefficient is positive. Moreover, it is robust to the addition of the potential transmission channels. Nevertheless, as mentioned before, countries total forest area is not a perfect indicator of forest endowments, simply because countries with large total areas naturally tend to have larger forest area, which can be related to development to some extend. For example, the USA have almost 300 thousands km^2 of forests (32.6% of the country's total area), while Gabon only has about 20 thousands km^2 (85.1% of the country's total area).

Therefore we also test the resource curse hypothesis using a relative forest endowment indicator (table 4.3). In contrast with the *Forest Area* indicator, the estimated coefficient using this *Forest Cover* indicator has the expected sign (negative), but is not significant either. Here again, the sign of the coefficient is robust to the addition of the transmission channels indicators. Overall, it seems that forest endowments are not significantly related to growth and development.

Forest endowments do not seem to constitute a resource curse. Considering forest exploitation, using a proxy for the forestry sector's economic importance gives different results (table 4.4). Indeed, when considering industrial roundwood production per unit of GDP, the estimated coefficients have the expected negative sign and are highly significative. This result gives the insight that countries relying on forest exploitation tend to grow slower. Moreover, this result is robust to the addition of the potential transmission channels.

Two potential explanations can be derived from this result. First, forest endowments may not represent a resource curse, while relying on forest exploitation does. Among the channels considered, we found that openness and investment are strongly negatively related to our proxy for forestry sector's importance (see table 4). More surprisingly, manufacturing sector's importance is strongly positively correlated to our proxy. Overall, however, this resource curse could not be totally explained by the traditional transmission channels, since their addition in the regression do not change the coefficient much. In this case, if the forest exploitation is not related to growth trough the traditional transmission channels, why would it be a resource curse?

A second explanation is that neither forest endowments nor forest exploitation represent a resource curse. In that case, why would forest exploitation be negatively linked with growth and development? A simple and quite intuitive answer would be that relying on forest exploitation is more a consequence of under development than a cause. Indeed, countries with low development opportunities are perhaps more likely to focus more on forest exploitation than countries with more diverse opportunities. This statement is compatible with the fact that countries relying on forest exploitation also tend to have smaller investment and openness. This second potential explanation seems to be more convincing than the first one.

Moreover, the forestry sector generally represents a small share of the countries GDP. In 2000, forestry sectors contributed for about 3% to 5% of GDP in Brazil, Guyana, Suriname, Paraguay, Chile, Latvia, Estonia and some African countries. Overall, forestry sectors contributed to 1.5% of GDP in Africa, 1.1% in Western Europe, 1.7% in Latin America and 1.2% worldwide (FAO, 2004). Thus interactions and behaviors related to the forestry sector are unlikely to have large macroeconomic effects. First, countries cannot totally specialize in forest exploitation. Second, even if some corrupt behaviors or rent-seeking activities may be enhanced by forest exploitation, they probably have too small impacts to be perceived at the country level. Finally, forestry sectors importance is too small to limit significatively institutional development and the implementation of proper macroeconomic policies.

Tab. 4.2: **Growth regressions as in Eq(2), considering Forest Area**

Dependent Variable: g^i	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(Y^i_{70})$	0.16	-0.15	-1.11***	-1.4***	-1.25***	-1.51
	(0.81)	*(-0.59)*	*(-3.89)*	*(-4.61)*	*(4.73)*	*(-5.56)*
Forest Area	1.01e-06	1.63e-06	9.18e-07	1.05e-07	1.32e-06	1.21e-06
	(0.38)	*(0.61)*	*(0.42)*	*(0.05)*	*(0.66)*	*(0.63)*
Manufacturing Sector	-	2.27***	1.90***	1.69***	1.22*	1.42**
		(3.02)	*(2.66)*	*(2.41)*	*(1.71)*	*(2.08)*
Corruption	-	-	0.55	-	0.28**	0.24**
			(4.38)		*(2.17)*	*(1.89)*
Rule of Law	-	-	-	0.64***	-	
				(4.97)		
Openness	-	-	-	-	2.09***	1.70***
					(3.93)	*(3.20)*
Investment	-	-	-	-	-	1.11***
						(2.62)
Constant	-0.31	1.60	8.31***	10.66***	9.59***	8.92***
	(-0.19)	*(0.80)*	*(3.79)*	*(4.61)*	*(4.75)*	*(4.58)*
Adjusted R^2	0	0.08	0.31	0.35	0.44	0.49
N	103	92	72	72	70	70

Notes: The t-statistics are in parentheses.

* 10% level of significance

** 5% level of significance

*** 1% level of significance

Corruption index: high score means low corruption

Tab. 4.3: **Growth regressions as in Eq(2), considering Forest Cover**

Dependent Variable: g^i	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(Y_{70}^i)$	0.20	-0.08	-1.10***	-1.39***	-1.21***	-1.51***
	(1.01)	*(-0.34)*	*(-3.90)*	*(-4.47)*	*(-4.73)*	*(-5.82)*
Forest Cover	-0.01	-0.01	-0.01*	-0.01*	-0.01*	-0.01**
	(-1.74)	*(-1.11)*	*(-1.57)*	*(-1.60)*	*(-1.72)*	*(-2.30)*
Manufacturing Sector	-	2.14***	1.77***	1.59***	0.99*	1.19**
		(2.86)	*(2.53)*	*(2.33)*	*(1.43)*	*(1.81)*
Corruption	-	-	0.55***	-	0.29**	0.26**
			(4.49)		*(2.27)*	*(1.95)*
Rule of Law	-	-	-	0.64***	-	-
				(5.10)		
Openness	-	-	-	-	2.15***	1.72***
					(4.10)	*(3.35)*
Investment	-	-	-	-	-	1.27***
						(3.07)
Constant	-0.13	1.44	8.58***	10.99***	9.80***	9.14***
	(-0.08)	*(0.73)*	*(3.92)*	*(4.83)*	*(4.95)*	*(4.88)*
Adjusted R^2	0.02	0.09	0.34	0.38	0.46	0.52
N	103	92	72	72	70	70

Notes: The t-statistics are in parentheses.

* 10% level of significance

** 5% level of significance

*** 1% level of significance

Corruption index: high score means low corruption

Tab. 4.4: **Growth regressions as in Eq(2), considering Forestry sector's importance**

Dependent Variable: g^i	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(Y^i_{70})$	0.01	-0.33	-1.57***	-1.68***	-1.58***	-1.77***
	(0.03)	*(-1.25)*	*(-4.98)*	*(-5.14)*	*(-5.52)*	*(-5.85)*
Forest Sector	-1.04**	-1.29***	-1.99***	-1.43***	-1.66***	-1.53***
	(-2.06)	*(-2.57)*	*(-3.19)*	*(-2.39)*	*(-2.81)*	*(-2.65)*
Manufacturing Sector	-	1.83***	1.15**	1.14**	0.66	0.87
		(2.50)	*(1.72)*	*(1.71)*	*(0.94)*	*(1.31)*
Corruption	-	-	0.68	-	0.46***	0.41***
			(5.84)		*(3.54)*	*(3.17)*
Rule of Law	-	-	-	0.70***	-	-
				(5.85)		
Openness	-	-	-	-	1.73***	1.47***
					(3.47)	*(2.92)*
Investment	-	-	-	-	-	0.87**
						(2.14)
Constant	1.33	3.61**	12.28***	13.25	12.57***	11.89***
	(0.70)	*(1.65)*	*(4.89)*	*(5.09)*	*(5.39)*	*(5.18)*
Adjusted R^2	0.03	0.12	0.40	0.40	0.48	0.51
N	103	91	71	71	69	69

Notes: The t-statistics are in parentheses.

* 10% level of significance

** 5% level of significance

*** 1% level of significance

Corruption index: high score means low corruption

Tab. 4.5: **Potential transmission channels**

Dependent Variable:	Terms of trade	Manufacturing sector	Corruption	Openness	Investment
Forest Sector	-0.40	1.74e-06***	-0.48	-0.35***	-0.75***
	(-0.59)	*(2.66)*	*(-0.75)*	*(-3.67)*	*(-5.66)*
Constant	0.09	0.29	3.41	0.47	2.90
	(0.26)	*(9.03)*	*(13.16)*	*(9.50)*	*(44.81)*
Adjusted R^2	0.00	0.05	0.00	0.10	0.18
N	128	109	83	116	143

Notes: The t-statistics are in parentheses.

* 10% level of significance

** 5% level of significance

*** 1% level of significance

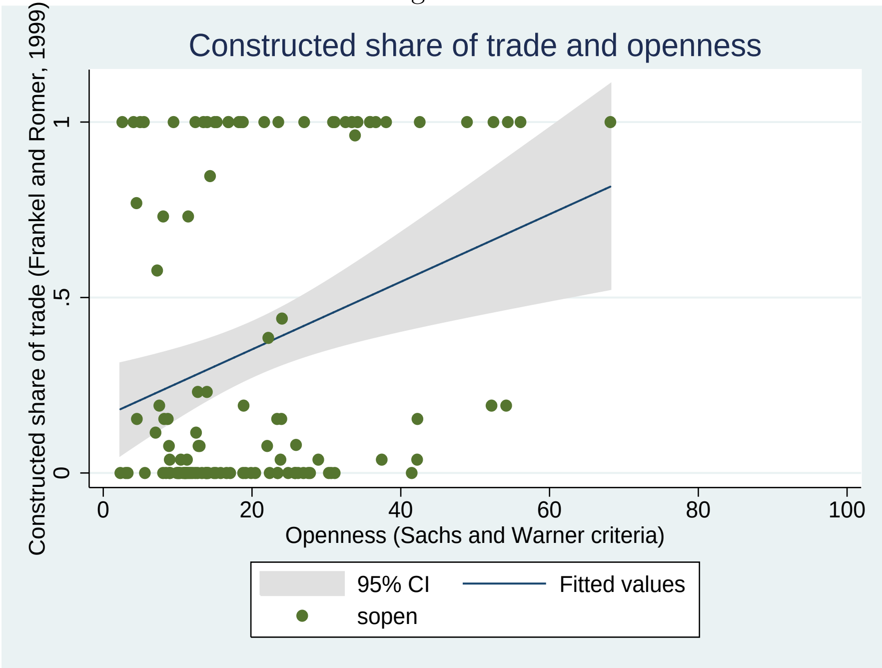
4.4.3 IV estimations

4.4.4 Instruments

Growth regressions are habitually subject to the problem of endogenous variable. Does trade cause growth, or does growth involve trade? Are good institutions a *sine qua non* condition to long term growth, or does economic development enhance better institutions? The resource curse literature usually does not consider this problem of endogeneity when considering control variables. In this section, we build on earlier growth literature to instrument institutional quality and openness. An good instrument is a variable that affect growth only through the instrumented variable.

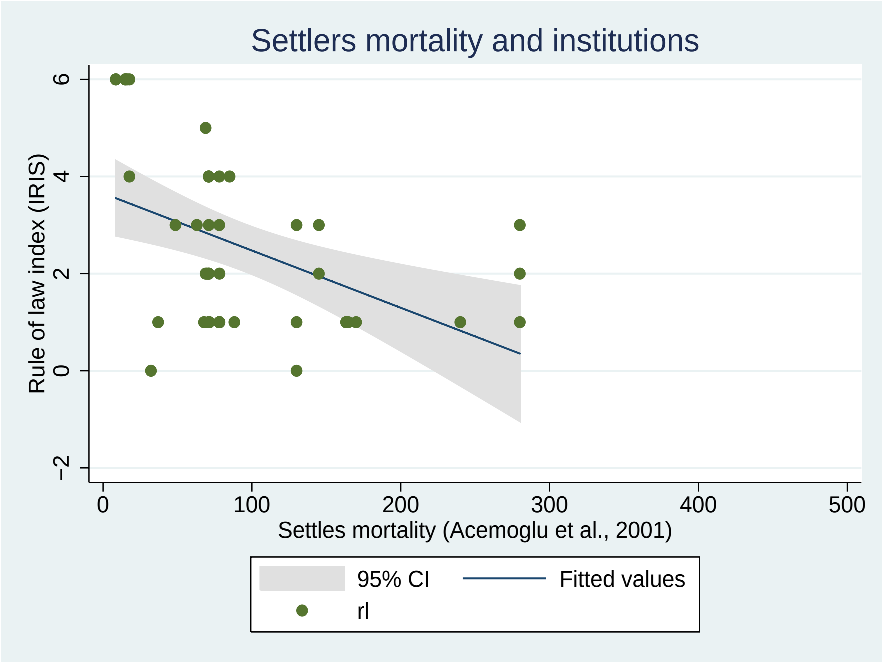
First, we use the Frankel and Romer (1999) indicator to instrument openness. In their paper, the authors use a constructed share of trade based on geographical characteristics, in order to get rid of endogeneity. Moreover, the Sachs and Warner criteria used in the precedent section may be criticized because of its *de jure* character, in contrast with *de facto* character, such as the Frankel and Romer instrument. Finally, figure (4.5) shows the strong relationship between the Sachs and Warner criteria and the Frankel and Romer indicator.

Fig. 4.5:



Second, we instrument institutional quality with the log of European settlers mortality (Acemoglu et al., 2001). Indeed, institutions may be related to this historical characteristic: settlers are likely to have set better institutions in less risky regions, which should be related somehow to current institutions. Figure (4.6) shows this relationship between settlers mortality and today rule of law indicator. However, our data for settlers mortality is quite small (51 observations). Thus we also instrument institutional quality with an index of ethnic fragmentation (Easterly and Levine, 2003).

Fig. 4.6:



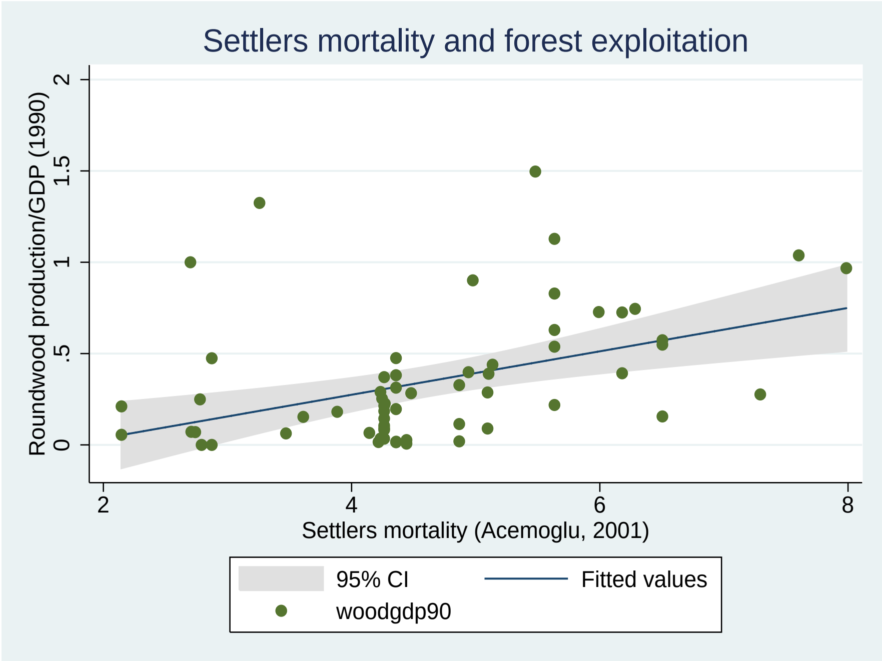
4.4.5 Results

Results are given in table (4.6). First, note that the constructed share of trade used to approximate openness is not significant, and that its sign is not stable when changing other control variables. Second, the log of settlers mortality and the index of ethnic fragmentation have the expected sign and are quite significant.

Considering our forest endowment indicator, the estimation does not change the result much when instruments are introduced. The sign related to our absolute forest endowment indicator (*Forest Area*) does not change and even becomes slightly significant, while our relative endowment indicator (*Forest Area*) is still negatively related to growth.

Considering forestry sector's importance, the introduction of the Acemoglu instrument change the sign of the relationship, and the coefficient is even slightly significant. This result may be explained by the potential relationship between settlers mortality and forest exploitation. Indeed, Acemoglu et al. (2001) note that *"colonization strategy was influenced by the feasibility of settlements. In places where the disease environment was not favorable to European settlement, the cards were stacked against the creation of Neo-Europes, and the formation of the extractive state was more likely"*. This statement helps to explain why

Fig. 4.7:



countries with high settlers mortality experience today important forestry sectors (see figure 4.7). The use of the instrument when investigating for a resource curse may thus lead to biased estimates. *Forest Sector* keeps the expected sign when using ethnic fragmentation as an instrument, although the coefficient is not significant.

Tab. 4.6: **Growth regressions as in Eq(2), using different instruments**

Dependent Variable: g^i	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(Y^i_{70})$	-1.57***	-1.18***	-1.38***	-1.09***	-1.36***	-1.08***
	(-5.44)	*(-4.45)*	*(-3.87)*	*(-4.28)*	*(-3.85)*	*(-3.93)*
Forest Cover	4.03e-06*	2.71e-06	-	-	-	-
	(1.52)	*(1.14)*				
Forest Area	-	-	-0.01	-0.02**	-	-
			(1.27)	*(2.29)*		
Forest Sector	-	-	-	-	1.32*	-0.48
					(1.64)	*(-1.00)*
Manufacturing Sector	1.10	2.27***	1.04	2.13***	1.31	1.99***
	(0.99)	*(3.50)*	*(0.91)*	*(3.35)*	*(1.21)*	*(2.99)*
Investment	1.29***	1.73***	1.42***	1.83***	1.47***	1.61***
	(3.35)	*(6.22)*	*(3.72)*	*(6.72)*	*(3.87)*	*(5.53)*
Settlers Mortality	-0.47**	-	-0.41*	-	-0.61**	-
	(-1.90)		*(1.66)*		*(-2.30)*	
Ethnic Fragmentation	-	-0.98*	-	-0.80*	-	-0.62
		(-1.60)		*(1.35)*		*(-0.93)*
Constructed Share of	0.01	0.02*	-0.004	0.005	-0.003	0.01
Trade	*(0.44)*	*(1.31)*	*(-0.18)*	*(0.42)*	*(0.15)*	*(1.02)*
Constant	11.85***	5.66***	10.57***	5.48***	10.20***	5.38**
	(3.27)	*(2.85)*	*(2.91)*	*(2.85)*	*(2.83)*	*(2.48)*
Adjusted R^2	0.34	0.40	0.33	0.42	0.34	0.36
N	51	87	51	87	51	86

Notes: The t-statistics are in parentheses.

* 10% level of significance

** 5% level of significance

*** 1% level of significance

4.5 Conclusion

Are resource-rich countries also cursed by their resource endowments for environmental quality? When focusing on forest resources, it appears that countries with important forest cover tend to deforest more than countries with small forest cover. This result is somehow intuitive: a very abundant resource is less valuated than a scarce one. More interestingly, countries exploiting their forest endowments intensively also tend to deforest more than countries with small forest sectors. This result gives the insight that forest exploitation is mainly unsustainable worldwide. A conventional view would be to think that forest exploitation is unsustainable only in countries with poor institutions. However the estimated tendency is robust to the addition of corruption or institutional index, which appears to be an alarming information. Conversely, countries relying on other natural resources do not seem to deforest more than countries not relying on this sector. Moreover, relying on natural resource exploitation is positively linked to the forest cover when corruption is considered in the control variables.

The second question this paper proposes to investigate is whether forests constitute a resource curse. This question is particularly interesting because, in contrast with the resource-curse literature, it allows to consider separately endowments and exploitation. Overall it seems that neither forest endowments nor forest exploitation represent a resource curse. Indeed, compared to mineral resources such as oil, diamond or gas are directly profitable, forests seem to represent a too small economic value to have macro level impacts and induce a resource curse. First, a country cannot totally specialize in forest exploitation in the way middle east countries have specialized in oil exploitation. Second, even if its exploitation may enhance rent seeking and corrupted behaviors, these perverse effects appear to be of too small scale to have country level impacts. Finally, because of this relatively low economic value, countries are not likely to jeopardize their future development by relying too much on forest exploitation.

Countries with relatively large forestry sector's economic importance tend nevertheless to grow slower than countries with relatively small forestry sectors. This statement can be explained by the fact that relying on forest exploitation may be a draw back for countries already experiencing low growth and bad institutional development.

Overall, forests do not seem to have macro level perverse effects. Forests could still, however, represent a resource curse at a regional level inside countries. A region with large forest endowments and specialized in forest exploitation may experience lower grow and bad development. This potential regional effect opens scale for future research.

Appendix A: variable description

Variable	**Definition**	**Source**
Deforestation	Percentage of variation of the forest cover for the period 1990-2005.	FAO
g^i	Average annual growth in real GDP divided by the economically active population between the years 1970 and 1990.	Penn World Tables
Forest Area	Total forest extend (ha), in 1990.	FAO
Forest Cover	Proportion of land area covered by forest in 1990.	FAO
Forest Sector	Roundwood production (m^3) divided by GDP in 1990.	FAO
Primary Export	Share of exports of primary products in GNP in 1970.	World Data 1995
$\ln(Y^i_{70})$	Natural log of real GDP divided by the economically active population in 1970.	Penn World Tables (GDP) and World Data CD Rom (population)
Manufacturing Sector	Share of manufacturing exports in total exports, 1970.	World Data CD-Rom 1995, World Bank
Corruption	Corruption in government index. Scored 0-6. Low score means "illegal payments are generally accepted throughout government".	Center for Institutional Reform and the Informal Sector (IRIS), 1982

Rule of Law	Rule of law index. The variable "reflects the degree to which citizens of a country are willing to accept the established institutions to make and implement laws and adjudicate disputes". Scored 0 (low)-6 (high)	Center for Institutional Reform and the Informal Sector (IRIS), 1982
Openness	The fraction of years during the period 1970-1990 in which the country is rated as an open economy.	Sachs and Warner criteria, 1995
Investment	Natural log of the ratio of real gross domestic investment (public plus private) to real GDP averaged over the period 1970-1989.	Penn World Tables
Instruments		
Settlers Mortality	Log of European settlers mortality	Acemoglu et al., 2001
Ethnic Fragmentation	Index of ethnolinguistic fractionalization, 1960. Measures probability that two randomly selected people from a given country will not belong to the same ethnolinguistic group.	Levine et al., 2003
Constructed Share of Trade	Constructed Share of trade based on geographic characteristics	Frankell and Romer, 1999

5. ARE CONSUMER BOYCOTTS EFFECTIVE?

Abstract

This paper derives the conditions of success of a consumer boycott generated by environmental preferences. Overall the chance of success of this kind of boycott appears to be small. Indeed, consumers the most able to hurt the targeted firm's profit also have the highest opportunity cost of boycotting. Thus they are less likely to participate in the boycott. Conversely, consumers the most involved in the boycott have high environmental preferences and small amounts of consumption, which prevent them from hurting the firm's profit enough. Moreover, coordination issues and free riding reduce considerably the likelihood of boycott success.

Keywords: consumer boycott, war of attrition, environment, technology choice.

JEL classification: D11, D21, Q59.

5.1 Introduction

A new consumption pattern has emerged recently. Nowadays citizens often use consumption as a political act, "a new way to save the world" (Mc Laughlin, 2004). Indeed, these consumption practices constitute a way to signal preferences and to conciliate consumption with social, environmental or health considerations. Among this tendency, consumer boycotts are for unsatisfied consumers a way to compensate for governments inactivity. They constitute a substitute to public policies. The objective is to put enough pressure on the target to make it adopt fair practices.

"Economic consumer boycotts" (Friedman, 1999), i.e. the individual or collective choice of not buying some product, is now a frequently used tool by NGOs or lobby groups to protest against unfair marketing, social or environmental practices. For example, in 1959, a group of South African exiles and their British supporters called for a boycott of fruits, cigarettes and other goods imported from South Africa to oppose apartheid. More recently, a boycott of Israeli products and tourism followed decades of refusal to abide by UN resolutions, International Humanitarian law and the Fourth Geneva Convention.

Consumer boycotts upon environmental arguments are a strategy commonly used by many environmental NGOs. A first example is the boycott of cosmetic firms (e.g: Procter and Gamble, Colgate-Palmolive), because of their use of animal testing. Another case is the boycott of major oil companies (e.g: Total, ESSO, Shell), for their environmental damages and their supposed lobbying efforts to deter climate change policies. Some large fast-food companies (e.g: McDonald's) have been targeted by boycott campaigns because of their supposed environmental unfriendly way to produce meat. Finally, some NGOs support the boycott of non-certified tropical timber, to protest against unsustainable harvest practices and corruption. In 2004, WALHI, the Indonesia's largest environmental group, and several other environmental groups, have called for a boycott of timber from Indonesia, Malaysia, Singapore and China, countries where illegal logging plagues local development and environmental indicators.

Most researchers have focused on field studies (Miller and Sturdivan, 1977; Pruitt and Friedman, 1986; Garrett, 1987; Koku et al., 1997; Teoh et al. 1999) or history of consumer boycotts (Friedman, 1985, 1995; Smith, 1990). Tyran and Engelmann (2005) provide an experimental analysis of consumer boycotts. Overall, most papers conclude a weak impact of consumer boycotts on the firms behavior.

Only few papers provide theoretical analysis of consumer boycotts. First, Innes (2006) considers a duopoly choosing between a clean and a dirty technology, while environmental organizations (EO) may invest in consumer boycotts to deter the choice of the dirty technology. The boycott effectiveness is determined by the EO's investment. Second, Baron (2002) considers that the action of boycotting by some consumers provides information to the other citizens about the seriousness of a situation. Boycotting constitute a way for consumers to signal their private information. Finally, Diermayer and Van Mieghem (2005) describe coordination between boycotting consumers as a stochastic process with threshold effects.

Analyzing under which conditions a consumer boycott is effective, this paper makes a simple point: boycott successes are quite unlikely, due to a simple trade off between the opportunity cost of boycotting and the boycott potential to hurt the firm's profit.

We consider a boycott effective if it induces a change in the targeted firm's behavior consistent with the boycotting group's objective. Therefore, we do not discuss the case of a boycott of which the aim is only to signal disapproval to its target. We focus on environmental boycotts, but consumer boycotts upon social and health considerations follow roughly the same analysis.

Consider a firm producing a good with a polluting technology, with no government intervention to internalize the negative externality. This firm could opt for another technology, less or not polluting, but more expensive. The choice of the cheap and polluting technology is the result of a profit maximization. The success of an environmental boycott is therefore determined by its capacity of hurting the firm's profit enough to make the second technology more profitable. In this context, the main factor determining the success of the boycott is the consumer preferences, which induce the demand structure.

Conditions of success of an environmental boycott depend on several market characteristics. First, the consumers environmental preferences may create some scale for ecological certification and product differentiation. With free entry, a second firm may enter the market and provide the good with clean production. Market structure is not considered explicitly in this paper. Only one firm is boycotted and the existence of an imperfect substitute is considered, of which the production is clean but which provides lower utility.

Second, information is crucial on both sides of the problem. On the one hand, the firm needs to have complete and perfect information of the demand side and of the consumers preferences in its profit maximization (for otherwise, there is room for signaling boycott). On the other hand, consumers also need good information on the demand characteristics, available technologies and the boycott's modalities.

Finally, coordination issues and strategic considerations are to be taken into account. Indeed, even a potentially successful boycott may fail because of coordination failures. Moreover, boycotting is subject to free riding. Any individual consumer, even if unsatisfied with the use of the polluting technology and hoping for the boycott to succeed, has an incentive to free ride and to consume the good anyway. Anonymity of consuming behaviors reinforces this incentive.

Of course, with perfect information, no coordination issue and no free rider behavior, one could only witness successful boycotts. Indeed, in that case, the perfectly informed consumers would only participate in a boycott if its success is certain. However, we will first consider this best case scenario, in order to determine which patterns of the demand provide room for successful environmental consumer boycotts. We assume therefore that both consumers and the firm have perfect information about the demand patterns and the producing process. Moreover, by assumption, the unsatisfied consumers behave as one community, which avoid coordination failures and free riding. We only introduce a boycott efficiency parameter, which considers the environmental organization's capacity to overcome coordination problems. Imperfect information and strategic behaviors are to be introduced more explicitly later in this paper.

In this context, an environmental consumer boycott resembles a complete information war of attrition with asymmetric preferences between the targeted firm and the boycotting consumers. Complete information war of attrition models were first introduced by Maynard Smith (1974, 1982), studying animal behavior. Economic applications of war of attrition models include predatory pricing (Roth, 1996), exit in oligopoly (Fudenberg and Tirole, 1986) and the provision of public goods (Bilodeau and Slivinsky, 1996). Kornhauser et al. (1989) and Fudenberg and Tirole (1986) proposed criteria for selection among potential perfect equilibria.

Burton (2004) first considers asymmetry in the players motivations in a war of attrition model. A group of environmentalists decides to blockade the access to an indivisible resource in order to preserve it, while a firm projects to harvest it. The player winning the conflict has *de facto* property rights on the resource. The following model is an application of Burton's asymmetry in the context of a consumer boycott. A group of consumers decides to stop consuming a good produced with a polluting technology, to induce the targeted firm to opt for a clean technology. The firm prefers the use of the polluting technology because it is profit maximizing. Overall, potential for success of a consumer boycott depends on the trade off between the hurting capacity of the boycotting group and the opportunity cost of boycotting. Consumers the most able to hurt the firm's profit have large amounts of consumption. Thus, their opportunity cost of boycotting is high. Overall, this simple tradeoff makes the likelihood of boycott success low.

Section 2 presents a complete information war of attrition model and section 3 analyzes coordination patterns of heterogeneous consumers, with imperfect information. Section 4 underlines the fact that free riding is a major problem of consumer boycotts. Finally, the analysis is applied to real life boycotts in section 5. Section 6 concludes.

5.2 Boycott as a war of attrition with perfect information

A war of attrition is a model of aggression between two players. The game takes the form of a succession of identical periods. Each period, the two players choose simultaneously between remaining in the game or withdrawing. The model is stationary: each period represents the same type of problem for both players, with no information gain nor change in costs or benefits. The winning player is the one able to remain longer in the game.

This model differs from usual war of attrition models, because it considers asymmetric motivations and payoffs. In the context studied here, the two players are a group of consumers and a firm. Some consumers refuse to consume the firm's good as long as it is produced with a polluting technology. The consumers considered act as one single group. Potential coordination failures between consumers are only considered through a boycott efficiency parameter. Coordination issues are to be introduced more explicitly later in this paper.

Overall, both players compare their maximum conflict duration, which is the point in time after which they would never plan to remain in the game. Indeed, with net cumulative payoffs decreasing with time, there is a point in time at which these payoffs become negative. Basically, if the maximum boycott duration of the consumers is larger than the maximum conflict duration of the firm, the boycott is likely to succeed. Moreover, we assumer perfect information. Thus, the two maximum durations are common knowledge. Therefore, the player with a smaller maximum duration withdraws immediately.

The outcome of the game is therefore determined at the first period. The best response for consumers with a maximum duration smaller than the firm's is to never boycott. Conversely, the best response for a firm with a smaller maximum duration is to withdraw immediately. The boycott is successful in that case.

5.2.1 Technology choice and consumers behavior

Firm's technology choice: The firm has chosen between two technologies. Technology 1 (T1) is cheap but polluting, while technology 2 (T2) is clean but more expensive. We consider the case in which the firm has chosen technology 1, which implies that it generates larger profit than technology 2, i.e. $\pi_1 > \pi_2$. The profit schedules, π_1 and π_2, differ simply because the production costs, the price of the good and the demand structure are not the same whether the good is produced with the dirty or the clean technology.

Consumption patterns: The consumers population is of size 1, with two homogeneous groups. The environmentalists represent a share α, exogenously given, of the population. The utility of an environmentalist increases with his individual consumption and decreases with the total amount of pollution. The environmentalists are unsatisfied with technology 1 and would prefer the firm to produce with technology 2: $U_1 < U_2$. U_1 is the utility derived by an environmentalist if the good is produced with T1, and U_2 is the utility for a good produced with T2.

A share $(1-\alpha)$ of consumers only considers individual consumption in its utility function. Therefore these consumers prefer the firm to use T1, because they do not care about pollution and T1 is cheaper. Thus they would never participate in an eventual boycott. Moreover, they do not moderate their consumption of the good, because they do not care about the pollution induced by their consumption. Therefore they consume larger amounts of the good.

Boycott as a war of attrition: The environmentalists would prefer the firm to use technology 2. An environmental organization announces a consumer boycott, requiring for any consumer unsatisfied with the use of technology 1 to stop consuming the good. Boycotting consumers switch their consumption of the good for the consumption of an imperfect substitute that provides lower utility, but of which the production is clean. The utility derived when boycotting is U_b.

As an extreme case, the targeted firm is in a monopoly position, and there is no substitute available on the market. As another extreme, if the market is very competitive and differentiated, there is room for ecological certification: a firm may provide the good considered with a clean production. In that case, boycotting is costless. More generally, a better substitute provides higher utility of boycotting. Moreover, the action of boycotting may have an utility by itself. Boycotting has therefore an opportunity cost, which is the difference between the utility derived by the consumption of the good, and the utility of boycotting: $\Delta U = U_1 - U_b$.

$\lambda\underline{\pi_1}$ is the residual profit of the firm under boycott. $\underline{\pi_1}$ is the residual profit when every environmentalist boycott and λ is an exogenous efficiency parameter measuring the environmental organization's capacity to coordinate consumers: $1 \leq \lambda \leq \frac{\pi_1}{\underline{\pi_1}}$. The EO is totally efficient in coordinating consumers if $\lambda = 1$, and there is full coordination failure if $\lambda = \frac{\pi_1}{\underline{\pi_1}}$. The success of the boycott consists of hurting the firm's profit enough to make technology 2 more profitable. In this context, a consumer boycott represents a kind of war of attrition, with an asymmetry in the players motivations.

The set of strategies is the following. Each period, the environmentalists choose whether to continue the boycott or to stop it, while the firm chooses whether to keep on using T1 or to switch for a T2 production. Switching technology is costless, but there can be no switch back.

The game proceeds as follow. Both players consider how long they could stay in the game without making loss. The maximum boycott duration of the consumers and the maximum conflict duration of the firm are the point in time at which their cumulative net payoffs become negative. There is perfect information, which means that both maximum durations are common knowledge. The player that has the shortest maximum duration will therefore choose to withdraw immediately. Therefore the boycott is successful if the maximum boycott duration is larger than the maximum conflict duration (see Appendix A).

Conditional on the parameters values, two kinds of outcome are possible. First, if the maximum boycott duration of the consumers is shorter than the maximum conflict duration of the firm, the best response for an environmentalist is to never boycott, while the firm's best response is to always keep T1. Conversely, for a maximum boycott duration longer than the firm's maximum duration, the best response for the consumers is always to boycott, while the firm's best response is to switch immediately for T2.

Thus the boycott outcome is reached at the first period. This result is somehow disappointing to describe real life boycotts. Nevertheless, this set up describes the necessary conditions of the demand patterns for a successful boycott. Introducing imperfect information and coordination issues will allow for multi-periods boycotts.

5.2.2 Maximum conflict duration of the firm

Consider first the firm's net cumulative payoff of winning the conflict after T periods. It consists of the smaller profit received during the boycott for T periods and the larger profit of keeping T1 forever. This cumulative payoff is net of the alternative strategy, which is the cumulative discounted profit of switching immediately to T2. ρ is the discounting factor.

$$B^f(T) = \sum_{t=0}^{T-1} \rho^t \lambda \underline{\pi_1} + \sum_{t=T}^{\infty} \rho^t \pi_1 - \sum_{t=0}^{\infty} \rho^t \pi_2 \tag{5.1}$$

The net benefit of winning the conflict is zero for:

$$T^f = \frac{1}{\ln \rho} \ln\left(\frac{\pi_2 - \lambda \underline{\pi_1}}{\pi_1 - \lambda \underline{\pi_1}}\right) \tag{5.2}$$

Therefore, T^f is the maximum duration after which the firm would never plan on continuing the conflict. For T^f to be strictly positive, the full profit under technology 1 must be larger than under T2: $\pi_1 > \pi_2$. Of course, if the profit derived under T2 is larger than under T1, the firm would never choose to use T1 and nobody would consider boycotting. Note that if the residual profit under boycott is larger than the profit under T2, the payoff is always positive and the maximum duration would go to infinity: $\lambda \underline{\pi_1} > \pi_2$. In that case, indeed, the boycott is not costly enough to make T2 more profitable. The boycott could last forever and the firm would never switch to T2.

5.2.3 Maximum boycott duration

The environmentalists net payoff of winning the game after T periods consists of the discounted utility of boycotting for T periods, plus the cumulative utility of having the good produced with T2 forever. It is net of the alternative strategy, which is the discounted cumulative utility of never boycotting:

$$B^c(T) = \sum_{t=0}^{T-1} \rho^t U_b + \sum_{t=T}^{\infty} \rho^t U_2 - \sum_{t=0}^{\infty} \rho^t U_1 \tag{5.3}$$

This net payoff is zero for:

$$T^c = \frac{1}{\ln \rho} \ln\left(\frac{U_1 - U_b}{U_2 - U_b}\right) \tag{5.4}$$

The environmentalists would never plan to boycott longer than T^c periods. T^c is positive if the utility derived with a T2 production is larger than with a T1 production: $U_2 > U_1$.

Obviously, the environmentalists would never consider boycotting if they derive a larger utility with T1. Similarly, T^c goes to infinity if the utility of boycotting is larger than the T1 utility: $U_b > U_1$. Indeed, in that case, boycotting by itself provides a positive net utility. The boycott could last forever even if the firm never switches to T2.

5.2.4 Outcome of the game

As shown before, the outcome of the game depends on the two maximum durations. If $T^f > T^c$, the consumers know that they couldn't stay long enough in the game to induce a change in the firm's behavior. Thus they will choose to withdraw immediately and will never boycott. Conversely, if $T^c \geq T^f$ [1], the firm knows that it cannot stay longer in the conflict than the consumers. Thus its best response is to switch immediately to T2.

There are several extreme cases, which lead to different outcomes (see table 1). First, if $\pi_2 > \pi_1$, technology 2 is more profitable than technology 1, and the boycott has no reason. Second, if $U_1 > U_2$, T1 is preferred by the consumers. There is therefore no boycott and the firm keeps using T1.

Third, for $\pi_2 \leq \lambda \underline{\pi_1}$, the boycott is not costly enough (or coordination is too weak) to induce the technology change. Indeed, if the decrease in the firm's profit is too small, the firm always chooses to keep the polluting technology whatever is the behavior of the environmentalists. In that case, if the opportunity cost is positive, the environmentalists know that their pressure is too weak to induce the technology change, and they never boycott.

Fourth, if $U_b > U_1$, the environmentalists always boycott, whatever is the firm's strategy. In that case, the opportunity cost is negative, which means that consumers derive positive net utility from boycotting. This case can explain why one may often witness unsuccessful boycotts that never end. If the boycott is costless for some consumers, they always will participate. But in that case, they are likely to have small amounts of consumption, which generate a too small decrease in the firm's profit to make it change its behavior.

[1] We assume implicitly that for $T^c = T^f$, the firm would be the one to withdraw. Let call it the firm's implicit preference for compromise. Thus we focus on pure strategies.

Tab. 5.1: Outcome of the boycott

Utility	Profit	T^c	T^f	Outcome
	$\pi_2 > \pi_1$		$T^f < 0$	Technology 2 chosen by the firm
$U_1 > U_2$		$T^c < 0$		T1 preferred by the consumers, no boycott
$U_1 > U_b$	$\pi_2 \leq \lambda\underline{\pi_1}$	$T^c > 0$	$T^f \to \infty$	T1 always kept, No boycott
$U_1 < U_b$	$\pi_2 \leq \lambda\underline{\pi_1}$	$T^c \to \infty$	$T^f \to \infty$	T1 always kept, always boycott
$U_1 > U_b$	$\pi_2 > \lambda\underline{\pi_1}$	$T^c > 0$	$T^f > 0$	Boycott successful if $T^c \geq T^f$
				T1 kept if $T^c < T^f$

Outcome for $U_1 > U_b$ and $\lambda\underline{\pi_1} < \pi_2$: For otherwise, i.e. for $U_1 > U_b$ and $\lambda\underline{\pi_1} < \pi_2$, the outcome of the game is determined by the value of the parameters. In this case, we can analyze which factors influence the two maximum lengths T^f (see Appendix B) and T^c (Appendix C).

First, a more profitable clean technology decreases the maximum conflict duration of the firm T^f: $\frac{\partial T^f}{\partial \pi_2} < 0$. Conversely, a more profitable dirty technology increases T^f: $\frac{\partial T^f}{\partial \pi_1} > 0$. Finally, T^f is larger if the residual profit under boycott is small and the EO inefficient to coordinate consumers: $\frac{\partial T^f}{\partial \underline{\pi_1}} > 0$, $\frac{\partial T^f}{\partial \lambda} > 0$.

Second, a larger utility derived from the clean technology increases T^c: $\frac{\partial T^c}{\partial U_2} > 0$. Moreover, a smaller T1 utility also increases T^c: $\frac{\partial T^c}{\partial U_1} < 0$. Finally, a higher utility of boycotting increases the maximum boycott duration, by decreasing the boycott opportunity cost: $\frac{\partial T^c}{\partial U_b} > 0$.

5.2.5 *What make a boycott successful?*

Quality of the substitute

The quality of the substitute increases the potential for success, by decreasing the opportunity cost of boycotting. Our specification does not consider the market structure explicitly. However, considering an imperfect substitute allows for flexibility in the analysis. As an extreme case, if the firm is in a monopoly position, there is no substitute and $U_b = 0$ (assuming boycotting provides no utility by itself). As another extreme, if the firm plays in a very differentiated market, , there is room for ecological certification or labeling, and another firm may enter and provide the good with a clean production. The exploitation of this niche would imply $U_b \geq U_2 > U_1$. Then the environmentalists would always choose to boycott, because the boycott would be costless. Therefore, boycotts are more likely to succeed if the targeted firm plays in a very differentiated and competitive market than if the firm is a monopoly, because the opportunity cost is likely to be smaller. Moreover, boycotting a single firm should be more efficient than boycotting an entire sector, because it gives more chance to find a good substitute.

Moreover, this specification of the utility of boycotting has some interesting implicit implications. First, boycotting may have an utility *per se*. Indeed, collective action participation to improve the quality of the environment may provide positive utility for an environmentalist, which would be positively correlated with U_b. Second, the utility of boycotting is likely to be positively correlated with the number of consumers participating in the boycott. Indeed, being a part of a large community with noble objectives may increase a consumer's utility. In the context described here, the utility of boycotting is directly related to the share of environmentalists (α) in the population. Third, the substitute, even if of good quality, may be quite difficult to find on the market, which creates potentially important transaction costs and thus reduces the utility of boycotting.

Demand structure

Overall, the chances of success of a consumer boycott depends on the ability to hurt the firm's profit enough. Thus if the share of environmentalists consumption in the firm's profit is large, the residual profit under boycott will be low, because the boycott deprives the firm of a large share of its profit.

The residual profit depends on the residual consumption. It is therefore decreasing in the number of consumers participating in the boycott (α). Moreover, it is also decreasing in the environmentalists consumption. Finally, it is increasing in the non-environmentalists consumption.

The share of environmentalists in the population: A large number of environmentalists (α) unambiguously raises the boycott potential for success. First, as mentioned before, it may increase the utility of boycotting. Thus, it is negatively correlated with the opportunity cost of boycotting and positively correlated with the maximum boycott duration of the consumers (T^c). On the other hand, a large boycotting population decreases the residual profit $\underline{\pi_1}$. Therefore, it decreases the maximum duration of the firm (T^f).

The environmentalists consumption: The amount consumed by the environmentalists has an ambiguous effect on T^f. Indeed, it decreases the profit from technology 1 under boycott (which has a negative impact on T^f), but it increases the full profit under technology 1 (which tends to increase T^f). Overall, the amount consumed by environmentalist is likely to decrease the maximum duration of the firm because it increases the pressure of the boycott, by increasing the difference between π_1 and $\underline{\pi_1}$. Thus it decreases T^f.

The impact of the amount consumed by environmentalist consumers on T^c is less straightforward. On the one hand, a larger amount consumed decreases indirectly the residual pollution, which tends to decrease the opportunity cost. On the other hand, a consumer used to consume large amounts of the boycotted good is likely to have a larger opportunity cost than a small-amounts consumer, simply because he has a larger amount to renounce. A larger environmentalist consumption thus increases directly the opportunity cost, because it increases the amount to transfer for the substitute consumption. Overall the environmentalists consumption tends to decrease T^c, because the direct consumption effect is likely to dominate the indirect pollution effect.

Overall, it appears that the consumers the most able to hurt the firm's profit are also those with the highest opportunity cost. Therefore, they are less likely to participate in the boycott. In the light of this proposition, it is easier to understand the existence of infinite consumer boycotts that never succeed. Indeed, people participating in boycott campaigns are usually those who are the most aware of and highly sensitive to their own pollution. Therefore, they are likely to be in small number, because of their high sensibility to their environment, and to be relatively small consumers, because they take into account the pollution induced by their own consumption. Boycotting is costless for them, but their consumption only represents a marginal share of the targeted firm's profit, and thus do not hurt the firm's profit much.

Take the example of the boycott of major oil companies because of their lobbying effort to deter climate change policies. Consumers the most likely to boycott these companies are those who feel the highest negative utility from pollution. Even if no boycott is announced, these consumers are likely to prefer using their bicycles or public transports to the frequent use of their car, and their capacity to hurt the companies' profit is small. Conversely, consumers the most able to hurt the firms profit consume a lot of oil, and thus have high opportunity cost, which make their participation to the boycott unlikely.

Its seems therefore interesting for NGOs willing to implement an environmental boycott to work on the α, i.e. informing and educating non-environmentalist consumers to increase their awareness of and sensitivity to their responsibility in the degradation of their environment.

Finally, the EO's capacity to coordinate environmentalist consumers is important. Coordination issues have only been considered through a boycott efficiency parameter. Coordination can be introduced more relevantly by relaxing two restrictions of this model. First, the environmentalists may not be perfectly aware of the threshold at which the firm decides to switch technology. Moreover, these consumers may have heterogenous preferences, which would induce heterogenous boycotting behaviors.

5.3 Coordination failure

We focus now on the consumers side and relax the perfect information assumption. There are N environmentalists who would prefer the firm to switch for the clean technology. We introduce here some heterogeneity between environmentalist consumers. We consider the fact than consumers can have different costs of boycotting and gains from a boycott success[2]. Consumer i's individual choice at time t is boycotting ($B_i(t) = 1$) or not boycotting ($B_i(t) = 0$). The number of boycotting consumers at time t is therefore:

$$n(t) = \sum_{i=1}^{N} B_i(t) \tag{5.5}$$

We adopt here a simpler boycott specification. First, the firm would switch technology if the boycotting population is greater than or equal to n^s. This threshold at which the boycott is successful is unknown to the environmentalists. They only have a probability of success, which is conditional on the boycott importance: $p[n(t) \geq n^s]$. The boycott success probability is zero if nobody boycott: $p[0 \geq n^s] = 0$. Moreover the boycott would

[2] Consumers are classified according to their environmental preferences: consumer 1 has the highest environmental preferences and individual N has the lowest environmental preferences.

be successful for sure if every environmentalist was boycotting $p[N \geq n^s] = 1$. [3] Thus the boycott is potentially successful, but the environmentalists need to coordinate.

We assume a basic structure of boycotting: consumers accept to pay a certain cost of boycotting C_i, to receive a gain G_i in case of success. Overall, consumer i decides to boycott at time t if his potential gain from a boycott success exceeds his cost of boycotting. Overall the individual choice of boycotting depends on the probability of the boycott success.

$$\begin{cases} B_i(t) = 1 \; if \; p[n(t) \geq n^s]G_i - C_i \geq 0 \\ B_i(t) = 0 \; if \; p[n(t) \geq n^s]G_i - C_i < 0 \end{cases} \tag{5.6}$$

Considering this equation, one can derive the participation threshold $\overline{p}_i = \frac{C_i}{G_i}$ at which consumer i decides to boycott.

$$\begin{cases} B_i(t) = 1 \; if \; p[n(t) \geq n^s] \geq \overline{p}_i \\ B_i(t) = 0 \; if \; p[n(t) \geq n^s] < \overline{p}_i \end{cases} \tag{5.7}$$

A first comment is that environmentalist consumers will enter sequentially in the boycott. Strong environmentalists, who have low costs of boycotting and small participation thresholds, will participate first. As the boycott importance and the probability of success grow, consumers with higher thresholds of boycotting decide to participate. Thus the first consumers deciding to boycott are those with negative costs of boycotting. Their participation threshold is therefore: $\overline{p}_i = 0$. As time goes on, the boycott importance grows as long as the probability of success gets larger than or equal to the probability threshold of some consumers.

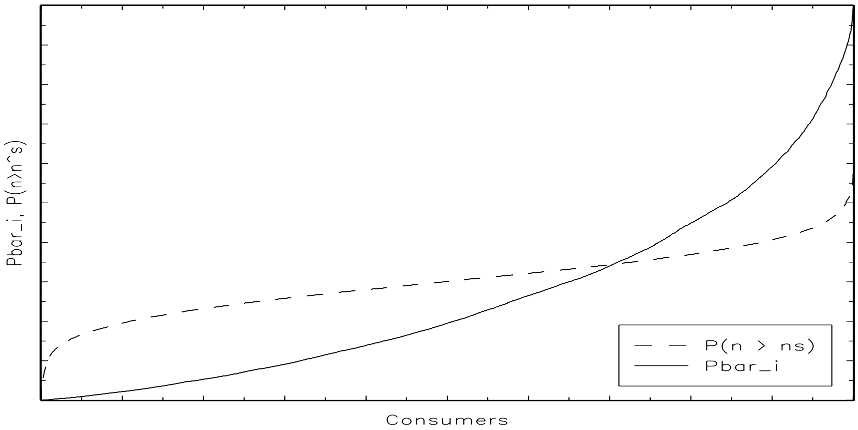
Therefore the last consumer $\overline{n}$ deciding to boycott is defined as follows. It defines also the equilibrium boycott participation.

$$\overline{n} : \; p[\overline{n} \geq n^s] = \overline{p}_n = \frac{C_n}{G_n} \tag{5.8}$$

Figure (5.1) gives a representation of the equilibrium boycott population, which is the intersection between the two curves $p[n(t) \geq n^s]$ and $\overline{p}_i$. The boycott is successful if $\overline{n} \geq n^s$. Overall, this equilibrium boycott participation and thus the potential for success depend on the distribution of boycotting costs and the beliefs structure. Coordination needs optimistic

[3] The beliefs formation is not considered here. This belief structure can be due to the firm's reputation or other boycott experiences.

Fig. 5.1: **Equilibrium boycott population**



Parameters: $\overline{p}$: *Chi*^{2} *distribution*

$p[n(t) \geq n^s]$: *normal distribution*

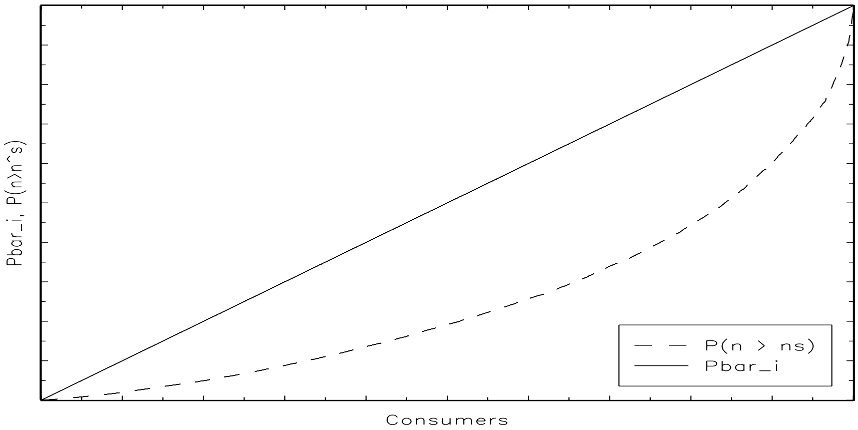
$N = 10000, \overline{n} = 7296$

consumers about the firm's withdrawal threshold n^s. Moreover, the consumers distribution needs to have fat tails, i.e. a large number of strong environmentalists, with low participation thresholds.

Figure (5.2) gives an example of coordination failure. The boycott would be successful if every environmentalist would participate. However, the consumers distribution (uniform in the case of figure (5.2)) and the beliefs structure (normal distribution) is such that nobody decides to boycott in equilibrium.

Overall one can easily see that even a potentially successful boycott may be ineffective due to coordination failures, even if a boycott success could be an equilibrium. Moreover, boycotting may enhance free riding.

Fig. 5.2: **Unsuccessful boycott due to coordination failure**



Parameters: $\overline{p}$*: uniform distribution*

$p[n(t) \geq n^s]$*: normal distribution*

$N = 10000, \overline{n} = 0$

5.4 Boycott and free riding

In the first two sections, the environmentalists were considering two strategies and related payoffs. The first strategy consists of participating in a potentially successful boycott, while the second one is not participating. In this case, we considered that the boycott was unsuccessful for sure. However, the choice of an environmentalist could come from comparing participating in a potentially successful boycott and not participating in a potentially successful boycott. In other words, any individual could decide to free ride, i.e not to participate in the boycott while hoping for it to succeed.

In this case, any individual environmentalist participates if the expected payoff of participating exceeds the expected payoff of not participating, conditional on the boycott success. Basically, boycotting consists of paying a cost (C_i) for sure (i.e not consuming the good) to receive a potential gain G_i (i.e the technology switch). In contrast, there is no direct cost of not boycotting, but this strategy also provides a potential gain: the boycott may be successful even if any particular individual does not boycott. Overall any environmentalist i boycotts $B_i = 1$ if:

$$p[\sum_{i\neq -i} B_{-i} + 1 \geq n^s]G_i - C_i \geq p[\sum_{i\neq -i} B_{-i} \geq n^s]G_i \tag{5.9}$$

Therefore the choice of boycotting depends on the impact of the individual choice of boycotting on the probability of withdrawal for the firm:

$$p[\sum_{i\neq -i} B_{-i} + 1 \geq n^s] - p[\sum_{i\neq -i} B_{-i} \geq n^s] \geq \frac{C_i}{G_i} \tag{5.10}$$

Overall the probability of the boycott success only increases marginally with the choice of an individual consumer. Thus, the difference between the two probabilities is close to zero, and only consumers with small $\frac{C_i}{G_i}$ ratios participate in the boycott.

5.5 *Case studies*

5.5.1 *Shell and the Brent Spar case*

In 1995, Shell Oil was planning to sink a 14 500 ton oil platform in the North Atlantic sea. The environmental organization Greenpeace initiated a vast protestation movement to oppose this practice. Activists occupied the Brent Spar platform, 200 Shell service stations were threatened in Germany and a widespread boycott of Shell took place. After a few months, Shell canceled its plan for deep sea disposal and decided to recycle the entire structure.

Several insights given in this paper can help to explain this boycott success. First, oil is quite an homogeneous good, and oil stations are easy to find almost anywhere. Therefore, one can consider that the non-polluting substitute (i.e oil companies not sinking the platform) is perfect, and the only transaction cost is going from any Shell station to the next oil station, which is likely to be quite low. Overall, boycotting shell was costless ($U_b \geq U_1$).

Moreover, sinking costs (π_1) were estimated at 11.8 million pounds, while the alternative method costs (π_2) were estimated at 46 million pounds. Considering the fact that Shell is a worldwide multinational, maybe this difference in costs was quite small compared to the size of the boycotting population, which reduces the maximum duration of the firm.

In other words, Shell was almost costless to boycott and easy to hurt, which can explain why the Brent Spar case is often considered as an example of successful boycott.

5.5.2 Cosmetic firms and animal testing

Animal testing (on invertebrates, rabbits, primates) is a commonly used practice in several industries (e.g: cosmetics, pharmaceutical companies). This practice is considered as incompatible with animal rights by many environmentalists. Several environmental organizations provide lists of companies using animal testing, in order to induce consumer boycotts.

Following this paper analysis, this type of consumer boycott has very few chances to succeed. Indeed, boycotting firms using animal testing is almost equivalent to boycott the entire cosmetic sector. Good substitutes (cosmetic firms not using animal testing) are therefore difficult to find and transaction costs are likely to be high. For example, "Ahimsa", a French organization lobbying for animal protection, lists more than 200 firms testing their products on animals (cosmetic firms and others). Note first that it is difficult to perfectly memorize a 200 firms list. There is therefore a problem of clarity of the boycott, which reduces considerably the utility of boycotting.

However, focusing on cosmetic firms, one can find good substitute on the market. For example, "bodyshop" provides products free of animal testing. But even in this case, there may be important transaction costs: although getting more and more important, bodyshop is not a trademark very easy to find worldwide. For instance, it can be very difficult to find bodyshop shops for people not living in large cities.

Overall, boycotting firms using animal testing should not be very effective, especially because of high transaction costs, due to a lack of clarity in the boycott and difficulties to purchase good substitutes. It is thus likely that only strong environmentalists participate in this type of boycott and their hurting capacity is probably quite small. Moreover, alternative strategies to animal testing, although an important research topic (see Johns Hopkins Center for Alternatives to Animal Testing) may be still probably far from profitability.

5.5.3 Boycott of non-certified timber

Several NGOs militate for a boycott of non-certified tropical timber. Indeed, illegal logging in developing countries plagues local development and degrades forest resources. This type of boycott first appears to be a perfect case for a success. Indeed, timber is quite an homogeneous good. Moreover, ecological timber certification offers good substitutes. Overall, the opportunity cost of boycotting non-certified tropical timber seems to be quite low.

However, a second look mitigates this first impression. First, quite a few ecological labels exist (SmartWood, Scientific Certification Systems, Certified Wood Products Council, Good Wood, Forest Stewardship Council), which may create confusion and decrease the clarity of the boycott. Consumers might be lost in determining which label is the most environmental-friendly, which creates an indirect cost of information searching.

Moreover, boycotting consumers stand mainly in developed countries, while the most important part of tropical timber is consumed in the country of production. The World Resource Institute estimates that only 20% of the wood produced is exported (Rezende de Azevedo et al., 2001). Potential impact of the boycotting population is thus fairly small, because tropical timber offers multiple markets options, which reduces the boycott influence. Finally, boycotting tropical timber may have adverse effects on the land use. Indeed, the aim is to decrease forest over-exploitation, by decreasing the value of non-certified timber. However, if the value of the exploited forest decreases too much, it may create an incentive for land use change and thus increase deforestation. Indeed, the landowner may choose to convert devaluated forest land into agriculture or pasture.

Overall, the boycott of non-certified timber, although presenting small opportunity cost, does not offer much potential for success, mainly because of a too small concerned population.

5.6 Conclusion

This paper explores the conditions under which a consumer boycott upon environmental considerations may be successful. A boycott is presented here as a war of attrition between a firm and a group of consumers, for the choice of the producing technology.

The first model presented is quite simple. Indeed, assuming perfect information, no coordination issue, nor free riding, the outcome of the boycott is known as soon as it begins. For the most common case, with a positive opportunity cost of boycotting, boycotts never really happen: either the threat of the boycott is enough to induce an immediate change in the firm's behavior, or this threat is too weak and consumers do not boycott. Moreover, environmentalist consumers act as one community, which is quite different from real life boycotts.

However, even with this very simple set up, some interesting implications can be derived. The ability of the boycotting group to hurt the firm's profit enough is the main element determining the chance of success of such type of action. Thus the share of the boycotting group's demand in total demand is crucial. Nevertheless, this share is directly related to the boycott opportunity cost. Indeed, the boycotting group needs to be composed of important consumers to hurt the firm's profit (especially if the group is of small size). However, boycotting is more costly for a large-amount consumer, who has to renounce to a higher utility of consumption.

Overall, it appears that this tradeoff makes consumer boycotts unlikely to succeed. This might explain why one can witness so few successful boycotts in real life: boycotting groups are usually composed of consumers with small opportunity costs, whose boycott does not hurt the targeted firm's profit enough to make it change its behavior.

A potentially more efficient policy for NGOs would be to work on the share of the population sensitive to the quality of the environment. Indeed, the game presented here is static, but informing and educating consumers may increase their awareness of environmental degradation, especially the degradation they are responsible of. The objective of this policy would have two main consequences in the long run. First, it would induce a decrease in overall consumption, which would reduce environmental degradation. Second, this would increase the population likely to participate in environmental boycotts. In the long run, the combination of education and boycott would increase the potential for environmental friendly technology adoption.

Although this model does not consider explicitly the market structure, it seems reasonable to assume that competition increases the chances for the clean technology to be present on the market. Indeed, if there is free entry, there is room for ecological certification and green labeling: a firm may choose to enter the market and to produce the good with the clean technology, if it is profitable. In that case, there is a perfect substitute on the market. In a monopoly case, consumer boycotts are less likely to succeed, because there is no good substitute for which the environmentalists could switch their consumption. Finally, even if the demand structure allows for boycott success, consumers need to coordinate and avoid free riding.

Considering a public choice approach, being confident in such consumers actions would be a tempting consideration: governments could just let citizens take their destiny in their own hands to make firms adopt fair practices. However, in the light of this paper, it seems that consumer boycotts do not constitute a good substitute to public policies. Indeed, if the emergence of political consumption practices may be a good tool to signal citizen preferences, its effectiveness considering firms practices and environmental quality is doubtful.

A potentially effective policy for governments willing to increase the influence of this political consumption could be to facilitate the emergence of credible and trustful ecological certification, giving comprehensive and clear set of rules defining labeled products. Another policy that could enhance boycott successes is to tax more heavily polluting technology, or to subside clean technology. Indeed, this type of policy would reduce the difference between the profits derived by the dirty and the clean technology, which would decrease the firm's maximum conflict duration. Increasing taxes on polluting technology would increase boycotts success likelihood. Thus, environmental policies and consumer boycotts do not seem to be good substitute, but they may be effective complement.

Appendix A: maximum durations and game equilibrium

This appendix follows Burton's (2005) application. We consider first responses to each player's conjectures, and then consider which duration both players actually choose.

Response to conjectures: Consider that the firm believes that the consumers have chosen as strategy to boycott for a strictly positive duration $\hat{D}^c$, and then withdraw. This strategy cannot be distinguished from the "always boycott" strategy.

The firm must decide to remain in the conflict for $\hat{D}^c + 1$ periods, or to withdraw immediately. Indeed, withdrawing immediately is preferable that remaining less than $\hat{D}^c$ periods. If the maximum duration of the firm is less than or equal to the conjecture on the consumer boycott length, $T^f < \hat{D}^c$, the best strategy for the firm is to withdraw immediately.

Similarly, the consumers may conjecture that the firm has chosen to remain in the conflict for $\hat{D}^f$ periods, and then withdraw. If the maximum boycott duration is smaller than this conjecture $T^c < \hat{D}^f$, the best strategy for the consumers is not to boycott at all.

Strategy choice: To succeed, both players have to choose a longer duration than its conjecture: $D^f > \hat{D}^c$, $D^c \geq \hat{D}^f$. This is known to both players, which also know the maximum durations T^f and T^c.

"A rational player will use those strategies that are best responses to some beliefs he might have about the strategies of his opponents" (Fudenberg and Tirole, 1991). Therefore it is not rationalizable to both player to conjecture a duration that is shorter than the shortest maximum duration ($min(T^c, T^f)$).

Thus, if the firm has the shortest maximum duration $T^f < T^c$, both can conclude that the consumers would choose a larger duration: $\hat{D}^c > T^f$. In this case, the firm would be better off withdrawing immediately and the boycott would be successful in that case.

Appendix B: factors influencing T^f

Note that ρ is likely to be smaller than 1, thus $\frac{1}{\ln \rho} < 0$.

$$\frac{\partial T^f}{\partial \pi_2} = \frac{1}{(\pi_2 - \lambda \underline{\pi_1}) \ln \rho} < 0 \tag{5.11}$$

$$\frac{\partial T^f}{\partial \pi_1} = \frac{-1}{(\pi_1 - \lambda \underline{\pi_1}) \ln \rho} > 0 \tag{5.12}$$

$$\frac{\partial T^f}{\partial \underline{\pi_1}} = \frac{\lambda(\pi_2 - \pi_1)}{(\pi_2 - \lambda \underline{\pi_1})(\pi_1 - \lambda \underline{\pi_1}) \ln \rho} > 0 \tag{5.13}$$

$$\frac{\partial T^f}{\partial \lambda} = \frac{\underline{\pi_1}(\pi_2 - \pi_1)}{(\pi_2 - \lambda \underline{\pi_1})(\pi_1 - \lambda \underline{\pi_1}) \ln \rho} > 0 \tag{5.14}$$

Appendix C: factors influencing T^c

$$\frac{\partial T^c}{\partial U1} = \frac{1}{(U_1 - U_b) \ln \rho} < 0 \tag{5.15}$$

$$\frac{\partial T^c}{\partial U2} = \frac{-1}{(U_2 - U_b) \ln \rho} > 0 \tag{5.16}$$

$$\tag{5.17}$$

The quality of the substitute has a positive impact on T^c:

$$\frac{\partial T^c}{\partial U_b} = \frac{U_1 - U_2}{(U_1 - U_b)(U_2 - U_b)\ln \rho} > 0 \tag{5.18}$$

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