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Institutions and deforestation in developing countries

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Université d'Auvergne, Clermont-Ferrand 1
Faculté des Sciences Économiques et de Gestion
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Centre d'Études et de Recherches sur le Développement International (CERDI)

INSTITUTIONS AND DEFORESTATION IN DEVELOPING COUNTRIES

Thèse Nouveau Régime
Présentée et soutenue publiquement le 27 Octobre 2011
Pour l'obtention du titre de Docteur ès Sciences Économiques

Par

Sébastien Marchand

Sous la direction de
Mme Pascale Combes Motel et M. Florent Garnier

Membres du Jury

M. Christian Dugas de la Boissonny	Président	Professeur émérite à l'Université de Nancy 2
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M. Louis Hotte	Rapporteur	Professeur à l'Université d'Ottawa, Canada
M. José Feres	Suffragant	Chercheur à l'IPEA de Rio de Janeiro, Brésil

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La faculté n'entend donner aucune approbation ou improbation aux opinions émises dans cette thèse. Ces opinions doivent être considérées comme propres à leur auteur.

A mes parents.

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RÉSUMÉ

Cette thèse étudie le rôle des institutions dans la compréhension du processus de déforestation dans les pays en développement. L'approche retenue est celle de la nouvelle économie institutionnelle qui définit les institutions comme le cadre incitatif d'une économie, qui structure les interactions économiques des individus. Le cadre institutionnel est donc un élément à part entière du système économique, qui agit sur l'environnement humain à travers la modulation des incitations des agents. A ce titre, les institutions jouent donc un rôle majeur dans le processus de conservation ou de conversion des forêts. L'analyse de ce rôle est la problématique centrale de cette thèse et s'articule autour de trois grandes parties: (1) le rôle de la persistance des institutions ou rôle de l'histoire dans la compréhension de celui des institutions, (2) le rôle de la demande de bonne gouvernance, et (3) le rôle des institutions comme élément catalytique conditionnant l'effet de causes plus directes de la déforestation. La première partie conclut sur le rôle majeur de la prise en compte des legs légaux et coloniaux pour expliquer l'effet des institutions sur la déforestation. La seconde partie explique le rôle majeur de la demande de bonne gouvernance pour préserver la forêt, en étant un substitut (complément) d'une mauvaise (bonne) offre de bonne gouvernance. Enfin, la troisième partie de la thèse suggère de comprendre les institutions comme un facteur catalytique de la déforestation qui permet de comprendre l'effet des causes directes de celle-ci telles que la productivité agricole des fermes de l'Amazonie Légale, ou les comportements stratégiques entre communes du Paraná dans la création de parcs municipaux.

Mots-clés : déforestation, institutions, gouvernance, droit forestier, origines légales, productivité agricole, intéractions spatiales, Brésil.

ABSTRACT

This thesis investigates the role of institutions on deforestation within the framework of the New Institutional Economics. This theory states that institutions can be defined such as the incentive system which shape economic interactions throughout the modulation of the incentives of agents. This way, institutions are at stake in the process of deforestation and the analysis of this role is the core of this thesis, articulated around three parts: the role of institutional persistence (part 1), the importance of the demand for good governance (part 2), and the implications of institutions and governance system as an underlying framework shaping proximate causes of deforestation (part 3). The first part stresses the importance of taking into account colonial and legal legacies to understand the role of institutions on deforestation. The second part explains the leading role of the demand for good governance to preserve forests throughout its interactions with the supply for good governance. The third part proposes two micro-economics applications in Brazil. The role of institutions and governance system on forest cover is defined as a catalytic role precipitating the effect of proximate causes on deforestation such as agricultural productivity in the Legal Amazon, or strategic behaviors between counties in the creation of municipal conservation units in the state of Paraná.

Keywords: deforestation, institutions, governance, forest law, legal origins, agricultural productivity, spatial interactions, Brazil.

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Part I

General introduction

Why should we care about the forest?

Over the last few years, the fight against deforestation has been at the top of environmental and development agendas to such an extent that 2011 has been designated "International Year of Forests" by the United Nations General Assembly. This initiative relies on momentum already generated around two closely related key environmental issues, climate change and biodiversity, which have brought even greater attention to forests worldwide.

On the one hand, there is the biodiversity issue which was internationally recognized by the Convention on Biological Diversity proposed by the United Nations Environment Programme (UNEP) at the end of the 1980s. This convention was opened for signature at the United Nations Conference on Environment and Development (the Rio "Earth Summit" in 1992). This was inspired by the growing commitment to sustainable development and was designed for the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from the use of genetic resources. Thus, several Conferences of the Party (CoP) followed and the last, the CoP10, was held in Nagoya (Japan) in October 2010. The international recognition of the major role played by biodiversity in the process of a sustainable development stresses the importance of forests which contains the majority of the world's terrestrial species (plants, animals and micro-organisms) and must therefore be preserved.

On the other hand, climate change is now widely recognized as the major environmental problem facing the world. In 1994, the Convention on Climate Change, namely the United Nations Framework Convention on Climate Change (UNFCCC), entered into force and recognized that the climate system is a shared resource or a public good affected by industrial and other emissions of carbon dioxide and other greenhouse gases. This set a global framework for intergovernmental efforts to tackle the challenge posed by climate change. The Kyoto Protocol has pre-empted this initiative and set binding targets to an average of five per cent against 1990 levels over the five-year period 2008-2012 for 37 industrialized countries and the European community for reducing greenhouse gas (GHG) emissions. Climate change remains one of the most important global environmental issues. For instance, the last UN Climate Change Conference was held in Bonn (Germany) in June 2011 and the last CoP (16th) of the UNFCCC and the 6th CPP of the Kyoto Protocol were held in December 2010 at Cancun (Mexico). Each of these reasserts the need to protect the world's forests, which are a major repository of carbon (Pan et al., 2011). Thus, considering that deforestation and forest degradation account for nearly 20 per cent of global greenhouse gas emissions, and that forests act as is a sink for carbon sequestration, the goal for stabilizing global average temperatures will be achieved by reducing emissions from the forest sector, in addition to other mitigation actions, particularly the reduction of land use, land-use change and forestry (LULUCF) activities[1].

[1] The UN Climate Change Secretariat has proposed this approach to highlight the fact that human activities,

Moreover, from that has emerged the fact that forests in developing countries should be considered as a global public good providing global services, such as biodiversity and carbon sink, and that these forested countries have to be incited to produce it, i.e. to preserve the forest. Consequently, the incentives-based mechanism for Reducing Emissions from Deforestation and Degradation (REDD) was proposed to reward the governments of developing countries for their performance in reducing deforestation (Angelsen, 2009)[2]. This mechanism relies on the assumption that developing countries have to pay an opportunity cost to conserve their forests, i.e. the income from alternative uses such as agriculture, and would prefer, in turn, other choices and convert their forest lands to other uses (Karsenty and Ongolo, 2011).

In addition to the long-term consequences of global deforestation in terms of loss of biodiversity, climatic disruption and the destruction of forest-based-societies, the health of forests plays an increasingly important role in the short-term for poverty alleviation[3], economic development, and for providing local environmental services such as soil fertility, a barrier against erosion, flooding and wind... Consequently, both short-term impacts and global long run issues push the tropical deforestation issue to the top of the development agenda (Cancun 2010 16th CoP, REDD mechanism). This is particularly relevant because deforestation occurs mainly in tropical forest areas, considered both as main biodiversity hotspots (Myers, 2000) and carbon sink, based in developing countries located in South America, Africa and Southeast Asia.

Understanding the figures

While the international community has recognized the great importance to preserve the forest all around the world for biodiversity conservation but also to mitigate climate change, global deforestation still continues and is estimated at around 13 million hectares a year in the last decade (compared to 16 million hectares per year in the 1990s, FAO (2010)).

In 2010, the last Forest Resources Assessment of the Food and Agriculture Organization

through land use, land-use change and forestry (LULUCF) activities, affect changes in carbon stocks between the carbon pools of the terrestrial ecosystem such as forests, and between the terrestrial ecosystem and the atmosphere. Several Articles of the Kyoto Protocol include the land use, land-use change and forestry activities and states actually that countries should implement policies to protect and enhance sinks of greenhouse gases as well as to promote sustainable forest management, afforestation and reforestation, and sustainable forms of agriculture. The clean development mechanism (CDM) was created to reduce LULUCF activities and allow emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO2, which can be traded, sold, and used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol. Thus, deforestation, as a LULUCF activity, is associated with this mechanism.

[2]REDD was proposed for the first time in 2005 by a group of developing countries led by Papua New Guinea and Costa Rica (in the 11th CoP of the UNFCCC), and then mentioned at the 13th Conference of the Parties (CoP 13) of the UNFCCC, later confirmed in Cancun during the 16th CoP in 2010.

[3]The goods and services from trees and forests can also benefit other sectors (agriculture, energy and water sector and tourism) and the quality of forest management plays an important role in rural development and the livelihoods of the poor.

estimated that forest areas represented around 4 billion hectares or one third of total land area[4]. The five most forest-rich countries, namely the Russian Federation, Brazil, Canada, the United States of America and China, account for 53 percent of the total forest area. In contrast, 2 billion people (in 64 countries) have forest on no more than 10 percent of their territories.

The largest tropical forest ecosystems are located in the Brazilian Amazon with 520 million hectares in 2010 followed by the Democratic Republic of Congo (154 million hectares) and Indonesia (94 million hectares)[5]. Concerning tropical forests in South America, wooded land represents 49% of land area mainly covered by the Amazonian forest. Africa has 23% of its territory covered by forest areas and the forest in Asia covers 19% of the territory.

Also, the total net change in forest area in the last decade is estimated at -5.2 million hectares per year, an area equivalent to a loss of more than 140 km2 of forest per day[6]. Compared to the 1990s, the current annual net loss is 37 percent lower attributed both to a decrease in the deforestation rate and an increase in the area of new forest due to natural expansion of existing forests and afforestation through planting or seeding.

At a regional level, South America is the sub-region which had the largest net loss of forests between 2000 and 2010 with about 4.0 million hectares deforested per year, followed by Africa which cut down 3.4 million hectares per year, and South and Southeast Asia with 0.67 million hectares (see figure 1).

In South America which contained over half of the world's primary forests (57 percent), the average annual net loss of forest was 3.6 million hectares per year in the period 2005-2010 compared to 4.4 million hectares in the period 2000-2005 and 4.2 million hectares in the 1990s. It is worth noting that regional trends reflect mainly the trends in Brazil, which accounts for 60 percent of the forest area in this region. In the mid-nineties, according to the Brazilian National Institute of Space Research (INPE, Instituto Nacional de Pesquisas Especiais), the rate of deforestation was 18,000 km^2 per year, and the average annual land forest-clearing was between 12,000 and 16,000 km^2 while the annual area cleared increased from 18,226 (in 2000) to 27,379 km^2 (in 2004) to then decrease from 18,759 (2005) to 11,224 km^2 (2007). The leading cause of deforestation in South America (as well as the Caribbean) is the conversion of forest

[4]Forest land can be grouped into two main categories: temperate and boreal forests and tropical forests. The last concerns mainly developing countries and is located within 28 degrees north or south of the equator, i.e. in Asia (mainly in South and Southeast Asia), Australia, Africa, South America, Central America, Mexico and in many of the Pacific Islands.

[5]China is the second most important developing country with the largest forest (207 million hectares in 2010) but China has a great variety of forest types: coniferous trees in the northern cold temperate zone, a mixed forest of deciduous and broad-leaved trees in the temperate zone, a deciduous broad-leaved forest and evergreen broad-leaved forest in the subtropical zone, and finally rain forest and monsoon in the tropical zone.

[6]The total net change in forest areas is the sum of all negative changes due to deforestation and natural disasters and all positive change due to afforestation and natural expansion of forests. Deforestation is the most important negative change and requires that forests are cleared by people and the land converted to other use, such as agriculture or infrastructure. Natural disasters provoke negative change when forest land destroyed by a natural disaster is converted to other land in the case where the area is incapable of regenerating naturally and no efforts are made to replant. Afforestation is planting or seeding of trees on land that was not previously forested and natural expansion of forests corresponds to abandoned agricultural land (FAO, 2010, p.19).

Figure 1: Annual change in forest area by region, 1990-2010

Region/subregion	1990–2000		2000–2010	
	1 000 ha/yr	%	1 000 ha/yr	%
Eastern and Southern Africa	-1 841	-0.62	-1 839	-0.66
Northern Africa	-590	-0.72	-41	-0.05
Western and Central Africa	-1 637	-0.46	-1 535	-0.46
Total Africa	**-4 067**	**-0.56**	**-3 414**	**-0.49**
East Asia	1 762	0.81	2 781	1.16
South and Southeast Asia	-2 428	-0.77	-677	-0.23
Western and Central Asia	72	0.17	1 31	0.31
Total Asia	**-595**	**-0.10**	**2 235**	**0.39**
Russian Federation	32	n.s.	-18	n.s.
Europe excl. Russian Federation	845	0.46	694	0.36
Total Europe	**877**	**0.09**	**676**	**0.07**
Caribbean	53	0.87	50	0.75
Central America	-374	-1.56	-248	-1.19
North America	32	n.s.	188	0.03
North and Central America	**-289**	**-0.04**	**-10**	**-0.00**
Total Oceania	**-41**	**-0.02**	**-700**	**-0.36**
Total South America	**-4 213**	**-0.45**	**-3 997**	**-0.45**
World	**-8 327**	**-0.20**	**-5 211**	**-0.13**

Source: Global forest resources Assessment 2010, FAO

land to agriculture. In addition, the important effort for biodiversity conservation has increased the area of forest used by about 3 million hectares annually since 2000.

In Africa, the average annual net loss of forest has gone down from 4.1 million hectares per year in the 1990s to 3.4 million hectares per year in the last decade. However, the FAO states that these trends should be treated with caution since few countries have reliable data from comparable assessments over time. For instance, the decreasing net loss is mainly due to a substantial reduction in the net loss reported by Sudan, where recent figures are much lower than those estimated for the 1990s after recent efforts to gather new reliable data. Afforestation has increased in Africa during the last decade, in particular in West and North Africa to combat desertification or to secure industrial wood and energy sources. Also, efforts have been made for conservation of biodiversity in Central and East Africa. However, there was a decline in productive forest areas. Finally, the leading cause of deforestation remains the wood-for-fuel removal as a result of rising population numbers in the region.

In South and Southeast Asia, deforestation remains substantial but has significantly decreased from 2.4 million hectares per year reported for the 1990s to 0.7 million hectares annually in the last decade. The regional trends are influenced by the Indonesian trends, characterized by a very significant drop in its rate of net loss over the 2000-2005 period compared with the 1990s although the rate raised again during 2005-2010. The leading cause of tropical deforestation in South and Southeast Asia is mainly timber production. The area of productive forests

has increased over the last decade and employment in the primary production of forest goods was more important than in the global total. As a whole, Asia reported an average net gain of more than 2.2 million hectares per year between 2000 and 2010 compared with a net loss of 0.6 million hectares per year in the 1990s. This figure was a result of large-scale afforestation reported by China (where the forest area increased by an average of 3 million hectares per year since 2000 while it rose by 2 million hectares per year in the 1990s).

Overall, the combined net loss of forest area of the ten countries with the largest net loss per year in the last decade was 6.0 million hectares per year compared with the same combined loss of forest of 7.9 million hectares per year during the 1990s. These reductions were mainly due to the improvements implemented in Indonesia, Sudan and Brazil[7]. To conclude with some figures on the forest, the world's total growing stock in forests represents 527 billion m3 or 131 m3/ha and is the highest in the tropical forests of South America, and Western and Central Africa. These figures stress the importance of studying the causes of deforestation in tropical developing countries considering that (1) global environmental services such as biodiversity and climate change and (2) alleviation of poverty and economic development are linked to the state of the pristine forest in terms of stock but also of management and governance.

Understanding the causes

If forested areas roughly cover one third of world land surface, regional dynamics are at work. The forest transition theory is an attempt to conceptualize the different stages occurring during the process of forested land cover change. This theory, initially developed by geographers such as A.S. Marther (Mather, 1992) and A. Grainger (Grainger, 1995), is a theory of land use allocation in which the value of land under competing uses determines whether the resulting pattern of land use leads to an increase or decrease in forest cover. Put differently, this theory states that the forest cover changes over time as the value of one land use relative to the value of its competing use, changes over time (Barbier et al., 2010).

With a more dynamic view forest transition represents a land use transition from two land use systems in dynamic equilibrium: the first is characterized by exploitative use of forests (the allocation of forest to agricultural activity) associated with declining forest cover, and the other, represented by a sustainable use of woodland (either the allocation of agricultural and other land to plantations and tree crops or the abandonment of agricultural land and its subsequent reversion to forestry) with recovering forest cover (Lambin and Meyfroidt, 2010). This theory can hence be used to explain both deforestation and afforestation in a general framework linked to land use and a land cover change (LUCC) approach. Thus it is possible to analyse the forces

[7] During the last decade, Australia was the second country with the largest net loss per year with 562 thousand hectares per year. However, this is due to severe drought and forest fires more than deforestation resulting from land conversion.

that affect human land uses and, in turn, land cover change such as forest cover change. Within this framework all stages of forest cover changes, from deforestation to reforestation, can be analysed (Turner et al., 1993; Ojima et al., 1994; Geist and Lambin, 2002). The LUCC approach stresses in turn the importance of identifying the complex interrelationships between human land uses, their causes and the final impact on land cover (see figure 2, page 13).

The forest transition theory thus explains why some countries face major deforestation and others afforestation or reforestation. More precisely, this theory suggests that the pattern experienced by developed countries, in which a transition from shrinking to expanding forest area occurs during the mid 80s, could be applied to developing countries (Mather, 1992). Thus, current similarities between historical deforestation in now-developed countries such as European countries and current deforestation in developing countries, are analysed to establish a theoretical explanation of forest transitions in an attempt to understand why and how forest transitions take place.

The main improvements in the forest transition theory concern the attempts which have been made to explain the typical paths of forest change that characterize forest transition. Rudel et al. (2005) proposes to distinguish a forest scarcity path and an economic development path. According to the former, a relative scarcity of forests can result in either new political pressures or price signals. A major land use change associated with forest transition is the allocation of agricultural land to plantations and tree crops when either private landowners or the forest products industry decide to invest in more plantations as well as in the management of the new secondary forests for both tree crops (i.e. palm oil, rubber...) and commercial timber products. Underlying motivations for new investments in forestry are mainly based on rising prices for timber and tree products in markets following the rising demand for these products, as per capita incomes increase (Foster and Rosenzweig, 2003).

According to the economic development path, after a period of massive deforestation, large areas of agricultural land are abandoned and left to forest regeneration. This abandonment is due to the economic development which has created enough off-farm jobs to encourage farmers to leave their activities. Labour force is thus driven out of agricultural and rural areas to other activities and urban areas. Parallel to this trend, market development following the rising urban food demand pushes the intensification of the agriculture in more suitable areas. Thus, agricultural production increases under the use of more productive technology resulting in a decrease of crop prices and leading to unprofitable areas in marginal fields where agriculture decreases.

Also, within the framework of land use allocation under competing uses, economic development may influence the values of competing uses of forested land through two other paths. As land use allocation depends on rent, economic exchange conditions underlying this allocation can be influenced by the institutions and government policies shaping these exchanges and moving along with economic development. For instance, land uses policies may change the forest cover path. For instance, Lambin and Meyfroidt (2010) argue that, though the extent

of forest scarcity can play a role in the motivation to implement such policies, the underlying motivations of these policies are often factors outside the forestry sector such as a willingness to modernize the economy and land use; integrate marginal social groups such as ethnic minorities living in forests; promote tourism or foreign investments by "greening up" the image of the country; or a geopolitical interest in asserting control over remote territories via the creation of natural reserves or managed state forests. Mather (2007) provides interesting examples of such policies in China and Thailand.

Moreover, forest transitions can occur through the globalization pathway which also moves along with economic development (Lambin and Meyfroidt, 2010). The starting point is that developing economies are nowadays strongly integrated into global markets. This integration, through tourism, exportation forest and agricultural products, remittances (Hecht et al., 2006) or global institutions to control tropical deforestation (REDD policy), may affect the way economic modernization shapes forest covers. In this view, globalization has contributed to a land use transition in some countries.

As a consequence, two kinds of forces drive forest transitions in these different pathways: (i) negative endogenous socio-ecological feedback and (ii) exogenous socio-economic dynamics. The former may happen with the decline of goods and services provided by natural ecosystems leading to more forest conservation. They are mostly local and endogenous, influencing more specifically the territory affected and its local population. The second comes from a higher organization level so that they are not a direct result of land cover change such as institutions.

Lambin and Meyfroidt (2010) highlight three cases of negative endogenous socio-ecological feedback. First is the natural adaptive cycle of resource-limited growth which states that the recovery of natural ecosystems and land use intensification are part of the backloop of the cycle of forest cover, following a phase of agricultural expansion and capital accumulation. Agricultural expansion is thus conceived as a spatial diffusion process, driven by a set of decisions by agents to migrate into frontiers and to clear land for crop production resulting in the stabilization of the area of natural ecosystems once the minimum flow of natural ecosystem services that is required by the local population, is reached. The second case of negative socio-ecological feedback is based on land scarcity and agricultural intensification. The starting point for this is that agricultural expansion leads to land scarcity which in turn leads to agricultural intensification. The latter features reduce the demand for land after the adoption of land-saving and yield-enhancing technologies, and the shortening of the fallow cycle. Thus the rate of conversion of natural ecosystem declines along with the shift of agricultural productivity. After, this could subsequently lead to land use transition with stabilization or even an increase in tree cover and natural habitats. The third and last case of endogenous negative feedback, following the theoretical work of Mather and Needle (1998), is the adjustment of agricultural land use to land quality. The basic idea is that as farmers learn more about the agro-climatic potential of their lands, they use only land more suitable for agricultural and abandon others with a lower productivity yield. These marginal regions are then reforested through natural forest

regeneration or tree planting.

Secondly, Lambin and Meyfroidt (2010) propose four kinds of exogenous economic factors affecting forest transitions. First is economic modernization (or economic development) which appears as an important element illustrated by the environmental Kuznets curve. This conceptual tool predicts that economies in transition have the stronger environmental impact characterized by highest rates of natural ecosystem conversion. However, as their economic modernization improves, these rates should decline and ecosystem restoration may take place. Behind economic growth is highlighted the development of sound environmental policies, the adoption of sustainable land use practices, the awareness of the value of natural ecosystem, the perceived value of the forest as an aesthetic and recreational resource which improve as a society becomes richer (Mather, 1992; Bhattarai and Hammig, 2001).

The second main exogenous economic factor is based on the desire to capture new economic opportunities to respond to factor scarcities and ecological constraints. This factor is apprehended through the concepts of land rent and market access within the von Thünen model. This theory predicts that any plot of land has to be used to provide the highest rent given its location and attributes. The relative rent between potential uses of nature and cleared land determine thus the land use changes. In developing countries, the deforestation process, i.e. land allocation from wooded land to other use such as agriculture, is often analysed within this framework. Deforestation occurs because non-forest use, such as agriculture, is more profitable (receives a higher rent) than using the land for forests (Barbier and Burgess, 1997, 2001; Arcand et al., 2008). Alternatively, nature restoration occurs if the value of the natural ecosystem goods and services is higher than the value of agricultural production or other uses of that same plot of land. A land use transition thus depends on changes in the opportunity cost of natural ecosystem maintenance.

The third exogenous economic factor relies on the nature of the land ownership regime. Land use transition is obviously affected by the form and strength of the ownership regime. The global trend is based on the fact that land ownership regimes have been transformed from open access or informal communal regimes to more formal government owned (including local community ownership and private concessions) and private land. The basic motivation is that an ownership regime has to permit the user to exclude other land users as well as to regulate resource extraction.

The last exogenous economic factor which shapes forest transition is globalization through international diffusion of environmental protection. The global diffusion of new attitudes and values towards physical environments such as forest, and the use of new knowledge systems through international institutions help to explain a transition towards more sustainable land use in many world regions.

The theory of forest transition provides an explanation for the different paths taken by each country. The global forest cover trend, highlighted in the previous subsection, suggests that the rate of deforestation is decreasing and thus that the transition towards a conservation system

has started to appear around the world in the last decade, though regional disparities remain high.

In the same way, the theory of deforestation, studying the causes of deforestation, uses the same LUCC approach. As suggested in figure 2, deforestation is the first stage of forest cover change. Thereby, the literature on the determinants of deforestation is mainly part of the more broad LUCC approach which encompasses both deforestation theory and forest transition theory.

The deforestation model can be broken down into three kinds of model. The first is the framework of the von Thünen land rent model as presented in the forest transition theory. This model assumes that people use land in order to obtain the highest land rent (surplus) (Angelsen, 1999; Barbier and Burgess, 1997, 2001; Arcand et al., 2008). This model relies on the neoclassical economic tradition (NET) since it states that a farmer manages production in order to maximize utility under some constraints and agricultural land use (i.e. the level of deforestation) depends on the profitability of land conversion (Browder et al., 2004). Thus, the NET uses the powerful concept of the bid rent model of von Thünen, which has focused on the role that accessibility plays in deforestation. The second approach is the household life cycle (HLC) which emerges from the work of the Russian economist Alexander Chayanov (Thorner, 1966; Kaimowitz and Angelsen, 1998) and focuses on the "domestic life-cycle". Unlike the NET, the HLC highlights the role of family dynamics in farming systems changes and focuses on the household composition and life-cycles (Walker and Homma, 1996; Walker et al., 2002). A third approach, political ecology, has been proposed to link local processes of environmental degradation to more global process (i.e. social class, government policies to promote export production, external debt and associated structural adjustments). This last kind of model can be used to simulate the effect of underlying causes such as institutions.

Through these three models and the LUCC approach, the taxonomy of deforestation causes can be put into three categories of factors (Kaimowitz and Angelsen, 1998; Geist and Lambin, 2002). First are the proximate causes which represent human activities originating from land-use that directly affect environment. This cause operates at local level and differs from structural, systemic or initial conditions. In deforestation literature, proximate causes are commonly grouped into four broad categories: agricultural expansion such as the expansion of cropped land and pasture (Angelsen, 1999; Caviglia-Harris, 2005), wood extraction such as harvesting or extraction of wood (Otsuki et al., 2002), expansion of infrastructures (Pfaff, 1999; Margulis, 2003; Pfaff et al., 2007; Kirby et al., 2006) and community management schemes (Alix-Garcia et al., 2005).

Second are the "underlying causes" or social processes which underpin the proximate causes of tropical deforestation (Contreras-Hermosilla, 2000; Angelsen and Kaimowitz, 2001). Literature groups these causes into five categories: demographic factors such as human population dynamics (Southgate et al., 1990; Cropper and Griffiths, 1994); economic factors such as com-

mercialisation, development, economic growth (Bhattarai and Hammig, 2001; Koop and Tole, 2001; Culas, 2007), change (Arcand et al., 2008), and government policies (Reis and Blanco, 1997; Andersen and Reis, 1997; Margulis, 2003; Pacheco, 2006; Bulte et al., 2007; Pacheco, 2009); technological factors (technological change or progress); policy and institutional factors such as a change or impact of political-economic institutions (formal policies such as pro-deforestation policy, policy climate such as corruption (Amacher, 2006), property rights regime such as open access conditions (Angelsen, 1999) and land secure ownership (Mendelsohn, 1994; Deacon, 1994; Barbier and Burgess, 1997; Hotte, 2001, 2005; Araujo et al., 2009); and socio-political or cultural factors such as public concern for forestland.

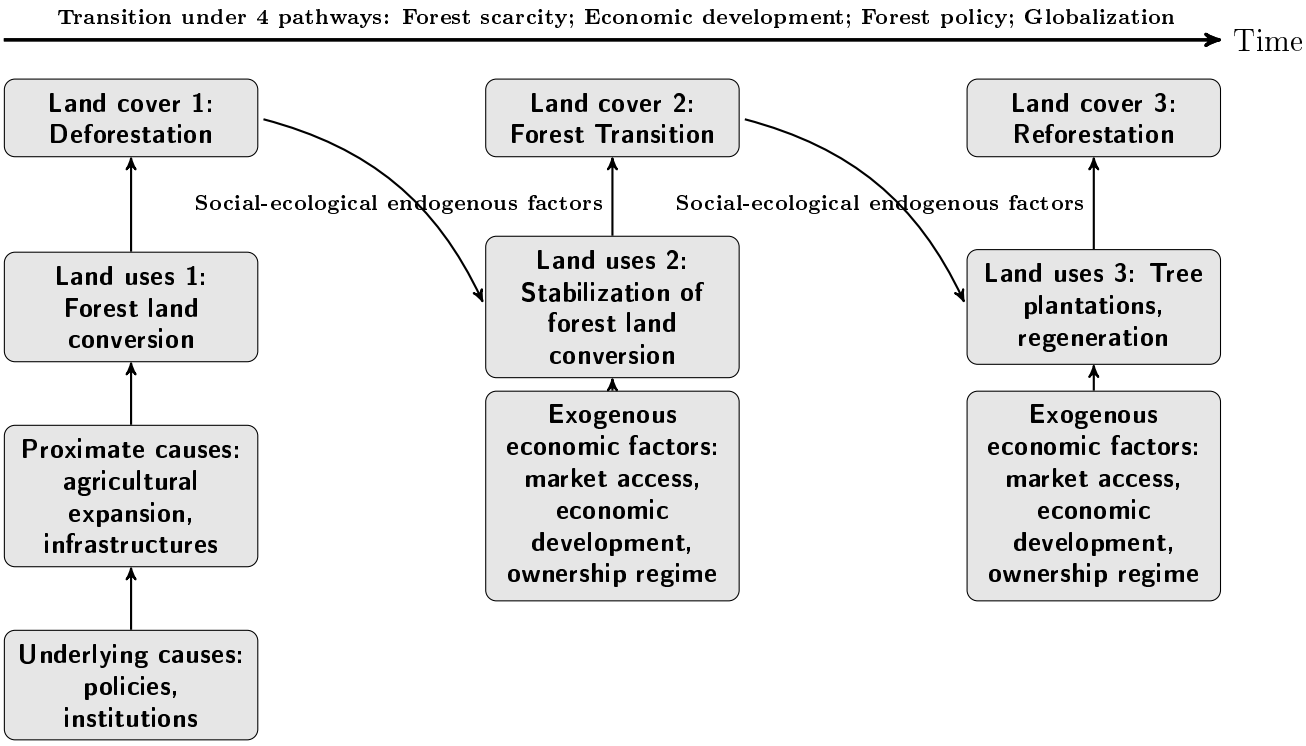
The last category concerns intermediate causes which shape the relationship between proximate and underlying causes. These intermediate causes are considered as pre-disposed environmental factors, i.e. geographical features such as rain, soil quality, forest fragmentation... (Chomitz and Gray, 1996; Chomitz and Thomas, 2003; Margulis, 2003; Kirby et al., 2006; Pfaff et al., 2007).

To sum up, the dynamic LUCC approach, presented in figure 2, conceptualizes the links between different land cover changes from deforestation to reforestation. The deforestation process is analysed through the role of proximate causes and (socially) underlying driving forces on the relative rent of different land uses and the consequences on land-cover change in terms of deforestation. The process can be resumed as follows: proximate causes are seen as a connector between the changes in land use (human purpose or intent applied to alter the physical environment) and land cover such as wooded land conversion (biophysical attributes of the earth's surface, i.e. the physical environment). In this process, direct human activities on land uses are also driven largely by changing economic opportunities which constitute underlying social driving forces (Lambin et al., 2001). As a consequence of the negative forest cover change, i.e. deforestation, the forest cover path moves towards forest transition under different pathways previously presented. Obviously, the state of wooded land cover has further environmental consequences which, in turn, influence human land uses through endogenous social-ecological factors. Parallel to this, human land use is also shaped by exogenous economic factors such as institutions.

Aim of this thesis: understanding the role of institutions

Within the LUCC approach, institutions and policies are thus viewed as the underlying causes which shape the incentives for forest land conversion or forest land conservation. Policy makers may thus influence the forest cover path by creating positive incentives for forest conservation. Thus, Angelsen (2009) proposes four sets of policies to reduce deforestation. First are policies to weaken agricultural rent at the forest frontier, second are policies to increase and

Figure 2: LUCC approach, deforestation theory and forest transition theory



Source: drafted by the author (adapted from Turner et al. (1993); Ojima et al. (1994); Geist and Lambin (2002); Lambin and Meyfroidt (2010)).

capture forest rents and third are policies that can directly regulate land use. The fourth represents cross-cutting policies such as decentralisation and good governance. This is of special importance because one of the main causes behind deforestation in developing countries is the weak governance structure for forest conservation, sustainable management of forest resources and investment in low-carbon paths to sustainable development (Segall, 2006). Thus, for instance, the REDD mechanism goes beyond this and becomes REDD+ including now the role of conservation, sustainable management of forests and enhancement of forest carbon stocks. In addition, the forestry sector and other sector policies such as agriculture and livestock management, energy, water and tourism, can achieve sustainable forest management by cross-cutting activities. This underscores the importance of governance issue for preserving the forest which calls for more efforts in the forestry management but also in the management of other sectors. Better governance enables the underlying causes of deforestation and forest degradation to be addressed, leading to the promotion of forest conservation through better management and rural development.

Consequently, the aim of this thesis is to better understand the role of an important underlying cause, the political and economic institutions, on forest cover. This thesis stresses the importance of institutions, as an element of social reality, due to the fact that institutions represent an essential input, especially heuristic, for the study of the phenomenon of deforestation in developing countries. Put differently, the aim of this thesis is to study if institutions matter for understanding the process of deforestation in developing countries.

Thus, this thesis is integrated in the new institutional economics framework (NIE) which is an attempt to incorporate a theory of institutions into economics or, put differently, to think about the theory of choice (i.e. Economics) through the role of institutions (North, 1990, 1994; Hodgson, 1998; Rodrik and Subramanian, 2003; Ménard and Shirley, 2005). The term "new institutional economics" was first coined by Oliver Williamson in 1975 (Williamson, 1975) following the pioneering works of Ronald Coase in 1937 ("The Nature of the Firm") and in 1960 ("The Problem of Social Cost") on the role of transactions costs (Coase, 1992). Williamson points out in a famous paper published in the Journal of Economic Literature in 2000 (Williamson, 2000) that the NIE counts six Nobel Laureates among the key figures: Kenneth Arrow, Friedrich Hayek, Gunnar Myrdal, Herbert Simon, Ronald Coase, and Douglass North. We can add, of course, Oliver Williamson, himself, as well as Elinor Ostrom, Nobel Laureates in 2009. The NIE is actually the new wave of the institutional economics which apeeared some time ago with Thorsten Veblen, John R. Commons and Wesley Mitchell (Langlois, 1986, p.2-5)[8]. The NIE emerged thus in the 1970s with the work of Williamson (1975) but also with North (1981) on

[8]The emergence of institutional economics can be attributed to the German Historical School of Economics with Gustav von Schmoller. Moreover, for some people, the old wave of institutional economics is completely different from the NIE for its atheoretical posture. In this sense, the old institutional economics can be associated to Polanyi's works (Polanyi, 1957). Globally, the old institutional economics are a historical institutionalism which tried to integrate social determinants into the economic analysis (Lafaye de Micheaux et al., 2007).

the theory of the development of capitalism, and Schotter (1981) on game theory analysis of institutions. Works of Armen Alchian, Harold Demsetz or Steven Cheung, for instance, have contributed to the emergence of the NIE in the 70s (see The International Library of The New Institutional Economics Edited by Claude Ménard). The NIE relies on the main proposition that "institutions do matter" in the explication of the performances of economies (North, 1991; Williamson, 2000).

Ronald Coase summarizes the role of institutions and the place of the NIE into Economics in a famous article published in the American Economic Review as follows (Coase, 1998, p.73):

> *The welfare of a human society depends on the flow of goods and services, and this in turn depends on the productivity of the economic system. Adam Smith explained that the productivity of the economic system depends on specialization (he says the division of labor), but specialization is only possible if there is exchange-and the lower the costs of exchange (transaction costs if you will), the more specialization there will be and the greater the productivity of the system. But the costs of exchange depend on the institutions of a country: its legal system, its political system, its social system, its educational system, its culture, and so on. In effect it is the institutions that govern the performance of an economy, and it is this that gives the "new institutional economics" its importance for economists.*

Consequently, the NIE defines institutions such as the incentive systems that structure human interactions (economic, political and social ones) and reduce uncertainty in exchange and so, in turn, transaction and production costs by making predictable human dealings (Schotter, 1981). Institutions are thus regarded as enabling human action by providing the incentive structure (Hodgson, 1988). Within this framework, institutions are made up of (1) formal rules such as laws, constitutions and regulations, (2) informal constraints with traditions, customs and sanctions, and (3) their enforcement characteristics (North, 1991). Institutions are thus the rules of the human game which shape both physical and human-created environments (North, 1990, 2006).

This way the economic institutions, such as property rights for instance, directly shape the human world but derive from political institutions also called institutions of governance (Hodgson, 1998; Williamson, 2000). The issue behind the best economic institutions, is who makes the rules, and for whom. The policy makes and puts into place the economic rules of the game (North and Weingast, 1989). Thus humans have evolved a political structure that in turn puts in place an economic structure that shapes how society works[9]. This is crucial

[9]This deals with the emergence of institutions. This question is intensely debated in the NIE to understand how institutions emerge. The main issue relies on the role of individual and institutions. In fact, in the NIE the-

since economic institutions rely on political ones which, in turn, have been shaped by the quality of political governance (Williamson, 2000, p.599). Consequently, this thesis evokes a broader notion of institutions through both the economic institutions such as property rights for instance, and political institutions such as the policy climate (corruption) and the legal structure (rule of law).

Put differently, institutions and governance are confounded notions and are defined as the incentive structure of an economy represented by legal and political rules but also by government practices. Thereby this thesis belongs to the field of economic governance which studies and compares the performance of different institutions under different conditions, the evolution of these institutions, and the transitions from one set of institutions to another.

In addition, the NIE argues that (1) institutions sustain, and are sustained by, shared conceptions and expectations, and (2) institutions have relatively durable, self-reinforcing, and persistent qualities (although they are neither immutable nor immortal) (Hodgson, 1998). The NIE states thus that there is a path dependence, the aggregation of beliefs and institutions that have evolved over time and survived, since human society has inherited institutions, i.e. rules, norms and beliefs (North, 2006)[10]. Each of us starts with a set of beliefs that are derived from the past so that the individual has to some degree been "socialized" through prior engagement with institutions. We obtain new experiences that modify that belief system over time. Thereby each of us receives information, used to make choices, that will be apprehended through the enculturation or cultural heritage faced by each of us and our own experience. Figure 3 tries to conceptualize the relations between cultural heritage, individual experience, learning and choices.

The cultural heritage of humans is crucial in the analysis of the effects of institutions on the performance of economies. Economic analysis requires background information and data concerning the cultural heritage of a society and the interplay between the formal rules and informal norms before analysing the effect of institutional change. The paths of institutional development should be understood and taken into account before making out policy recommendations on any change of the institutional framework. Each society has inherited a set of institutions and beliefs carried forward over the generations which constitutes, in turn, the basic way current generations perceive their world (North, 2006). The NIE relies thus on the "extensive use (...) of historical and comparative empirical material concerning socio-economic institutions" (Hodgson, 1998, p.172).

ories, some argue that individuals and the institution-free assumption are the starting point in the explanation. Other argue that it is useless to understand how institutions have emerged without seeing individuals as embedded in a culture made up of many interacting institutions. See Hodgson (1998, p.184–185) and Williamson (2000, p.596-597) for more information. In any case, this thesis is not part of this debate and draws attention to the institutional persistence rather than institutional emergence.

[10]In chapters four (pages 23-37) and five (pages 38-47), North (2006) provides interesting explanations of the creation of human perception, i.e. the process of human learning, and human beliefs from information derived from individual experience and cultural heritage, and apprehended by cognitive processes (North, 2006, p.25).

Understanding the role of institutions in three parts

Within the framework of the LUCC approach concerning forest cover changes and the new institutional economics theory, the aim of this thesis is to study whether institutions matter for understanding the process of deforestation in developing countries through the role of institutional persistence (part 1, chapters 1-4), the importance of the demand for good governance (part 2, chapter 5) and the role of institutions and a governance system as a catalytic role (underlying framework) precipitating the role of proximate causes on deforestation (part 3, chapters 6-7). In this sense, this thesis tries to analyse deforestation in light of the underlying framework represented by institutions.

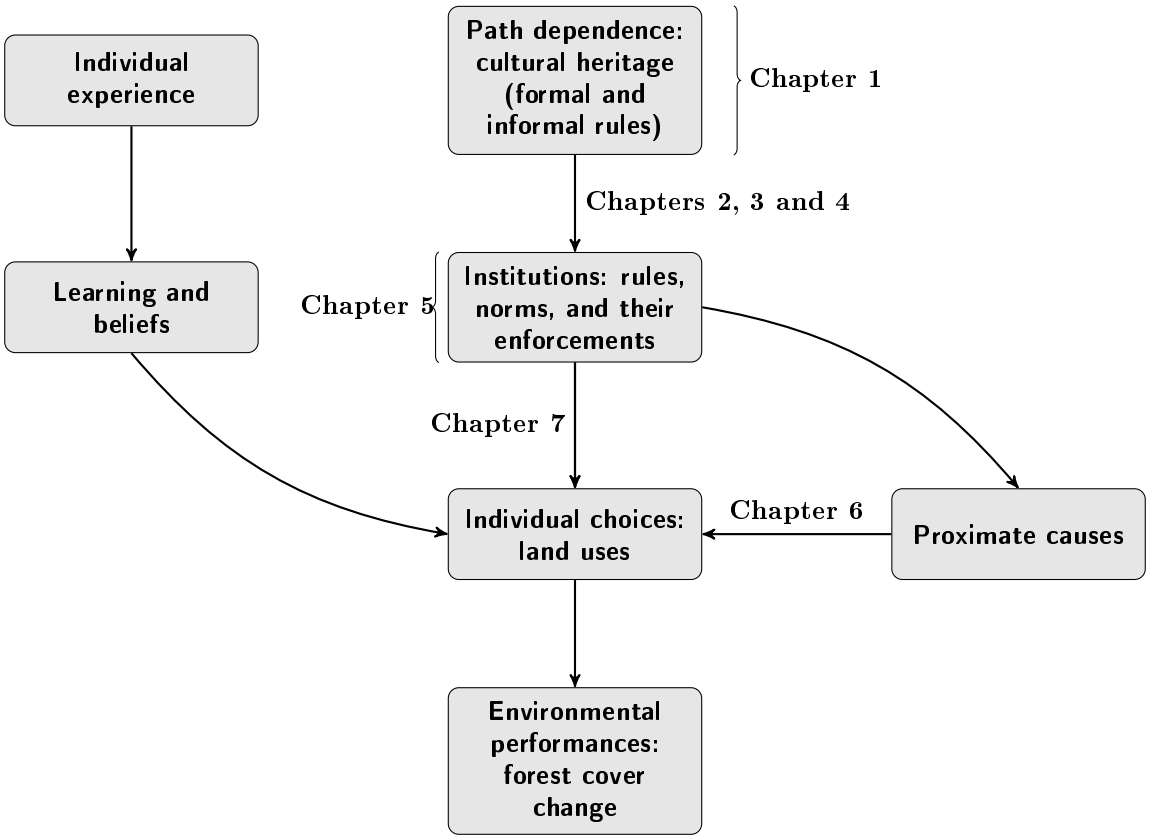
The following figure 3 helps to understand how the thesis is part of the LUCC approach and new institutional economics theory. The starting point begins with the determinants of individual choices such as land uses in the case of the LUCC approach. The NIE theory proposes to understand individual choices as being determined by personal beliefs and the institutional framework behind incentive structures. From the LUCC approach, proximate causes of forest cover change can be added as a determinant of individual choices. From these determinants of choices, the main attempt of the NIE is to understand the role of the institutional framework in light of the path dependence. Put differently, institutions are crucial to explain individual choices but their effects are conditioned by the cultural heritage, i.e. institutions persist.

Within this conceptual representation of the determination of individual choices, stemming from the LUCC approach and the NIE, the **first part** of the thesis is based on the theory of the persistence of institutions (a part of the NIE) and uses the framework of historical and comparative institutional analysis (HCIA) which states that the current institutional framework "is a reflection of an historical process in which past economic, political, social, and cultural features interrelate and have a lasting impact on the nature and economic implications of a society's institutions" (Greif, 1998, p.82). Consequently, the first part begins with a historical and comparative analysis of the evolutions of the forest law in France and Great Britain from the 11th to the 20th century (chapter 1) to investigate whether inherited legacies such as legal origins of law and regulation (chapter 2 and 4) (La Porta et al., 2007) and colonial origins (chapter 2 and 3) (Acemoglu et al., 2001; Acemoglu and Johnson, 2005; Chong and Zanforlin, 2000; Lange, 2004) can be used to understand how institutions shape deforestation. The first part of the thesis relies thus on the literature which studies the existence of institutional persistence through legal origin of law and regulation as well as colonial origins.

Given that the investigation of the role of institutional persistence on deforestation relies on differences between legal origin (the French civil law and the British common law), as well as colonial origins (particularly the French and British heritage), the first chapter provides an analysis of the main historical differences between the French and English Forest policy in order to identify the role of legal and colonial legacies on deforestation (chapter 2, 3 and 4).

The starting point is the direct effect of the role of legacies on deforestation, i.e. whether

Figure 3: Sum up of the thesis: heritage, institutions and deforestation



Source: drafted by the author from Williamson (2000) and North (2006)

inherited legacies such as legal origin and colonial origins explain deforestation, assuming that differences in deforestation rates among countries can be attributed to their legal systems (chapter 2). The next two chapters give an illustration of the effect of legacies on deforestation by conditioning the effect of institutional background on deforestation, i.e. to test the presence of institutional persistence in the deforestation process. The role of both inherited colonial legacies (chapter 3) and legal origin (chapter 4) is investigated. The first part shows that institutions are important factors in the process of deforestation but, overall, suggests that these influences should be understood in the light of the past experiences of each country including colonial and legal legacies. These results highlight the importance of relativism in understanding the effect of institutions on deforestation.

The **second part** of the thesis studies an important issue concerning institutions and deforestation in developing countries: the role of the demand for good governance. As noted before, governance systems have to become more effective to respond to deforestation issues in developing countries, as they are the way to shape human actions towards common goals such as sustainable development. Zaelke et al. (2005, p.38) argue that "all forces that can in-

fluence human behaviour are potential tools of governance." Moreover, the deforestation crisis in developing countries is mainly a problem of rule of law crisis (Segall, 2006). In this context, good governance has to depend on the rule of law defined as a set of rules applied fairly, efficiently and predictably by independent institutions in a framework of public-private interaction process. Thus, a set of social norms, comprising the rule of law or anti-corruption norms, was proposed by the suppliers of good governance to enhance governance in line with the rule of law theory which is an attempt to discover and promote appropriate legal structures for sustainable development. However, this approach is mainly oriented towards the supply side of reforms. Thus, the demand aspect of good governance should now be taken into consideration (chapter 5) (Young, 1979; Odugbemi and Jacobson, 2008).

This second part tackles thus the problem of deforestation as linked to the rule of law defined by a lack of social norms, which in turn leads to the perception of the forest in terms of capital and political control rather than a natural resource worth preserving. The second part proposes thereby to design governance regime or institutional framework that encourages the promotion of the demand for good governance in an attempt to preserve forests through the development of sustainable (local or national) forestry management practices.

The demand for good governance is defined more broadly as the degree of accountability of public officials. The more people are inclined to have accountable public officials in place, the more they are willing to demand good governance practices in their society. Based on that, the demand for good governance can be defined as the degree of compliance with the law, related to the respect and the enforcement of the legal system (chapter 5). As a result, the relations between the demand and the supply side are complex because compliance (demand side) may be treated as an indivisible part of the rule of law (supply side): the rule of law cannot have meaning without compliance. In consequence, the growing focus on compliance seems to be important to enhance the success of efforts to strengthen the rule of law, which in turn will improve the achievement of efforts to promote good governance, and thereby allow society to reach sustainable development. In this context, understanding the interactions between the demand side and the supply side for good governance is nowhere more important than in the field of environment and sustainable development, such as forestry, in developing countries (chapter 5).

The **third part** of this thesis offers two micro-economics applications in Brazil concerning the impact on forest cover of institutions and governance system as underlying causes (i) shaping the effects of proximate causes on deforestation (chapter 6) or (ii) promoting forest land conservation (chapter 7). This last part proposes to understand the effect on deforestation of agricultural productivity in the Brazilian Legal Amazon (chapter 6) and of a fiscal tool, named the ICMS ecologíco (ICMS-E), in the state of Paraná (chapter 7). The impact on institutions is accepted as being part of the game, such as the land market and the ownership regime (chapter

6) or the fiscal policies (chapter 7), shaping economic incentives of private or public agents such as farmers/peasants (chapter 6) or municipalities (chapter 7). The quality of the rule of the game can condition the behavior of agents towards more conservative activities such as parks (chapter 7) or conversion such as agricultural expansion (chapter 6). Institutions have thus to be understood as playing a catalytic role, precipitating the role of proximate causes on deforestation such as agricultural productivity (chapter 6) or undermining incentives for deforestation such as ICMS-E (chapter 7). Institutions are thus elements that serve to bring about a change towards more sustainable development.

To summarize, the aim of this thesis is to study whether institutions matter when trying to determine the process of deforestation in developing countries through the role of institutions persistence (part 1), the importance of the demand for good governance (part 2) and the implications of institutions and governance system as an underlying framework shaping proximate causes (part 3). This thesis proposes thereby a new investigation of the causes of deforestation within the framework of new institutional economics.

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Part II

Institutional persistence and deforestation

Institutions and deforestation in the light of History

"*We see now that the greatest efforts are needed if this legacy of humanity's is to prove a blessing and not a curse*" Albert Einstein in *The World as I see it* (Einstein, 1949, p.80)[11].

"*The cultural heritage provides the artefactual structure–beliefs, institutions, tools, instruments, technology–which not only plays an essential role in shaping the immediate choices of players in as society but also provides us with clues to the dynamics success or failure of societies through time*" Douglass North in *Understanding the process of economic change* (North, 2006, p.36).

The first part of this thesis investigates the theory of the persistence of institutions from the framework of the historical and comparative institutional analysis (HCIA). This theoretical framework suggests that the current institutions have been shaped by the historical process in which the past economic, political, social, and cultural features had been interrelated. These features are then assumed to have a lasting impact on both the nature and economic implications of institutions. Consequently, the first part analyses whether inherited legacies such as legal origin of law and regulation, and colonial origin can be used to understand how institutions shape deforestation.

The first part is divided into four chapters. First is presented an historical and comparative analysis of the evolutions of the forest law in France and Great Britain from the 11th to the 20th century. Given that our analyse of institutional persistence relies on differences between legal origin (the French civil law and the British common law), as well as colonial origins (particularly the French and British heritage), the first chapter provides (1) an analysis of the main historical differences between the French and English forest law in order to (2) better understand the role of legal and colonial legacies on deforestation. The main result is that from the 18th century, the French forest law became more severe and promoted a huge durable forestry management compared to the English Forest Law. This chapter finally gives a historical explanation of the potential effects of differences between the French legacies and the English ones on deforestation.

The second chapter, in turn, investigates the role of legacies on deforestation. This chapter studies whether inherited legacies such as legal origin and colonial origins explain deforestation in developed and developing countries. The theoretical framework used is the Legal Origin Theory of development developed by La Porta, Lopez–Silanes, Vishny and Shleifer which assumes that differences on economic performances are mainly attributed to legal traditions. Thus, this chapter has the attempt to show whether deforestation among countries can be attributed to their legal systems, i.e., the French civil law or the English common law. The underlying motivation of this chapter is to understand whether deforestation could be explained by differences in legacies assuming, from the first chapter, that relevant heterogeneities happened in

[11]"Nous comprenons mieux maintenant que les efforts les plus considérables doivent être entrepris pour que l'héritage devienne pour l'humanité non une catastrophe, mais une chance" in Einstein (1949, p.80).

the emergence and persistence of forest law between France and Great Britain.

Thus, from the first chapter and the Legal Origin theory, that assumes that these differing legal traditions imply that each legal origin is correlated with a wide range of institutions and policies which could be expected to produce higher rates of deforestation, this chapter proposes a new way of studying deforestation. The main result is that civil law countries deforest significantly less than common law countries even in colonized countries in which the implementation of the legal system is more exogenous. However, the colonial history and legal origin are highly correlated so that it is difficult to attribute the differences in environmental performance to legal origin as opposed to other aspects of colonial policy. Put differently, the differential impact of the French civil law (common law) could be attributed to French (British) colonial legacies. Fortunately, not all previously colonized countries with a French civil law inheritance were colonized by France, which allows of testing a specific French difference. The main result is that former French colonies are found to deforest less than former British, Spanish, or other colonies. This difference can be attributed to forest law legacies inherited from the 1827 French Forest Code (chapter 1).

The last two chapters of this first part give an illustration of the nature of the institutional persistence. In fact, these chapters provide an explanation of the effects of different economic and political institutions at the light of the historical process defined such as the inherited colonial legacies (chapter 3) and legal origin of law and regulation (chapter 4). Put differently, these chapters investigate whether colonial origin and legal origin allow for the explanation of deforestation by shaping the current impact of the institutional background on deforestation.

From a broader definition of institutions in terms of political and economic institutions as well as of governance quality, these two chapters show that institutions are important factors in the process of deforestation but, overall, suggests that these influences should be understood at the light of the past experiences of each country (including colonial legacies and legal origin). More precisely, the third chapter shows that an enhancement of the quality of institutions decreases deforestation in countries previously colonized by Spain or Great Britain compared to these colonized by France whereas former French colonies tend to deforest less than former British and Spanish ones in a context of bad governance. This chapter proposes that, in a context of poor governance (such as poor property rights, corruption, autocracy, low level of government functioning), previous French colonies are relatively better off than other former colonies, suggesting, in turn, the presence of some French colonial legacies helping to conserve the forest.

The fourth chapter gives a clear illustration of the differential impact of each institutions on deforestation according to legal origin. It is found that an improvement of the control of corruption is more likely to dampen deforestation in French civil law countries whereas better democratic rules and less ownership risk are more prone to dampen deforestation in common law countries. By contrast, an increase of the quality of legal structure, and the rule of law lead to a reduction of deforestation whatever the legal origin. In addition to these institutional

effects, French civil law countries tend to deforest less than common law countries in a context of bad governance. This result stresses, as in the chapter 3, the presence of some French legacies helping to conserve the forest, and suggests thus to puzzle out the role of the origin of the legal system for combating deforestation.

To sum up, the two last chapters proposes to understand that the effects of institutions on deforestation is conditioned to colonial (chapter 3) and legal origins (chapter 4) what questions, in turn, the validity of some policy recommendations in terms of an improvement of institutions without taking into account the historical process in each country.

Above all, this first part suggests to make out the importance of the relativism in the understanding of the effects of institutions on deforestation based on the comprehension of the role of legacies.

Chapter 1

French and English forests throughout the ages

"Le peuple mû par la haine des seigneurs, porta sa hache impitoyable dans les bois domaniaux: les arbres disparurent de tous côtés" Alfred Maury in *Histoire des Grandes Forêts* (Maurry, 1850, p.319).

To better understand the role of legacies on current deforestation, we first propose a historical and comparative analysis of the evolution of the French and English forests given that these two countries were the main influence over the world in the eighteen and nineteen century through colonization and the implementation of their respective legal system.

Moreover, this analysis is an historical study in the sense that the history of the forest is interrelated with the History of these two countries. Royal forestry resources have often been associated with royal prerogative and, in turn, affected by political, economic and demographic context. Indeed, the French historian Michel Devèze went so far as to point out that "the forest history is an important element of History" (Devèze, 1973, p.7)[1].

In turn, this chapter proposes a comparative analysis of the Forest Law and forestry policy between France and England from the 11th to 18th century (section 1.1), and from the 19th to 20th century (section 1.2) by taking into account the global historical process as well as the political, economic and demographical context.

1.1 Comparative analysis from the 11th to 18th century

A historical analysis, by definition, has to be both illustrative and explanatory. For these reasons, the starting point for the period of study will be the 11th century. In fact, before this century, the role of forest and Forestry policy (through the legal framework and forestry) was far less important. In addition, from the 11th century, the two countries had experienced

[1] "l'histoire des forêts est un élément important de l'histoire en générale" in Devèze (1973, p.7).

significant modifications in terms of Forestry policy[2].

First we propose to set forth the evolution of the English Forest Law from the arrival of the Norman dukes to the 19th century forestry disaster. Secondly, we will analyse the history of the French forest from the 11th to the implementation of the French Forest Code in 1827. Overall, the two forests underwent separate trends. While England was initially more forested than France, the country is now a sparsely forested despite a belated recognition of the importance of the forest in the 20th century.

1.1.1 History of the English Forest Law

The History of the English forest is associated with the evolutions of the Forest Law which were first implemented by the Normans, who arrived in 1066. Over the centuries, the territory of Great Britain has experienced several evolutions, the latest to date being the Independence of Ireland in 1922. Great Britain was created in 1707 after the reunification of the Kingdom of England (including Wales) and the Kingdom of Scotland. But before this reunification, the kingdom of England also changed frequently. For instance, Henry II, the first of the House of Plantagenet to rule England, ruled as King of England and controlled parts of Wales, Scotland and western France. Consequently, and despite these evolutions, the territory of Britain and so of its forestland was confounded with the Kingdom of England due to the demographical, political, economic and geographic importance of England in the History of Britain. Thus, the History of Britain's Forest Law proposed here is the History of the English Forest Law.

However, it is worthwhile to point out that the Forest Law is an area of law which has been relatively less modified by the Royal Courts of Justice than the English law (Gaurier, 2006). This was the result of the importation of the Forest Law from the Continent by the Norman dukes. Consequently, the Forest Law was severely subjugated to local habits such as rights of use, and its codification was often subjected to resistance on behalf of both lords and peasants.

The English forest is mainly characterized by a decreasing secular trend of its area, and, in this sense, the History of the Forest Law governing the use of the forest is an important element of this decrease. Indeed, from an initial situation without Forest Law to a situation with Forest Law exploited by arbitrary and violent Kings, and finally to a situation which saw the decline of Forest Law for the benefit of habits and local powers, the History of the English Forest has been severely conditioned to the evolution of the English Forest Law.

Moreover, forestry was also impacted by the political context and the Forest Law was often weakened by the kings to win a war or a battle. Forestland was one of the main royal financial resources used by the Kings to generate money with which to wage war. Thus, the forest was also the collateral damage in a context of unstable and violent medieval political life.

The presentation of the History of the English Forest Law is divided into four parts. First

[2]The 11th century is also the century of the emergence of differences between the English common law and the Continental civil law (Gambaro et al., 2011, p.59).

we introduce the emergence of the royal Forest Law with the arrival of the Norman dukes in the 11th century. Secondly we study the period between the 12th and 14th century which was marked by the adoption of founding texts. Thirdly we present the period up to the 19th century and the weakening of the Forest Law under the pressure of New World conquests and the agricultural and industrial revolutions. Lastly we set out the evolution of forestry institutions from the Charter of the Forest of Henry III in 1327 to the legislative evolutions at the end of the 18th century.

Emergence of the Forest Law with the arrivals of the Normans dukes

The decisive Norman victory in the Norman conquest of England during the Battle of Hastings by the Norman-French army of Duke William II of Normandy ended the Anglo–Saxon domination which had lasted from the 5th century.

Following the Norman Conquest, the term of forest, which did not exist before, was introduced to designate the reserve for royal hunting. The forest was only a "royal" forest and included both wooded and non–wooded land (Cox, 1905, p.5–6). Thus, the other forests, such as seigneurial sectors, were not legally speaking a forest and, so, in turn, not fully protected.

Anglo–Saxon domination The English forest under the domination of the Anglo–Saxons was not totally in the thrall of Kings. While some Anglo–Saxons Kings, such as Alfred the Great (849–900) and Edward the Confessor (1041–1066), established a beginning of forestry administration to protect their forests used for hunting, the Forest Law was almost non-existent and the forest was mainly used for rights of use (firewood and grazing) and the distraction of lords. Apart from these activities and due to the weak demographic pressures, the forest was barely exploited. With the arrival of the Norman dukes the forest came under royal authority.

Norman invasion In 1066, William the Conqueror (William I of England, 1066–1087) was the original enactor of the unfair Forest Law in England already established in France under the Carolingians. William the Conqueror was a great lover of hunting and established the system of Forest Law which operated outside of the common law, and served to protect both game animals and their forest habitat from destruction. Forests were in turn designed as hunting areas for a monarch or the aristocracy. Forest Law prescribed thereby harsh punishment for anyone who committed any of a range of offences within the forests (such as grazing for instance). In addition, royal forests included wooded land but also large areas of heath, grassland and wetland that supported deer and other game. Consequently, any villages, towns and fields that lay within a forest area were also subject to Forest Law.

In fact, the Forest Law was the perfect illustration of the unfair feudal system established in France and imported by the Normans (Gambaro et al., 2011, p.61-64)[3]. The consequence of

[3]The Norman Conquest largely removed the native Anglo-Saxons ruling class, replacing it with a French–speaking monarchy and aristocracy.

the introduction of this Forest Law was the implementation of a strong forestry administration to both preserve the forest and create new forests for hunting (Gaurier, 2006, p.226)[4].

In 1086, the Forest Law became more severe to include more than the perimeter of royal properties. So the death penalty could be applied for anyone found guilty of gathering wood, hunting or harbouring weapons in a forest, possessing undocked hunting dogs, or living on forestland. The Forest Law expressed a strong royal arbitrary for a royal hunting right more fierce and exclusive than in France (Maurry (1850, p.121) and Devèze (1973, p.40)). Consequently, traditional rights of use were strongly forbidden and punishable by death to guarantee the royal right to leisure and distraction. This situation was so unfair that Henry I (1100–1135), the fourth son of William I of England who succeeded his elder brother William II (1087–1100) as King of England, had to promise to abolish these severe Forest Laws while royal forestland continued to increase (fully one-third of the land area of southern England was designated as royal forest). However, the unfair Forest Law remained and persisted up to the civil war known as the Anarchy between Henry's nephew Stephen of Blois and Henry's daughter Matilda in 1139 following the death of Henry I. The Anarchy pushed each camp to make concessions in favor of a less severe Forest Law. The forest was not used for hunting game but for political negotiations with the lords. For a while, the Forest Law had been flushed out.

Plantagenet's domination: from the 12th to 16th century

In 1154, the accession of Henri II, the William I's great grandchild (1154–1189), son of Geoffroy Plantagenet and Matilda, marked the return of the Forest Law but with less severity: fines in lieu of death. The civil war weakened the King's power and the King had thus to grant more freedom to the Lords. Thereby, Henry II, through the establishment of the Plantagenet line, would strongly influence English constitutional history and the evolutions of the Forest Law are the illustration.

Founding texts during the 12th and 13th century First was the Assize of the Forest in 1184 under Henry II. This text enforced the Norman royal Forest Law concerning the rights and customs pertaining to the royal forest in order to guarantee hunting and revenues. This assize, also known as the Assize of Woodstock, summarized most previous laws but in a slightly milder way (since punishments included blinding, mutilation, and castration). However, the death penalty remained but only after the third offence: "*[...]But if he does wrong a third time, for the third offence no further pledges shall be accepted from him, nor anything other than the body of the misdoer*" (article 12). This text instituted also the creation of forest staff such as agisters (4 cavaliers) and verderers (12 cavaliers) to control animal warrens.

However, this moderate form of the royal Forest Law failed to eliminate the breaches concerning the use of the royal forest. The lords and barons wished to clear more and more wooded

[4]For instance, New Forest in the Hampshire was created by William the Conqueror.

areas, and the inhabitants wished to continue to exercise their rights of use necessary to their subsistence. The severity of the royal Forest Law, even its more flexible form, strengthened the gulf between the King and his subjects on the use of the forest[5].

Furthermore, at the end of the 12th century, the Crusades of Richard the Lionheart (1189–1199) and the rivalry between John Lackland (Richard's brother) and Arthur of Brittany (Richard's nephew) forced these kings to use their forests to fill the Treasury coffers.

John Lackland (1199–1216) had thus to make concessions to the barons and sell forest land, and despite these concessions, the severity of the royal Forest Law continued to exacerbate the King's subjects. In consequence, these pressures led John Lackland to proclaim certain liberties such as the Magna Carta in 1215[6]. This Charter was the first document forced onto an English King by a group of his subjects, here the feudal barons, in an attempt to protect their privileges and limit King's powers by law.

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This Charter also marked the Forest Law by establishing clear rules regarding the use of both private and royal forests in five clauses relating to royal forests (Article 31, 44, 47, 48, 53). Article 31, for example stipulated that "*Neither we nor any royal official will take wood for our castle, or for any other purpose, without the consent of the owner.*" This article allowed the primacy of the forest owner to be established and, in turn, permitted the lords and barons to guarantee their wood against royal use. Also, Article 47 illustrated the end of the royal arbitrary regarding forestland and stipulated that "*All forests that have been created in our reign shall at once be disforested. River-banks that have been enclosed in our reign shall be treated similarly.*"

Then, in 1217, Henry III (1216–1272) created the Charter of Forest recording the Forest

[5]See (Wijffels, 2010, p.145) on the role of Henry II to strengthen the royal courts and weaken feudalism.

[6]Magna Carta, also called the Charter of liberties, is an English charter including the most direct challenges to the monarch's authority to date. The charter was first originally created in 1215 by John Lackland but passed into law in 1225 by his son Henry III. The most famous version which still remains on the statute books of England and Wales and influenced the United States Constitution, the 1297 version, had the following title *The Great Charter of the Liberties of England, and of the Liberties of the Forest.* This pointed out the great importance of the Forest Law in the representation of the King's arbitrary power. This charter can be consulted on this site, www.fordham.edu/Halsall/source/magnacarta.html.

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Law[8]. This document was written on February 11th 1225. Contrary to the Magna Carta, which dealt mainly with the rights of the barons, the Charter of the Forest also addressed the rights, privileges and protections of ordinary people against the abuses of the encroaching aristocracy. This charter ensured economic protection for free men in the use of the forest for grazing or forage (though at this time only about 10 per cent of the population was free). It granted, in turn, free men access to the forest. The death penalty was removed for anyone stealing venison, though they were still subjected to fines or imprisonment (article 10).

These two texts, the Magna Carta and the Charter of the Forest, ended the unfair royal Forest Law by limiting the penalty, tolerating some rights of use and giving more lords' freedom of their forests. The consequence was a slight increase of deforestation but the weak demographic growth limited the pressure on forest cover.

14th and 15th century Edward I (Henry III's son, 1272–1307) reaffirmed the Magna Carta and the Forest Charter as a concession for tax money in the Confirmation in 1297. The short reign of Edward II (Edward I's son, 1307–1327) and the great reign of his son Edward III (1327–1377) did not change the statutes of the Forest Law. The Hundred Years' War was declared by Edward III in 1337 on King of France Philip IV as the latter attempted to claim the title of King of France, while the former, the Plantagenet house, claimed the thrones of both France and England. During this war (until 1375) several Kings of England succeeded (from Richard II the Edward III's grandson (1377–1399) to the accession to the throne of the House of York with Edward IV (1461–1483)).

During these two centuries, royal forests were sold off to finance the war against France. The civil war between the House of Plantagenet and the House of York in the second part of the 15th century reinforced the financial role of the forest. The accession to the throne of the House of Tudor with Henry VI (1485–1509) after the defeat of Richard III (the Edward IV's brother (1483–1485) and the last of the House of York) reopened the Forest Law issue (though the more remote royal forests such as the Exmoor forest were granted on lease).

Until the end of Henry VI's reign, the pressure on forest cover remained limited due to weak demographic growth. However, the beginning of the 16th century was marked by both a substantial demographic growth and a philosophical revolution (the theoretical root of the enclosure issue) which was to be prejudicial for forest cover (Devèze, 1973).

Decline of the royal Forest Law: from the 16th to 18th century

Henry VIII (1509–1547), second crown of the House of the Tudors, was both a despotic and politically strategic King. Just after the discovery of the New World in the late 15th century,

[8]In fact, the original charter of Liberties of John Lackland was expanded to form a complementary charter, the Charter of the Forest. Thus the term *Magna carta libertatum* was then used to differentiate the charter of common liberties from the Forest Charter. This stressed again the importance of the Forest Law during this time of recognition of Lords freedom and royal arbitrary. The Charter of the Forest can be read here *http://www.constitution.org/sech/sech*$_0$*45.htm*.

Henry VIII decided to create the first English navy to compete with the Spanish empire. The naval industry was born and, with it, its enormous requirements of wood. Major logging activity resulted from this royal ambition. The forest became now more a nature reserve than a playing field or an element to be used in political trade-offs. This reign was also marked by the last creation of a royal forest by a King (Hampton Court in 1539). In addition, following the English reformation, Henri VIII also supported the deforestation of the ecclesiastical forests which were seized by the King and then sold to private individuals who cleared them. The English forest suffered, once again, from the political and societal instability of the English kingdom (Devèze, 1973, p.62). Until the end of the reign of Elizabeth I (1558–1603) (the fifth and last monarch of the Tudor dynasty), the Kings' right consisted in being able to sell forestland to fill the royal cases to finance the wars against Spain and Scotland.

The advent of the Stuarts in 1603 with James I (1603–1625) occurred in a context of hard forestry exploitation for the naval construction. Though this King tried to restore an effective Forest Law, after the concessions made under the Tudors, the financial pressure pushed him to weaken the Forest Law.

The reign of Charles I (1625–1649), the second son of James I, was despotic. In this context, he returned to the old royal Forest Law to ensure maximum profits for the Navy's timber production. However, his despotic policy illustrated by the unfair Forest Law was so unpopular for the nobles and the local population that Charles' last years were marked by the English Civil War, in which he fought the forces of the English and Scottish Parliaments. The monarchy was then abolished in 1849 and a republic, called the Commonwealth of England was declared. Under the direction of Oliver Cromwell, the new Republic set aside of the Forest Law and accentuated the pressures on the forest to raise financial resources. The restoration of the monarchy and the return of the Stuarts with the son of Charles I, Charles II (1660–1685), in 1660, reopened the royal concessions. However, the growing need for wood for the Navy caused a renewed interest in Forest Law to develop a sustainable forestry. In this context, the Royal Navy launched a campaign in favor of the forest, called *Sylva, A Discourse of Forest Trees*, through the work of the landscape architect John Evelyn in 1664 (Devèze, 1973, p.62). However, this campaign changed nothing and the Forest Law was perceived by local people as a simulacrum of the old feudal royal Forest Law, this in a context where wood was mainly imported from Scandinavia and the colonies[9].

During the 18th century, timber imports increased and the remaining British forests were still used to develop the Navy during the reigns of the House of Hanover with George I (1714–1727), George II (1727–1760) and George III (1760–1820). The forests were increasingly subjected to this pressure while the colonial empire of the British Crown supplied the metropolis in wood. In a context of a growing industrial development coupled with a strong population growth and pressure on agriculture, deforestation increased during the 18th century. The de-

[9]For instance, London was rebuilt with Scandinavian wood after the Great fire that devastated the city in 1666.

velopment of the individualistic system with enclosures, and the end of the old Community system served to further decrease forest cover.

Finally, Forestry policy was based on an antagonism, i.e. develop sustainable forestry for the Navy or sell the woodland to fill the royal Treasury coffers? The latter focus became more pressing so the Forest Law lost its utility. However, the depletion of the forest cover and the need to ensure a durable supply in timber would lead to a growing awareness of the need for a sustainable Forestry policy in the late 18th century.

Sustainable Forestry policy: the end of 18th and early of 19th century

At the end of the 18th century, a statement of the royal forest was implemented between 1787 and 1793 by a royal commission. Seventeen reports were published and stated that the Kingdom of England possessed the following forests: Sherwood Forest in the North of Trent, and several in the South (four forests in Hampshire including New Forest; Windsor Forest in Berkshire; Dean Forest in Gloucestershire; Epping Forest in Essex; Wychwood in Oxfordshire; and three forests in Northamptonshire) (Cox (1905, p.85) and Gaurier (2006, p.233–234)).

The commission concluded that these forests were poorly preserved and that the courts were completely abandoned (see the following subsection 1.1.1 on forestry institutions) such as the swainmote courts. In some forests no monitoring was performed so that the royal forests were left under the control of local populations. As a result, concessions of the royal forest to private users were more frequent as well as enclosures which were made by illegal users to transform the forest into grassland.

The third report was a display of the great source of profit related to the timber trade for the crown but also for users. The report defined then two types of forest to underscore intense forestry exploitation without regarding the regeneration of the forest. First was forestland to remain under the King's authority for the Navy timber production. This was the case of forests near the coast such as New Forest. In these royal forests used by the King, private users were compensated by the King to give up their rights of use or past enclosures. Second, other forests which were granted to users for enclosure in exchange for compensation for the King, resulted in significant forest-clearing of those areas which were previously neglected by the Forest Law (Gaurier, 2006).

In addition, the decision to remove rights of use had been taken. This decision led to the development of enclosure with a "strict" property right. Private users and property owners received a share from these enclosures but the poor, who lived in a community system, suffered from this situation and rebelled many times by breaking down the fences protecting the enclosures in the private lots (Gaurier, 2006).

Forestry institutions: forest courts and forest officers

Henry III's Charter of Forest had developed the first forestry courts and forest officers in charge of the implementation of the Royal Forest Law. Unlike France, the royal forest courts did not compete with the lord's courts and forestry administration became less important.

Forest courts There were three main Forest Courts in the old royal Forest Law defined by the Normans and enforced by Henry III's Charter of the Forest in 1317.

The lowest level was the Court of Attachment, also called the Forty–Day Court or Woodmote court. This was held every 40 days and was presided by the verderers (designated for the protection of the forest) or the Warden. So called because its object was mainly to receive the attachment of the foresters (or woodwards), and enter them on the verderers' rolls. The foresters attached persons who had committed crimes against the royal Forest Law and brought them before this court to have them enrolled. Furthermore, the verderers did not possess the power to try or convict individuals, and such cases had to be passed upwards to the swainmote or the court of justice seat (Cox, 1905, p.11–14). Also, a Court of regard, held every third year, to enforce the law requiring the declawing of dogs within the forest.

The second level of court was the Swainmote Court, whose purpose was to try offenders before a jury of swains (or free tenants). This was held three times a year and was presided over by the Warden and verderers, the agisters being in attendance. Verderers did not judge but decided to hold or not offenders who would be tried by the superior court. He could also regulate agistment (or pasturage) and pannage as well as carry out investigations of abuses committed by foresters on free tenants (Gaurier, 2006).

Third was the Court of justice–seat or Forest Eyre which was the highest of the forest courts. It was to be held every three years and had to be announced forty days in advance. This court was presided over by a Justice in Eyre, also called the Chief Justice of the Forest appointed by the King. There was one Chief Justice north of the Trent River and one for the South. It was, in theory, the only court that could pass sentence upon offenders of the Forest Laws and an appeal was possible at the Court of Justice of the King (Gaurier, 2006).

Moreover, in practice, the distinctions between forest courts were not always observed. Swainmote court and the court of attachment could be one and the same (for instance in the Dean forest). Moreover, as the courts of justice–seat were a triennial court, the lower courts often assumed the power to judge offenders against the Forest Law. In turn, the Swainmote was often the judgement court so that justice was carried out by a local jury (the swains). The last features, which marked the English common law since the Magna Carta, differed from the French legal system where the judgement was administered by the *Maître des Eaux et Forêts*, appointed by the French King.

Moreover, in 1810 the two Chief Justices of the Forest were replaced by General Inspectors in charge of the royal forest, and the courts of justice–seat, which became gradually less important,

were abolished in 1817 and their powers transferred to the First Commissioner of Woods and Forests.

The other two courts, the Courts of swainmote and attachment, disappeared at various dates in the different forests while a Court of Swainmote was re-established in the New Forest in 1877.

Forest officers First was the chief royal official called the Warden or the Keepers of The Forest. He was often a lord or an eminent and preoccupied magnate, who frequently delegated his power to a deputy. He supervised the foresters and under–foresters (Gaurier, 2006).

Second was the forester, also called the *verderer*: the officer who held a judicial power. He held the Swainmote court and he was hence responsible for Forest Law enforcement. He was responsible for patrolling the woodlands. His duties included both negotiating deals for the sale of timber and stopping poachers from illegally hunting. The second officer was the surveyor or the *regarder* who determined the boundaries of the forest. He ensured only an executive function without judiciary power. He reported to the court of justice–seat, and investigated encroachments on the forest and invasion of royal rights, such as assarting. He could also provide a check against collusion between the foresters and local offenders. Third was the agister which supervised pannage and agistment (or pasturing) as well as collected any fees thereto appertaining (Gaurier, 2006).

Their subordinates were the under–foresters. These included a *Beadle*, who announced courts and performed procedures, the Keeper–Bailiff of Walks sworn in by the verderer, and the Forest Ranger who was the patroller of the purlieu (Gaurier, 2006).

Conclusion: royal Forest Law in the early 19th century

In the early 19th century, forestry courts and Forest Law were very limited and only three commissioners were in charge of the royal forests. This change in the administration of the royal forest, from the old forestry justice to the nomination of commissioners, reflected a secular change in the perception of the forest. The Forest Law remained only to protect the royal forests in order to promote the timber supply for naval construction. In contrast, the private forests were increasingly disconnected from the Forest Law.

The agricultural enclosures associated with the economic and population growth in the early 19th century had weakened interest in the forest, which became more an impediment for the British agricultural and industrial development. Great Britain had become the first economic and political nation in the early 19th century but had forgotten its forests.

1.1.2 History of the French Forest Law

The History of the French forests follows the same dynamics as the English forest. Population growth, political change through civil and continental wars had always shaped the forest cover.

Thereby, human tragedies such as war or disease, reduced for a while the pressure on the forest cover, and as noted by Michel Devèze "Every cloud has a silver lining" (Devèze, 1973, p.37)[10]. However, the French population increased steadily over the centuries and forest cover irreparably diminished.

Before turning to the presentation of the History of the French forest, underlying motivations related to the choice of 11th century as the beginning of the historical study have to be presented. This century did not really see the beginning of an effective forestry administration. For this, we could go back to the Gallo–Roman registration of each plot of land as private property. The advent of the Merovingians in the 5th century introduced a customary Germanic law based on local customs [11]. The Merovingian and the following Carolingian registration aimed at governing customs which were as numerous as the number of lords in the kingdom. In the early 11th century, the kingdom of France had not an effective forestry administration but rather a registration of several forestry customs which was a combination of the Roman law and the old common Germanic law[12].

Consequently, we have chosen the 11th century as a practical starting-point for our comparative analysis of English and France in the same century. Furthermore, this century is also of great interest for the study of the French forest. It marked the beginning of an important economic and demographic growth in France with the advent of the Capetian era, so much so that the French forester Gustave Huffel pointed out in his *Histoire des Forêts Françaises* that "the extent of the crops had become (...) insufficient [that] bad or poor harvest [could] cause a famine" (Huffel, 1925)[13].

Obviously, the History of the French forest goes deeper than what is proposed here, but our aim is to give an outline of the historical change of the French forest to better understand the context in which the French Forest Code was promulgated in 1827.

The History of the French forest can be divided into four parts. First, we present the evolution of the forest from the 11th to 13th century. The emergence of important deforestation coupled with substantial royal possessions led the Kings to create a forestry administration. Second, we see the period of four centuries between the 14th and 17th century which was marked by the first royal ordinances related to forestry administration through the centralization and unification of forestry customs. Our third part is devoted to the 17th and 18th century: the former stood for the emergence of an effective forestry administration with Colbert's 1669 Ordinance while the latter was a dramatic century for foresting. Our last part concludes on the importance in the early 19th century of the creation of a forest code which could abolish customary differences, establish governmental authority in terms of forest management, and

[10] In French, "A quelque chose malheur est bon" in (Devèze, 1973, p.37).

[11] See (Wijffels, 2010, p30-38) and (Rigaudière, 2010, p.60-67) on the legal pluralism made of the plurality of German customs and the survival of Roman law.

[12] This duality in the French legal system remained over centuries and was to disappear with The Napoleonic Civil Code in the early 19th century (Huffel, 1925).

[13] "L'étendue des cultures étaient devenue (...) insuffisante [qu'une] récolte mauvaise ou même médiocre [pouvait] provoquer une famine" (Huffel, 1925).

rule private properties. The analysis of the 1827 Forest Code and its implications will be presented in section 1.2 of this first chapter.

Forest in danger from 11th to 13th century

Feudalism and its consequences French royalty was different from English royalty. In France, since the fratricidal war between the grandsons of Clovis in the 6th century and the introduction of the first mayor of the palace as the right arm of the King, the influence of feudal lords on policy decisions was very important in contrast to England. In France, the feudal system was deeply rooted in the society. This system involved powerful local chief (lords) so that the central government was strongly subjected to the will of the lords. This difference between France and England was one of the reasons for the divergence in the conception of the lawmaking process (Gambaro et al., 2011, p.192)[14].

This feudal system led to the establishment of the unfair Forest Laws during the advent of the Carolingians in the 8th century. This Forest Law, imported into Brittany by the Duke of Normandy, William the Conqueror (see subsection 1.1.1), represented the arbitrary and brutal feudal system which had allowed the preservation of the forest until the 11th century. This Forest Law guaranteed the absolute use of the forest by the seigneur, obtained legally or not, who could forbid use to anyone under threat of bloody sanctions. This feudal system had dramatic consequences and led to the ruin of the local populations as well as the abandonment and degradation of land. The forest cover increased whereas the agricultural activities were severely penalized resulting in the impoverishment of peasants (Maurry (1850, p.217) and Devèze (1973, pages 31–32)).

Forest in danger in the early 11th century The 11th century saw the beginning of an economic development and population growth. The relative peace under the advent of the Direct Capetian Dynasty under Hugh Capet in 987, despite occasional seigneurial disputes, had launched a revolution in the use of wooded land which was to last until the 13th century. Thanks to the tough Carolingian Forest Law and little Capetian flexibility, forestland expanded until the 11th century. Consequently, the lords and seigneurs were caught in a "trap" of their own making. In fact, the extension of the forests also involved an extension of local rights of use such as grazing (Maurry, 1850, p.221). Thereby, the forests were used by peasants in a context of increasing population growth which forced migration away from villages (being too small and at the brink of famine) to forests. The need to feed this growing population forced the inhabitants to clear forestland to survive and both the lords and King were forced to facilitate

[14]The local power in France had facilitated the emergence of the codification of the legal system given the weakness of the central power (the King). In contrast in England, the central authority was strong and respected so that the local lords and vassals were not encouraged to contradict the royal will which could implement a justice based on oral laws and the constitution of the jury (i.e. the common law). See Gambaro et al. (2011) for a comparative analysis of the common law and civil law.

such uses of their forests to avoid peasant revolts[15].

Emergence of the forestry administration in the 13th century In the 13th century, the Direct Capetian Dynasty imposed the royal domination in the Kingdom. The reign of Philip II Augustus (1180–1223), the seventh in the Direct Capetian Dynasty, was a great symbol in expanding the royal demesne and the influence of the monarchy. In this context, forest management became a royal prerogative leading to the creation of the *Administration des Eaux et Forêt* in 1215. This first royal forestry administration had the aim of preserving the royal forest against uncontrolled grazing, or cutting and removal of timber[16]. Lords and seigneurs imposed in their forests their own rights of use (grazing, acorns) for the peasant populations. Thus, an old royal Forest Law coupled with peasant and seigneurial customs represented the French Forest Law in a context of non industrial use of wood.

Moreover, the feudal system inherited from the Merovingians began to weaken from this century onwards, under the monarchy of Saint Louis (1226–1270) and Philip IV (1285–1314). In this context, the emergence of a forestry administration became effective due to the growth of royal power.

However, despite this royal administration, forestry management was not subjected to any regulation and forest cover decreased until the first Forest Code enacted by the first King of France from the House of Valois, Philip VI (1328–1350) in 1346[17].

Forest became a royal prerogative from the 14th to 16th century

14th century The French historian Michèle Devèze stressed the importance of this century as the first step to save the French forest after three centuries of strong pressure and political instability after the death of the last son of Philip IV, Charles IV, who died without leaving a male heir (Devèze, 1973, p.33)[18].

Thus the advent of the House of Valois in 1328 with Philip VI plunged France into the Hundred Years' War against England. In this context, the forest was seen as a timber stock

[15]The Lords had to accept some rights of use in their forests in exchange for services rendered by the farmers. Moreover the seigneurial power relative to the King and local populations lessened so that they had to accept some rights of use.

[16]Duby (1962) argued that the timber trade became more important in the 12th century due to shortages in the wood production in Orient. He said: "La fôrêt devient au XIIe siècle comme une culture protégée de l'arbre, destinée au besoin de la construction, de l'artisanat et du chauffage" *in* (Duby, 1962).

[17]Philip VI was a member of the Capetian dynasty. He was the son of Charles of Valois, the brother of King Charles IV (1322–1328), the last direct Capetian King of France.

[18]This event was one of the sources of the Hundred Years' War. In 1314, the Direct Capetian, King Philip IV, died, leaving three male heirs: Louis X, Philip V, and Charles IV who died without a male heir. However, a fourth child of Philip IV, Isabella, was married to Edward II of England and had a son, Edward of Windsor, who was a potential heir to the thrones of both England (through his father) and France (through his grandfather). However, the French nobility refused to have a foreign King, as the King of England. Therefore, on Charles IV's death the most senior man of the Capetian dynasty was Philip of Valois, grandson of Philip III of France and nephew of Philip IV, who became the legitimate heir based on the French nobility's interpretation of the ancient Salic Law.

which could be used to finance the war. Consequently, Philip VI enacted the first Forest Code in 1346, which became the first royal ordinance regulating the use of the forest into 42 articles.

However, the young foresters were strongly corrupted so that Philip VI, his son John II (1350–1364) and his grandson Charles V (1364–1380) all tried to curtail this corruption. The most important trial was the 1376 ordinance of Charles V which dealt with officers, tax and rights of use, organized into 52 articles. This ordinance reaffirmed the King's interest in timber, and, for instance "settled wood forest-clearing in the Roumare and Normandy forests, (...), to the vassals construction"(Maurry, 1850, p.225)[19]. The end of the 14th century was thus marked by a growing timber need for military and industrial use despite, again, a weak royal forestry administration.

15th and 16th century In the 14th century, the Hundred Years' War (1337–1475) and the Black Death (1348–1350) had both reduced the population which had increased during the two previous centuries[20]. During the 15th century, Charles VII (1422–1461) established centralisation and unification of the customs and rights of use in all the kingdom in 1454 ((Wijffels, 2010, p.101), (Rigaudière, 2010, p.436-442) and (Gambaro et al., 2011, p.224-225)). This also concerned forestry customs. This policy ended in the next century. Moreover, since there was little population growth, there were fewer royal ordinances.

However, the 16th century, marked by both political stability and an increase of peasant rights of use in the forest, was affected by an important forestry crisis. Moreover, the French economy was more and more oriented towards the wood industry for the marine. According to the study of Michèle Devèze, this industry accounted for a sixth of French forest resources (Devèze, 1961). Consequently, Francis I (1515–1547) of the House of the Valois of Angoulême, lover of hunting and at war with Charles Quint, took over forest ordinances from March 1516 (reproduction of the forestry code of Philip VI) until his own forestry code in 1543 to reaffirm the royal prerogative on forests (Collectif, 1997, p.84). This Forestry code severely limited the peasant rights of use in royal domains to protect forests from logging but also pointed out again the importance of the administration and forest justice (see subsection 1.1.2 for a presentation of the forestry institutions). This code also allowed all forest owners to apply this code and penalties more consistently.

Despite these improvements in the forestry administration, Francis I and his son Henry II (1547–1559) were subjected to the revolt of the peasant class who did not accept these measures impeding their rights of use. These revolts were nourished by the nature of the forestry administration which was, as in England, both the administrator and judge. For instance, many breaches of conduct were committed in terms of sanctions and taxation on timber sales (Maurry, 1850, p.307–308). In addition, the beginning of the agricultural revolution reinforced

[19]"(R)égla la coupe de bois dans le forêt de Roumare, en Normandie, (...), à la construction des vaisseaux et bâtiments du roi" in (Maurry, 1850, p.225).

[20]In a sense, and as suggested by Michèle Devèze, the French forest recovered thanks to the English (Devèze, 1973).

the need for rural populations to use land more extensively. Also, the premise of the revolution of enclosures began to be implemented, increasing the pressure on woodland.

At the end of the reign of Henry II in 1559, forest cover was under pressure with the onset of the War of Religion. Up to Henry II's son, Henry III (1574–1589), and his grandson Henry IV (1589–1610), the forest was mainly used as currency and so deforestation was substantial. The Moulins ordinance of the second son of Henry II, Charles IX (1560–1574) in 1566 attempted to forbid the alienation of the royal forest but was unable to stop the sale of the royal forest for financial purposes. In the same way, the emergence of a forestry economy at the end of 16th century only slightly curtailed deforestation. However, neither Henry IV who tried to protect the royal forests with the creation of a General Superintendence of Forestry or the project of Sully, the faithful right-hand man of Henry IV, to plant trees along roads and in the center of each village throughout France, changed the decreasing evolution of forest cover. The political years of Richelieu and Mazarin during the minority of Louis XIV (1643-1715) accentuated this trend. At the beginning of the reign of Louis XIV in 1661, the French politician Jean-Baptist Colbert began to rule the General Direction of Finance. Colbert would later become the most influential politician and protector of the forest in the History of French forestry.

Forest in the 17th and 18th century

Colbert's influences from 1661 to 1681 The first royal ordinances (from the 13th century) could not regulate the forest use and, in turn, the forest cover diminished. Just like the British crown in the 17th century, the French royalty with Louis XIV decided to implement strong forestry regulation. Moreover, contrary to the political context in England, the French model was appropriate for royal intervention. After the Fronde against Cardinal Mazarin and the young Louis XIV (1643–1715), the advent of the reign of Louis XIV in 1661 provided the backdrop for strong royal intervention.

In 1665, Colbert became Minister of Finance and renewed interest in the royal forestland. The Navy had previously been abandoned by Richelieu and Mazarin, but now Louis XIV began to develop his Navy to make up for lost time, in comparison with England. In 1661, the King appointed Colbert as Superintendent of finance and created a commission of 20 members in charge of reforming the Forestry led towards a great period of reformation. The first measure carried out by this council was to close the royal forests. After eight years of reports on the state of the French forests made by Colbert's agents, Louis XIV, based the final report of Colbert, established the great ordinance in August 1669. It was based on thirty-two titles which later inspired the 1827 Forest Code.

This ordinance could be viewed as a forest code which governed all aspects of the forest. The main contribution was to clarify the Forest Law (Collectif, 1997). For instance, the hammering wood became mandatory to clarify the movement of the wood and taxation. Also, the royal prerogatives were related to both the King's forests and others (community forests, church

woodland, private users). Rights of use and customs were banned in the royal forests but regulated in other forests. For instance, it was only permitted to enter royal forests by roads or during the day. Sickles or axes were prohibited, as was to remove wood, sand, plants, soil under penalty of punishment. For example, the Article 4 of Title 30 of this royal ordinance banned hunting entering the royal forests at night (Baudrillart, 1821-1848, p.994). This ordinance also regulated the forest courts and officers, and authorized the latter to act in all forests. Finally, the forests on the coast and along the rivers were particularly controlled in order to sustain the Navy timber production (Devèze, 1973; Dugas de la Boissonny, 1999). This ordinance helped to reorganize the Forest Law with the establishment of a Forest Code governing the scope, use and respect of all forests, and the banning of some rights of use to protect royal timber.

This 1669 ordinance was the illustration of the Great Reformation (1661–1683) of Colbert. However, Colbert had to strengthen the royal power to curb civil and ecclesiastical disobedience which grew as had happened in the previous reforms, including those of Francis 1 (Collectif, 1997). Colbert's death in 1683 marked a turning point in forestry regulation which subsequently became weaker. The increase of the risk of a peasant crisis supported by the Church led the King to tolerate more customary practices and rights of use.

Despite this failure relative to the increase of forestry customs, the 1669 ordinance of Colbert aimed to sustain the forestry industry in a context of a strong timber demand for the navy. Unlike England, France, in the 17th century, relied on a powerful central government based on the interventionist ideology of Colbert and the great influence of Louis XIV. This Forestry code helped to improve the King's authority on forest use, by introducing a goal of self-sufficiency in timber production for the first time, unlike England. The forestry administration, as the body enforcing the ordinance, was thus strengthened.

Forest in the 18th century Colbert's death was a break in the royal Forestry policy. The pressure of local people and the Church led the King to not implement some articles of the ordinance. The end of the reign of Louis XIV and the beginning of 18th century, with the advent of Louis XV (1715–1774), were marked by an increase in the forestry staff contrary to the Colbert's initial intention, which was to limit and clarify the various forestry positions to increase the effectiveness in monitoring and sanctions. He removed, for example, the *Grands Maîtres des Eaux et Forêts*, which were restored in 1689.

Until 1750, forest cover was stabilized with the work of great foresters such as Ballainvilliers and Vauban whereas in the second half of the 18th century, the French forest decreased substantially. Several causes can be identified: population growth, the timber needs of the Navy, the demand for more comfort (heating), and the emergence of an intellectual class inspired by the philosophers of 16th century. These intellectuals, named the Physiocrats, called for a rise of agriculture, and a decline of royal and communal properties. As a result, private properties and deforestation were accelerated just before the revolution of 1789. In addition, the famines of 1762 and 1766 accentuated the pressure on agriculture. With the support of the Physiocrat

philosophers and economists, Louis XVI (1774-1791) gave new orders promoting deforestation (Huffel, 1925, p.193). Finally, forest cover in 1789 was much less extensive than in 1689.

Forest after the 1789 French revolution The principles of the Old Regime based on inequality between feudal lords and peasants as well as the common property of local communities was removed by the 1789 political Revolution. The political philosophy of society, based on the natural law of individual equality between humans, founded the New Regime and established the principle of individualism as a pillar of the new society. Forest Law and land rights were obviously influenced by these developments already implemented in the economic sphere by the Physiocrats, themselves influenced by the school of modern natural law (Grotius, Pufendorf, Locke (see Halpérin (2008); Larrère (1992)).

The old Forest Law was abolished by the acts of December 19th–25th 1790, which removed the jurisdiction of *maîtrises* and the *Table de marbre*. Other acts (September 15th–29th 1791) continued to dismantle the Old Regime, and the New Forestry Regime changed little until the 1827 Forest Code (Bourgin, 1989, p.192). In the new system, private property became a natural right. The communes were created with a common ownership which owned communal forests[21]. Forests, previously in open access, became then communal. In addition, seigneurial forests also became communal forests under the act of August 28th 1792 and the *droit de triage* was abolished by the act of June 1st 1793 (Baudrillart, 1821-1848, p.985) following an act of August 24th 1792 stipulating in Article 1 that this right was a feudal right[22]. In the same way, under the act of June 10th 1793, communal forests were strengthened because all waste land was now communal. Finally, the act of September 5th 1791 on the forestry administration stipulated that the community forests were ruled by this administration while the private wooded land was not within the administration (Title I, art.6, Bourgin (1989, p.198)).

However, this new regime was nourished by the emergence of an anarchic management of communal forests. Consequently, the most important deforestation in the History of the French forest occurred in the early 19th with a decline around a quarter of the national territory (against 29% today). This led to the need for a legal framework coding forestry behavior.

The Napoleonic Forestry policy was also less efficient. This was mainly a set of the Old Regime policies lumped with New Regime ones. Under the Restoration in 1814, there was a systematic alienation of State forest resources to increase the revenues of Louis XVIII (1814–1824). In addition, the forest was no longer seen as a royal prerogative so that Louis XVIII abolished the *Administration des Eaux et forêts* in 1817 (Baudrillart, 1821-1848, p.715). This change in forestry administration was also marked by a royal ordinance of January 2nd 1817 which stated that the King's forest was now under the control of the Minister of Finance and

[21] In the Old Regime, the notion of common property was present but this form of ownership was poorly developed and represented mainly the areas for which it was difficult to know who was the owner (Huffel, 1925, p.100–102).

[22] According to the 1669 ordinance, the Lord donor or his descendants could claim a third of the wood granted tax free to a community of people. This was the *droit de triage*

a General Director. However, an ordinance of October 11th 1820, restored the forestry administration ruled by foresters whose aim was to take "care of the propagation and conservation of forests in the woods of the state, municipalities and public areas [...]" (Baudrillart, 1821-1848, p.875–876)[23].

The accession of Charles X (1824–1836), Louis XVIII's brother, was marked by a strong return to the Old Regime. However, the Forestry policy was strengthened with the creation of the National School of Forestry in Nancy and the Forest Code in 1827.

Forestry customs and use rights

Before the 1669 Ordinance Rights of use are an important part of the history of the forest in France. Rights of use can be defined as the use of the forest or its products by persons who do not own the forest. The most widespread rights of use since Gallo–Roman times were grazing rights (grazing, acorns) and drawing rights (removal of deadwood). These rights were adapted in each forest. There were as many rights of use as customs. Thus, rights of use were customary (or common) rights.

The evolution of rights of use was linked to the use of the forest by the owner. Up to the 13th century, the forest was not used for financial purposes by its owners (the King, lords) and rights of use were thus tolerated without any real control and without being subjected to restrictions and rules.

The great French foresters, Gustav Huffel, defined rights of use as fee, real and subjected to precise rules Huffel (1925). The pecuniary nature of these rights went back to ancient times and Huffel (1925) argued that some texts of the 7th century showed that the sale of rights of use allowed lords to impose a value on their forests and increase, in turn, their personal incomes. The real nature of rights of use stated that they were held by a community of people or individuals. Finally, the rights of use were subjected to rules and restrictions which were more or less restrictive, forcing users to comply with the concession act. The rules and restrictions in the rights of use changed according to the value of the forest for its owner (the King or the lord).

In the 11th and 13th century, rights of use began to be established in documents to ensure some incomes for forest owners. From the 13th century, the expansion of rights of use charges coupled with the emergence of a strong royal authority with Philip VI, in a push to protect the forest, marking the beginning of the systematic establishment of a title for the rights of use checked by officials. Also, Henry IV, with his Letters Patent in 1589, ordered the transcription of the titles related to rights of use. However, these efforts were often not followed and many users were able to avoid having to present their titles (Huffel, 1925, p.111).

[23]"soins à la multiplication et à la conservation des futaies dans les bois de l'État, dans ceux des communes et dans les Établissements publics [...]" in Baudrillart (1821-1848, p.875–876).

After the 1669 Ordinance All previous royal ordinances on rights of use were never implemented due to the corruption of forest officials, a lack of royal will, or a lack of compliance of local community and church to follow orders. Colbert's Great Reformation illustrated by the royal ordinance of 1669 had the aim of clarifying forestry legislation, as we have seen. Thus, the 1669 ordinance also clarified the rights of use and divided them into two parts (Huffel, 1925).

The ordinance of 1669 distinguished thus the rights of use related to pasture and those related to wood. The first were allowed more freely but had to be approval by the Council of the King. The second category was forbidden in the royal forests but only for rights of use no older than one hundred years (in 1650) and compensated for the oldest. However, the part of 1669 ordinance devoted to rights of use was not implemented. King's financial difficulties slowed the compensation of users having old rights of use. In addition, the ordinance imposed to compile an inventory of all rights of use in the royal forests. This inventory was particularly well established and remained the legal framework for the title of rights of use until the 1789 revolution (Huffel, 1925).

Forestry administration and courts

Forestry administration underwent many changes since the establishment of the *administration des Eaux et Forêts* in 1215 by Philip IV. The establishment of an administration in charge of the management, control, surveillance and policing of royal forests were needed when they became a royal prerogative.

Forestry administration Merovingian and Carolingian forestry administration was non–existent and the premise of the Forestry administration under the first Capetian consisted in using provost to manage royal forests. These officers were in charge of policing, judgement, revenues and other prerogatives.

In 1202, Philip IV (1180–1223) annexed Normandy and its vast forests in which the King had the right of *tiers* and *danger* that allowed him to capture a portion of the timber sold and to create a tax burden. This King created new officers, named *baillis* in the North in charge of the *bailliage*, and *sénéchaux* in the South in charge of the *sénéchaussées* (Rigaudière, 2010, p.338-340), and established the concept of *Eaux et Forêts*.

When the forest became a royal prerogative in the 13th with Philip VI, the *Administration des Eaux et Forêts* and the first foresters named *Maîtres des Eaux et Forêts* were thus created (Devèze, 1973, p.35). Foresters were divided into three levels. First was the agent also called the *sergent*, second was the verderer also called *Maître sergent*, *châtelain* or *gruyer* (Decq, 1922a, p.78–79), and third was the *Maître des Eaux et Forêts*.

The *sergent* was the lowest function despite some heterogeneity between them. There were sergeants on horseback, on foot and those with or without a guarantee of the King (Roquelet, 1984, p.XXV). The latter were appointed by the King, and had to monitor the users and

assigned them to the gruyer in the plaid (court) of the forest (Decq, 1922a, p.99–100)[24].

The *Maître sergent* or *gruyer* (*verdier* in Normandy, (Roquelet, 1984, p.XX)) were in charge of a *gruerie* and were appointed by the King or the lord. The *gruyer* had to live in the forest to ensure the "good" use of it for the King. He had to know and judge the crimes in his *gruerie*. He had to control the sergeants and assigned them a part of the forest. In addition, the *gruyer* manage the rights of use in his forest, called the Reformation, so that users often had conflicts with the *gruyer*, because the latter was the first link between the *Maître des Eaux et Forêts* and peasants (Roquelet, 1984, p.XXXV). The *gruyer* was also in charge of the wood hammering for the navy (Decq, 1922a, p.85–89). Aside these administrative functions, the *gruyer* had judicial responsibilities and he administered the justice in the plaids of his forest. Finally, the *gruyer* had financial responsibilities and had to inform the *Maître des Eaux et Forêts* responsible for the *maîtrise*, which the *gruerie* was allotted to, on the management of the forest.

The *Maître des Eaux et Forêts*, also called *Maître et inquisiteur*, was both administrator, judge and accountant (Decq, 1922b, p.339). Concerning his administrative functions, he represented the link between agents (sergeants and *gruyers*) and the King or the lord. He managed the sergeants and *gruyers*, reported their actions to the sovereign master, and could punish or dismiss them. The *Maître des Eaux et Forêts* had to go to his *maîtrise* twice a year to decide on logging volumes and judge illegal hunting and other offences (Decq, 1922b, p. 341). The *Maître des Eaux et Forêts* was also responsible for checking the rights of use and for granting or denying a right of use after notifying the *gruyer* (Decq, 1922b, p.341 and p.346). He was also responsible for monitoring the trade of wood and had to resolve disputes relating to this activity (Decq, 1922b, p.344). Concerning his judicial functions, the *Maître des Eaux et Forêts* judged in a trial court called "les jours des Eaux et Forêts" (Decq, 1922b, p.351). He judged all offences relating to customs, sales and crimes committed by users or officers in the royal forests. Finally, the *Maître des Eaux et Forêts* also had financial and accounting functions. He had to present the accounts, given by the *gruyer*, to the *receveur* who centralized them before returning to the royal *Chambre des Comptes* (Decq, 1922b, p.385). Finally, there was a *procureur du roi* in all *Maître des Eaux et Forêts*'s jurisdiction who represented the King during trials.

In the middle of the 14th century a fourth officer was created called the *Maître inquisiteur des Eaux et Forêts* and then *Souverain grand Maître des Eaux et Forêts* also called *Souverain Maître* which monitored the *Maître des Eaux et Forêts*. He had administrative and judicial powers, and was appointed by the King. In his administrative capacity, he received the agents and assigned their offices although several Kings granted authorizations for the *Souverain Maître* to appoint agents himself. This practice was frequently abolished due to misuse and corruption, forcing the King to appoint officers himself (Decq, 1923, p.98). Concerning his judicial duties, he judged in appeal court in the *Parlements* of Paris and Rouen called *Tables de Marbre* (Roquelet (1984,

[24]There were many other agents who were specific to certain regions such as Normandy, as well as those in charge of the right of *tiers* and *dangers*. For a complete presentation, see Decq (1922a, p.100–109).

p.XVIII) and Collectif (1997, p.100)). However, the Parliament disputed this judgement which could still be appealed before the Parliament (Decq, 1923, p.100)[25].

In 1575, Henry III abolished the *Souverain grand Maître des Eaux et Forêts* replaced by six new officers, called grands *Maîtres enquêteurs, réformateurs généraux* or *Grands Maîtres*[26]. The *Maître des Eaux et Forêts* became *Maître particulier*. In addition, Henry IV sought to clarify the administration and remove the *Grands Maîtres* but failed. In 1667, Colbert abolished the *Grands Maîtres* and imposed in each forest office only five officers: a *Maître particulier*, a lieutenant, the King's attorney, a guard–hammer (responsible for designating trees to cut or keep) and a clerk. In the more remote forests, the *gruyers* were in charge of monitoring and managing the royal forests (Huffel, 1925, p.158). Colbert clarified the forestry administration and also imposed selection criteria for officers (for instance over 25 years old). However, this clarification was not maintained after Colbert's death. The *Grands Maîtres* were restored, and the number of foresters continued to increase during the 18th century.

In 1789, France had 20 *grandes maîtrises* and 135 *maîtrises particulières*. The Revolution and the overthrow of the Old Regime had huge consequences on forestry administration. For a time, the foresters were all dismissed by the Act of September 4th 1791 according to Title XV of the Law (Bourgin, 1989, p.216–217) which established a *conservation générale* in charge of the forest of the New French Republic. This new administration was composed of five commissioners and an administration made up of guards, inspectors and conservators (Bourgin, 1989, p.198–209). This law was implemented in 1801 under the Consulate, and Emperor Napoleon I replaced the five commissioners with a General Director in 1806. For 10 years, poor administration without effective prerogative was in place.

The Restoration in 1814 and 1815 brought a misfortune to the forestry administration which was removed and attached to the *enregistrement des domaines*. The Forestry policy was thereafter under the control of the Finance Minister and a General Director with no forestry administration. The ordinance of October 17th 1820 restored the forestry administration and one month later, the royal decree of November 22nd restored the Conservator of forests.

Forestry courts The forest officers were part of the forestry administration based on a judiciary organization established in the kingdom in the 14th century[27]. The forestry court was made up of three levels: the *maîtrises particulières* in first instance, the *grandes maîtrises des Eaux et Forêts* in first instance or in appeal, and the *Tables de Marbre* linked to Parliaments also on appeal.

As of 1555, the *maîtrises particulières* were generalized to all forests in each *bailliage* and

[25]Several lieutenants were created from the 15th century to fill in the Souverain Maître. For more information, see (Decq, 1923, p.105).

[26]The number of officers increased. There were twelve in 1589, up to thirty–six in 1706 and twenty at the beginning of the 1789 revolution (Collectif, 1997, p.93).

[27]In addition to these royal courts, the Lords had their own courts and officers who were gradually absorbed by the royal administration. See (Wijffels, 2010, p.148-150) on the judiciary organization toward more powerful royal courts.

sénéchaussée[28]. They were led by a *Maître des Eaux et Forêts* who judged civil and criminal offences related to forests.

The *grandes maîtrises des Eaux et Forêts* were led by the *Grand Maître*. When the Grand Maître visited the *maîtrises particulières* in his *grande maîtrise*, he was called upon to pronounce sentences at first instance or in appeal but only with the officers of the *maîtrises particulières*.

The *Table de Marbre* took its name from the large marble table in the hall of the *Palais de Justice* in Paris (Huffel (1925, p.116) and Devèze (1973, p.50))[29]. The *Table de Marbre* could be used to judge in first instance or in appeal by an edict dated March 1558 (see Decq (1923, p.100–101) for more information). In 1707, all the *Table de Marbre* sessions were removed (except those of Paris) and replaced by a special Chamber in charge of the forest.

Evolution of the French forest cover

The evolution of the forest cover in France was severely subject to the evolution of the territories (lost or annexed by France) and the analysis of forest cover evolutions since the 11th century is, of course, sensitive to this aspect[30]. Moreover, until the Revolution, forests were referenced into five categories: the royal forests, ecclesiastical forests, seigneurial forests, communal forests (community ownership) and commoners' forests.

In the 13th century, under Philip IV, French forest cover was estimated at about a quarter of the territory with a population of about 20 million. However, no review of the royal forests was established until Colbert but Huffel (1925, p.75) noted that the forest cover in the late 17th century was similar to forest statistics for the 14th century. In addition, according to the reports of Colbert's Commissioners, the royal forest represented about 750,000 hectares and remained relatively stable until the 1789 Revolution Huffel (1925, p.137).

In 1790, the surface area of the French forest covered about 8 million hectares with 500,000 reserved for the King, about 800,000 for the clergy, 2.2 million for communities and hence about 4.5 million hectares for private owners including 3.3 million for commoners and 700,000 for lords. The 1789 Revolution led to an increase in private woodlands (lords and commoners) after the sale of ecclesiastical and royal forests.

Finally before the 1827 Forest Code, forest cover was about 15% with forests including 1.2 million hectares of State forests, 1.9 million hectares of communal forests, and about 5 million hectares of private forestlands. French forest cover was severely reduced until the 1827 French Forest Code. Forest-clearing was intensive and the forestry administration had become inefficient.

However, the 1827 Forestry Code reversed the trend by imposing a strong and sustainable forestry management. This century highlighted the main differences with the English Forest

[28]See (Wijffels, 2010, p.150) on the local organization of royal courts.

[29]The oldest *Table de Marbre* was created in Paris in the 13th century (Huffel, 1925, p.115). In addition, in 1520, a specific forestry court was created but kept the name of *Table de Marbre*. The second *Table de Marbre* was created in Rouen in 1508 henceforth there were as many *Table de Marbre* as *Grandes Maîtrises*.

[30]See Huffel (1925) who proposed a detailed history of the French forest from the Merovingian period.

Law which proved to be too archaic and inefficient to prevent the wide-spread deforestation which was to occur in the 19th century. The important turning point of the 19th century between the forestry policies in the two countries was initially illustrated by strong royal implication in preserving forestland in France in the 17th century with the Great Reformation of Colbert. The reasons for this divergence will be analysed in the following subsection.

1.1.3 Comparative analysis of the divergence in the 17th century

Political and economic reasons can be proposed to better understand the first difference in the Forest Law and Forestry policy between France and England during the 17th century (Gaurier, 2006).

Different political approach

In France, the Forestry policy of Colbert and Louis XIV relied on the strength of the absolute monarchy to ensure both an intensive and sustainable timber production. The main motivation was to develop a strong navy, and support the buildings and heating in a view to guarantee French self–sufficiency in wood supply. The King intervened directly. He sent commissioners to monitor communities; he conducted timber harvesting in a context in which local communities had to be authorized by one of the royal experts or the *Grand Maître des Eaux et Forêts* for the use of a forest plot.

In England, the 17th century marked the beginning of the constitutional monarchy characterized by a weakening royal will and a strong body of lords and commoners. These later legalized their encroachments on the royal forests resulting in substantial deforestation as well as definite concessions. In other words, although the royal will was to preserve forests to ensure local wood production, the King had to abide by the rules of lords and commoners. The French legal historian, Dominique Gaurier, sums up this evolution by stressing that "it is the interests of local owners that have largely prevailed over the preservation of wood, as many enclosures are made at the expense of forests" (Gaurier, 2006, p.240)[31].

Different economic approach

In France, Colbert's dirigiste policies were different from English liberalism. However, this diverging conception of the economy was not the sole explanation. Two other explications can be proposed.

First was the supply of timber. In the 17th century, the needs for wood were similar in both countries. Each country wanted to increase their naval activity with a view to conquer the New World (Gaurier, 2006). However, the English did not consider the sustainable use of wood as important, contrary to France which developed a major wood industry to guarantee

[31]"Ce sont les intérêts des propriétaires riverains qui ont largement prévalu sur la conservation des bois, puisque bien des enclosures se firent au détriment des forêts" in Gaurier (2006, p.240).

self–sufficiency in wood supply. The English policy was impacted by the large timber imports from Scandinavian countries. The cost of imports was offset by two major advantage: a) the possibility of undermining royal power through the forests and increasing the lords and commoners' power, in fact, the Forest Law was perceived as an unfair law representing the arbitrary royal power - thereby, a reduction of the royal forest prerogative led to a reduction of the royal power and b) the huge Scandinavian timber stock reduced the risk of timber shortage. In contrast, the French timber supply was produced by national production according to Colbert's dirigiste policies, where self–sufficiency in terms of wood was a priority for France.

Second was the consumption of timber. In 1709, England created the first process of coke (coal) replacing charcoal (wood) supplied for blast furnaces. In France, the first attempts took place in 1769 but this production did not compete with the traditional production of charcoal (wood). This led to an intense use of wood in France, which implied a sustainable approach to forestry management, contrary to England which had based its industrial development on coal.

Use rights

Gaurier (2006, p.241) noted that the main role played by the protection of rights of use was crucial to explain the evolution of forest cover in the two countries. In England, rights of use had been relatively more protected than in France. In the English Forest Law, the local users could save their rights of use over time whereas, in France, Colbert's ordinance had forbidden several rights of use following the general dirigiste policy implemented by Colbert leading to a centralized Forestry policy. In France, the main consequence was the impoverishment of local community. The 1789 revolution ended a part of these rights of use but the creation of communal and private forests had led to an anarchic forestry management. In England rights of use had never been removed or limited despite an increase of private ownership through the enclosure system.

Finally, in the early 19th century the two countries did not have the same policy regarding rights of use although the consequences were the same. Deforestation was more and more intense due to an increase of agricultural activities through the expansion of enclosures and private ownership. In France, rights of use were limited by law whereas, in England, they were limited by facts.

1.1.4 Conclusion

In the early 19th century, Forestry policy became less important in the two countries. However, the turning point in the 17th century created an irreversible change in the respective visions of forestry.

The 19th century saw the beginning of a strong forestry policy in France with the creation of the 1827 French Forest Code reflecting the aim of promoting economic and ecological development of the forest. England neglected its forest due to its chronic inability to adapt its Forest

Law which remained as a forgotten medieval royal law in a parliamentary monarchy. Despite political pressure to save forests for the British Navy, the substitution of iron for wood in the shipbuilding signaled the end of the political interest in forests. The art of forestry was lost in the United Kingdom because the forests were, in the early 19th century, incompatible with the economic evolution of English society up to the First World War (Gron, 1947).

Overall, the 19th century marked changes in the Forestry policy of both countries. The comparative analysis of this change is set out in the following section.

1.2 French and English forest in the 19th century

The first section of this chapter on the History of French and English forests presented the historical development of forestry policy and Forest Law from the 11th to 18th century. This analysis put forward differences in the design and vision of forestry policy from the 14th century, accentuated by Colbert's 1669 Ordinance.

In France, the forest was therefore considered as a natural resource which had to be sustainably used, requiring a strong Forestry policy to protect and enhance the economic value of forestland. In contrast, the English Forestry policy remained based on the medieval royal Forest Law, whereby the forest was the King's leisure area. In the early days of the philosophical and industrial revolution of the 17th century, the English forest was not protected for its economic value, and was thus seen as an impediment for the English economic development illustrated by the agricultural enclosure system.

In the early 19th century, deforestation was wide-spread both in France following the 1789 Revolution and in England after the strengthening of the parliamentary monarchy. However, the 1827 Forest Code was born of the legacy of the French forestry administration. In contrast, the 19th century was a disaster for English forestry. Forestry policy and Forest Law were absent and unable to adapt to the economic evolutions of the British Empire, which had by then become the leading political and economic power in the world.

In the following section we present the French case with the creation of the 1827 Forest Code, followed by the English forestry disaster that lasted up to the First World War.

1.2.1 French forest in the 19th century

Before the 1827 Forest Code

The 18th century (The Age of Enlightenment) was less dominated by a strong centralized state at the death of Louis XIV in 1715. The culmination of the philosophical revolution with the 1789 political and societal revolution had had important implications for the French forest. The Revolution abolished the principles of the Old Regime based on communal and seigneurial property as well as inequality between lords and peasants. From the Natural Law that all

humans are equals, the New Regime established the principle of economic individualism as a pillar of political equality between men, which hence modified the Forest Law.

Communal forest owned by local authorities and private forests became more and more important so that the new owners deforested major sectors of their forests to develop their plots for agricultural purposes. Consequently, deforestation was the most intense in the early 19th century leading to the great necessity to create a strong forestry legal framework.

The Napoleonic policy as well as the first years of the Restoration neglected forestry management. However, as of 1820, the return of the Forestry administration and the creation of the Forestry School in Nancy in December 1824 marked the beginning of a real revival for a sustainable Forestry policy.

1827 Forest Code

Context of its promulgation The second Restoration after Napoleon's defeat at Waterloo in 1815 restored the monarchy, which became constitutional and limited by the charter of 1814. Louis XVIII (1814–1824) took power until his death in 1824 and the advent of his brother Charles X (1824–1830). The latter was overthrown in July 1830 during the Three Glorious Days sanctioning his reactionary policies (Wijffels, 2010, p.252). In this context of severe political instability between the Chamber of Deputies and the King, the Forestry policy was finally defined by law. The promulgation of the Forest Code in 1827 defined legally the forestry system, which was finally completed after the removal of the Old Regime by the act of December 24th 1790. Mr Martignac, commissioner of the King, explained in his speech to the Chamber of Deputies, the need for a complete definition of Forestry policy in a global law governing the management, preservation and exploitation of the forest. He said: "The conservation of forests is one of our primary interests and therefore one of the first duties of government (...). It is not only by the wealth offered by forestry (...) that we have to judge their usefulness; their existence is an invaluable benefit for the country (...). The destruction of forests has often become, (...), a real curse and a proximate cause of decay and ruin. Their damage (...) is a trouble to be prevented (...)"[32].

Beyond these "progressive concerns" of the Forestry administration, two other arguments can be advanced to explain the political will for the creation of the Forest Code (Vigier, 1980, p.129). First was the importance to increase timber production to ensure the effectiveness of the Navy but also to support the growing industrial and urban development in France. For instance, Viney (1962, p.533) stated that ironworks used 10 million cubic meters of wood and Paris more than one million for heating. Second, was the emergence of a new body of commoners and bourgeois who saw the opportunity to increase their forestry revenues by supplying to

[32]"La conservation des forêts est l'un des premiers intérêts des sociétés et par conséquent, l'un des premiers devoirs des gouvernements (...). Ce n'est pas seulement par les richesses qu'offre l'exploitation des forêts (...) qu'il faut juger de leur utilité; leur existence même est un bienfaits inappréciable pour le pays qui le possède (...). La destruction des forêts est souvent devenue, (...), une véritable calamité et une cause prochaine de décadence et de ruine. Leurs dégradations (...) est un malheur qu'il faut prévenir (...)" in Brousse (1828).

the growing timber demand for construction, heating or charcoal. Since the parliamentary monarchy was essentially dominated by a conservative bourgeois class with rich landowners, it was possible to create a legal framework allowing the protection the forest mainly owned by these rich landowners. In a sense, the Forest Code was created to increase the forestry revenues of rich landowners (Vigier, 1980, p.129).

The 1827 Forest Code The Forest Code, initially a project of the Forestry administration in 1823, relied on three important points. First was the distinction between the administration and justice in the logic of the revolutionary reform of 1790. Thus, forest offences and crimes were now judged within the jurisdiction of ordinary courts. The second great principle implied that the forest system also covered now the communal forests as well as forests held by public institutions. Third was the relative liberty of private owners, in the sense of the revolutionary tradition concerning the primacy of individualism though some obligations were created to avoid a revival of the anarchic period that followed the 1789 Revolution (Devèze, 1973, p.84).

The Forest Code, promulgated July 21st 1827, was divided into 16 titles. The French forest was broken down into the State (Title 3), the Crown (Title 4), municipalities and public institutions (Title 6) or private owners (Section 8). All these forests were now subjected to the Forest Code which defined the functions of the forest as well as the rights and duties of its users. The Code also managed the rights of use and defined them very precisely such as the time-period for gathering of acorns and grazing. For instance, Section VIII of Part 3 dealt with rights of use in the forests of the State. The second Article (Article 62) defined the role of new rights of use stating that "it will not be done in the future, in the forests of the State, grant of any rights of use of any kind and under any pretext it may be" (Brousse, 1828, p.15)[33]. In addition, private owners could also remove all the rights of use pertaining to their forests (Article 118) or grant new rights of use with the support and authorization of the administration. As noted, the paths used by the local users were to be defined by the private owners.

The Code also regulated forest-clearing in both public and private forests. Municipalities, for example, could not clear their forests without governmental permission, and private owners had to report their plans to the Prefect of their department. Article 219 of Title 15 stipulated that a 6 month period should be respected by the owner to clear his plot if permission was granted. This period allowed the Conservator, also called the forester, to obtain information about the statute and situation of the plot to clear. This legal disposition also enabled the Navy to be informed about which private oaks to clear. As a result, the private owner could be forced to renounce on forest-clearing if the Conservator judged that it was not sustainable for the forest, or if the Navy decided to use his plot (Title 9, Section 1, Article 125).

The Forest Code also governed the organization of the Forestry administration (Title 2) but the most important legal application concerning the administration was enforced by the

[33]"Il ne sera plus fait, à l'avenir, dans les forêts de l'Etat, aucune concession de droits d'usage, de quelques natures et sous quelque prétexte que ce puisse être" in Brousse (1828, p.15).

ordinance of August 1st 1827 relating to the Forest Code (Devèze, 1973, p.84). This ordinance was divided into 12 titles. The first concerned Forestry administration. Articles 1 and 2 defined the higher administrative authority. The Minister of Finance was responsible for the Forestry administration headed by a General Director and three administrators (Brousse, 1828, p.55). Section 2 dealt with the administration staff composed of agents, surveyors and guards (Article 11) as well as the territorial division (Article 10) (Brousse, 1828, p.104). Section 3 was devoted to the Nancy forestry school with its disciplines, professors and admission requirements.

To sum up, the 1827 Forest Code had established the legal principles of private property that guaranteed for the forest owner both the *usus*, *abus* and *fructus* of his property. The Forest Code had also specified the need for public ownership (State and local with municipalities) for the management and preservation of public forests (premise of sustainable development). The Forest Code succeeded in associating private and public uses in a context that accepted the primacy of private ownership. The strict definition of the legal framework on private forest-clearing illustrated this success.

The subsequent political events failed to change the Forest Code. The Forestry policy based on the Forest Code became more and more effective and many afforestation projects were implemented despite the industrial and agricultural development of France.

Immediate consequences of the Forest Code: the forestry turmoil from 1827 to 1848 The 1827 Forest Code allowed foresters to apply a strict Forestry policy to preserve and manage the forest in order to increase timber production. Forest officers were responsible for enforcing the law which implied the removal of some rights of use in State and communal forests. This resulted in communal revolts against forest officers.

These riots were the most violent and passionate in the History of the French forest. The first occurred a few days after the promulgation of the Forest Code in the Ariege (Pyrenees) and spread to several other communal mountain forests in the Pyrenees, Alps, Vosges, Jura or Cevennes regions. This outcry defended the old practices now made illegal by the Forest Code, perceived as too liberal and capitalist by the local forest users. The riots became more violent during the revolutionary years of 1830 and 1848. After the July revolution in 1830, the *guerre des Demoiselles* broke out in the Ariege region, exploiting the political instability and revolution in Paris. A break in the revolts was possible the following year after strong military repression and concessions from the Forestry administration to rebels (Vigier, 1980, p.130).

From 1840, reforestation projects were decided in the Alps in order to reduce floods. Consequently, the activities of foresters increased, and fines and lawsuits became more frequent. The 1848 Revolution marked the beginning of a bloody peasant revolt in the Alps, Vosges, and Vercors, forest officers were assaulted and drive out. The situation was restored by the new republican and conservative government and in some cases, concessions were granted to communities as a propaganda tool for the conservative government of Louis–Napoleon Bonaparte.

These revolts were put to an end by their very cause: the Forest Code. In fact, Forestry

legislation was so painful for rural communities that some peasants chose to migrate towards cities so that the rebellion lost intensity. This occurred especially in mountainous alpine areas where afforestation became more wide-spread during the Second Empire of Napoleon 32[34]. At the beginning of the second Republic, the Forest Code was accepted by the majority of local forest users but at the price of painful demographic changes.

Expansionist Forestry policy after 1850

Second Republic The European proletarian revolution led to the fall of the parliamentary monarchy of July and the sovereign, Louis Philip (1830–1848). The French Second Republic began until the coup by Louis–Napoléon Bonaparte who initiated the Second Empire (1852–1870).

The elections of April 23rd 1848, officially dominated by conservatives and royalists, lead to the Second Republic which became authoritarian and repressive. Unlike the 1789 Revolution, the consequences for Forestry policy were not so disastrous as the government of Louis–Napoleon Bonaparte, both conservative and royalist, elected in December 1848, implemented a policy close to the conservative policy of parliamentary monarchy. The coup of December 4th 1851 and the referendum of December 20th 1851 allowed Napoleon 3 to reform the Constitution and create the Second Empire after the referendum of November 7th 1852.

Forestry policy was slightly modified. However, the timber demand continued to increase for both heating of growing cities and naval supply, leading to a heavier forestry trade deficit. This was due to the inertia of the Forestry administration despite the strong legislation with the Forest Code, which remained in place. The 1848 communal revolts underscored the communal concessions through the sale of communal forestland under different laws (August 8th 1850 and May 5th 1855). The weighty political context illustrated by communal riots and the difficulty to enforce the Forest Code pushed the private forest users to create, in 1853, the Foundation of the Forestry Society of France to organize their management (Viney, 1962, p.534).

Second Empire The electoral successes of Napoleon 3 in 1851 and 1852, following on the general economic prosperity enabled the new emperor to impose an authoritarian period. Moreover, he had a strong interest in forestry issues, and in 1852, for instance, he ordered the reactivation of the project of his uncle, Napoleon I, for the creation of a forest in the Landes. This project consisted in stabilizing the dunes and transforming wetlands into pine forests. This created more than 1 million hectares of forest, enabling the local development of the region.

Other areas were also subjected to this active policy of reforestation or afforestation. For instance, the Sologne region (which was unsuitable for construction or agriculture) was subsequently forested and drained by channelling. More than 100,000 hectares of woodland were

[34] The urban population in 1850 grew rapidly but the majority of the population remained in rural areas: 26 million out of 35 million (Viney, 1962, p.535).

planted in this region. The project to afforest and restore mountain forests was also an interesting example of this policy which strongly reduced the impact of terrible floods generated through past forest-clearing activities. This policy continued under the Third Republic and contributed to ensure the environmental long-term balance of mountain areas (Viney, 1962, p.539).

The Forestry policy was also oriented towards the restoration of the forests of the State as well as the acquisition by the crown of new forests. Planning commissions were created by Vicaire, the new director of the Forestry administration in 1860, in order to develop national forests. An important policy of protection and development of urban and suburban forests was also undertaken such as the creation of the *Bois de Vincennes* in Paris (Viney, 1962, p.540). The economic and industrial revolution enabled the development of Forestry in line with a substantial increase in government spending. The Forestry policy also continued to limit rights of use to ensure the sustainability of reforestation and afforestation policies and forest restoration. The Second Empire ended with the Napoleon's defeat at Sedan against Bismarck's army, yet the Forestry policy was certainly one of the great successes of the Emperor, still visible today.

Third Republic The Third Republic had little effect on the French Forestry policy which continued to restore forests, create new ones and limit forest-clearing. During the first years of political instability, there were few legislative changes. A significant change was the attachment of the Forestry Administration to the Ministry of Agriculture and Commerce by a decree of December 15th 1877.

The use of new forestry management techniques of conservation led to major transformations in forestry budget management (Degron, 1998, p.76). Indeed, from 1820, two key French foresters, Lorentz and Beaudrillart, and later Vicaire, imposed the conversion of coppices into timber forests leading to a long-term shift in financial revenues. This coupled with a decline in wood prices, implied a financial decrease of more than 10 million francs between 1875 and 1895 according to Degron (1998, p.77). In this context, the secular upward trend in spending for forest restoration and afforestation projects, particularly in mountain, had been questioned at the beginning of the third republic. Also, the efficiency of the forest restoration projects in mountain initiated during the Second Empire was thrown into question. In fact, in 1874, only 37,609 hectares were restored while the initial target was 1,133,000 hectares (Vivier, 1998, p.263). Despite those events, a new law was enacted in 1882, supplemented by a law of 1913, to reinforce reforestation efforts in the mountains. This law, more complete than the 1860 law, helped to create more than 200,000 hectares of forests between 1882 and 1940.

To sum up, the strong French Forestry policy was continued during the late 19th century. From the creation of a great legal framework in 1827 with the initiative of the Forest Code, the implementation of the Forestry policy both under the July Monarchy or the Second Empire was significant and allowed of creating new forest and restoring old woodlands. The third Republic

maintained this strong French forestry policy. Coupled with the secular decrease of agricultural areas (especially in mountain areas), the Forestry policy generated an increase of French Forest areas representing 20% of the national territory at the end of the century as opposed to 15% in the early 19th century (Devèze, 1973, p.73, p.105).

During the 20th century, French Forestry management became more sustainable by relying on a strong Forestry administration and the Forest Laws[35]. Today, thanks to the efforts implemented with the 1827 Forest Code, forest cover represents 29% of the French territory.

1.2.2 English forest in the 19th century

The study of the English forest during the 19th century is particularly difficult due to few sources. For instance, the French historian Michèle Devèze in his history of forests gave a long analysis of the evolution of the English forest through the ages but without mentioning the 19th century (Devèze, 1973). John Charles Cox also analysed royal forestland in England from the Middle Ages to the 20th century but only with a rapid analysis of the 19th century (Cox, 1905). In the same way, the French legal historian, Dominique Gaurier gave a presentation of the English Forest Law without discussing the 19th century (Gaurier, 2006).

This lack of bibliographical sources is an illustration of the English forestry disaster in the 19th century. The Forestry policy was non–existent without political prerogative and the great forest exploitation that spread over several centuries continued to increase. The French historian Alfred Maurry summarized the forestry disasters of Great Britain in the 19th century, as follows "Great Britain is currently the country that is the most destitute of forests. After consuming arboreal plants which shaded the ground, it now digs into the heart and gives to the flame the fossil debris of those who covered it millions of years ago. It seems that its civilization, its industry, the queen of this world, are eager to reduce our world to the nudity and the drought it offered before life appears on this surface" (Maurry, 1850, p.1312)[36].

Context

Since the 11th century and the arrival of the Normans Dukes, the Forest Law became the expression of the royal prerogative to protect forestland as hunting areas reserved for the King. The Forest Law was a royal law both punitive and unfair. Despite changes in legislation, the Forest Law remained based on the archaic and unfair royal law which could not adapt

[35] We do not include a detailed analysis of the 20th century since, during this century and despite two major world wars, forest cover has continued to grow. As noted, the National Forests Office (*Office national des forêts* or ONF) was created in 1964 to replace the *administration des Eaux et Forêts*. The ONF is a public establishment appointed to manage national forests. The private owners, who represent more than three quarters of the French forest are still highly regulated.

[36] "La Grande–Bretagne est actuellement le pays le plus dépourvus de forêts de l'univers. Après avoir consommé les végétaux arborescents qui ombrageaient son sol, elle fouille maintenant ses entrailles et livre à la flamme les débris fossiles de celles qui la couvraient, il y a des millions d'années. Il semble que sa civilisation, que son industrie, reine de celle du monde, aient hâte de réduire notre globe à cette nudité et à cette sécheresse qu'il offrait avant que la vie prennent naissance à sa surface" in Maurry (1850, p.1312).

to the evolutions of British society[37]. Peasant revolt, industrial revolution and land change occurring in the 17th century reinforced the decline of the Forest Law as well as Forestry policy by promoting the enclosure system, and agricultural and industrial development. Forests had been felled to make way for farming and to supply timber for ships, houses, fuel and metal smelting.

In addition, the Forest Law represented the absolute and arbitrary medieval monarchy in a modern parliamentary monarchy heavily under the influence of a class of landowners and merchants, namely the gentry. Consequently, contrary to France which implemented a strong Forestry policy to sustain timber production, England neglected its Forestry policy. The timber supply was provided by Scandinavian partners and wood from the colonies.

Over the centuries, the Forest Law became non–existent due to the increase of rights of use, agricultural expansion, population growth and economic development. In the early 19th century, the English forest lacked a Forestry policy and the Forest courts and Forest Law were all but forgotten. This fact was highlighted in the late 18th century by a Royal Commission which made a review of the royal forests between 1787 and 1793. As a result, several royal forests were not administered, and hence were left to local populations. Forest concessions granted to local forest users were becoming more frequent leading to enclosures that gradually transformed forests into grassland.

From the 1850, the already weak interest in forests continued to decrease, and by the end of the 19th century woodland had dropped to below 5% of the British territory, with the advent of the iron ship, the Industrial Revolution and the availability of cheap timber imports. Government activity in terms of Forestry was minimal until a national forest authority was formed in 1919 to create a strategic timber reserve (Holmes, 1975).

Forestry disaster

Until the late 19th century, Britain had no forestry service and, contrary to France, there was no formal training of foresters. Forest were mainly owned by the aristocracy and managed by foresters with traditional management techniques. British forestry was strongly fragmented, not formalised, and not centralised during the 19th century. Due to the lack of Forestry policy, most of the forestry remained concentrated on large privately owned estates. The forests served the double aim of wood production for local use and almost ornamental woods.

Both the British Government and private landowners did not feel the necessity to increase local timber production as well as introduce modern formalised forestry practices from France and Germany. This was due to the fact that the British had direct access to the large timber reserves of their Empire (mainly in India), of Scandinavia and the Baltic states. Moreover, timber imports were much cheaper than producing in Britain.

[37] Contrary to the the common law which had been modified throughout the 19th century to conciliate the huge transformation of human society by the industrial revolution and the judiciary organization of England (Gambaro et al., 2011, p.101).

However, at the same time, both the expansion of commercial agriculture (with the East Indian Company) and the construction of the railways seriously reduced timber resources on the Indian sub–continent. To face this issue, the colonial authorities in India created the Indian Forestry Service and introduced modern scientific forestry from Germany and France to prevent further depletion of the forest resources (Ribbentrop, 1900).

However, in the early 20th century, Forestry remained non–existent in Britain in contrast to its Indian colonies. The English forest conservator, John Nisbet, criticized the non–timber objectives and the lack of a scientific approach to Forestry. He argued that Britain could become self–sufficient in timber if "our present three million acres of woodlands were trebled in extent, and were all managed on business principles, in place of being under uneconomic management as game coverts and pleasure grounds, as is now mostly the case with British forests" (Nisbet, 1900, p.83).

The consequences of the absence of a strong Forestry programme and dependence on imported timber became all too painful during the First World War. Timber imports were restricted and there was a major shortage of wood. Between 1913 and 1918, the volume of wood imports fell to 25% of the 1914 level while the price of wood increased by 400% according to the Forestry Commission in a 1920 report. Consequently, the remaining private woodlands of Britain were ransacked, so much so that the Acland committee, in charge of reviewing the state of British forests during the Great War, identified a need for state forestry administration, namely the Forestry Commission.

Forestry Policy

In the early part of the 19th century, the Forest Law was very limited and concerned only royal forestland.

In 1810, the Commissioners of Woods, Forests, and Land Revenues were established in the United Kingdom by merging the former offices of the Surveyor General of the Land Revenues of the Crown and Surveyor General of Woods, Forests, Parks, and Chases into a three–man commission. In 1832, the name changed and became the Commissioners of Woods, Forests, Land Revenues, Works, and Buildings.

In 1851, the high instance of the Forestry policy was replaced by the Commissioners of Woods, Forests and Land, named the Office of Woods, in charge of the management of Crown lands including the royal forests.

Finally, in 1924, the remaining Royal Forests, including the Forest of Dean and the New Forest managed under the Office of Woods, were transferred to the new Forestry Commission. Consequently, the title of the Commissioners of Woods, Forests and Land Revenues was changed to Commissioners of Crown Lands.

The new Forestry Commission, still in charge of British forests, was created just after the First World War, in 1919. The strong wartime demands on timber led to major difficulties for

Great Britain as the country was no longer able to rely on timber imports. In July 1916, the Acland Committee was appointed by Minister Herbert Asquith to look for the best ways of promoting woodland resources in the country. The Committee recommended a state organisation to coordinate a reforestation and restoration plan to meet timber needs for the future.

Consequently, the Forestry Act came into force on September 1st 1919 and created the Forestry Commission with responsibility for woods in England, Scotland, Wales and Ireland. The Forestry Act also created eight Forestry Commissioners in charge of developing afforestation and restoration, promoting forestry and the production of timber, and making grants to private landowners.

The Forestry Commission had shaped the British forest throughout the 20th century until today. Results are encouraging. Compared to the 5% forest cover in the early 20th century, woodland across England, Scotland and Wales represented 13% of Britain's land area in 2011.

1.3 Concluding remarks

The comparative analysis of the History of French and English forests allows us to draw three important conclusions.

First, observe the comparable evolution of the two countries from the 11th century to the 16th and 17th century. Each of the countries implemented a royal Forest Law targeted to preserving forests for royal hunting. The rights of use and forest ownership were controlled and the forest land cover was strongly subject to the evolution of population growth. In each country, the wooded land decreased slightly over time.

Second, the conquest of the New World from the 16th century and the development of the Navy triggered France's political interest in forestry. Woodland was thus felled to supply timber for ships. The forest was now to be protected. However, despite this necessity shared by both countries, the Forestry policy began to present major differences between the two countries from the 17th century onwards. France decided to implement a strong Forestry policy to sustainably manage its forest resources while England did not improve its Forestry policy which remained the archaic Forest Law no longer adapted to the context of the 17th century. In fact, from this century and until the late 19th century, the industrial revolution and agricultural modifications brought about by the enclosure system served to deplete the English forest of its resources.

Third, in the early 19th century, both France and England underwent massive deforestation. The enclosures, the wood demand for heating and fuel in growing cities, the timber supply for the Navy and iron smelting led to wood-clearing in both countries. However, for the second time, the two countries went on to implement two different Forestry policies. France chose to protect its forest by creating the Forest Code in 1827, based on a centralized and formatted Forestry scheme. In contrast, in England neither Forestry policy nor Forest Law were implemented to curtail the wide-scale deforestation.

To sum up, the French motivation to preserve its forestlands in the 17th century and later

in the 19th century could have influenced its colonial policy. In contrast, the English policy to allow its forests to disappear can also have colonial implications. However, the question is not to understand French and English colonial history but mainly to examine if there is coherence today in the way of managing and protecting the forest. In other words, as these two countries have largely influenced the world through their respective colonization practices and the functioning of their legal system, they have also played an influential role on their Forest Laws. This question will be addressed in the following three chapters.

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Chapter 2

Legal origin, colonial origin and deforestation*

2.1 Introduction

Recent empirical work shows that countries whose legal systems are based on French civil law differ systematically from those whose legal systems are based on English common law. The Legal Origin Theory of development, mainly developed by La Porta, Lopez-Silanes, Vishny and Shleifer (LLSV–several papers La Porta et al. (1997, 1998, 2008)), investigates the role of legal origin on law and regulation on economic performance. The style of a legal system is influenced by political institutions (legal procedures,...), ideology, broader attitudes and philosophy. These latter features rely on the historical background and the historical institutional framework represented by the legal origin which is defined as "the style of social control on economic life" (La Porta et al., 2008). The main assumption is that some national legal systems are sufficiently similar to others to allow a classification of national legal systems into major families of law, though each country has a particular national legal system because each country has experienced its own changes and its own local circumstances. Despite particular adaptations, some fundamental legal features, shared by a group of countries, have persisted.

The Legal Origins Theory relies on three important conceptual ideas. First, by the eighteenth or nineteenth centuries, Continental Europe, particularly France, and Great Britain had developed separate styles of social control of economic activities as well as the underlying institutions supporting these styles. Second, both these styles and their legal institutions were transplanted by the origin countries to most of the world through colonization, rather "than written from scratch." Third, despite country specific changes, these styles have persisted in addressing the social control of economic life.

This way, this theory suggests that all law in a country is influenced by either the English common law or else the French civil law. The first one originates in the laws of England and has

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been transposed through conquest and colonization to England's colonies, including the United States, Canada, New Zealand, Australia, and many countries in Africa and Asia (Gambaro et al., 2011, p.132-140). The second one originates in the Roman law. Rediscovered in the eleventh century by the Catholic Church, the civil Roman law shaped the law in many European countries (Gambaro et al., 2011, p.191-193). However, the French civil law developed at the beginning of the nineteenth century after the French Revolution with Napoleon Bonaparte. This French law has been exported to many countries such as Spain, Portugal, Belgium, Italy, and the Netherlands through Napoleon's conquests. Moreover, the French civil law has been transposed to many countries in the world through colonization and conquest by France in the nineteenth century in Oceania, Indochina, Africa, and some Caribbean Islands. Besides, the influence of French civil law has also been implemented in Latin South American countries in the nineteenth century after the independence of the Spanish and Portuguese colonies. Finally, French civil law is now present in many South American, African and Asian countries (Gambaro et al., 2011, p.277-279).

The Legal Origins Theory attributes a heavier role of government in the civil law countries compared with the common law ones. This difference is mainly attributed to historical differences between the two legal traditions (see Glaeser & Shleifer (2002) for a theoretical presentation, and Klerman & Mahoney (2007) and Roe (2007) for a critical view of the Legal Origin Theory). The French civil law had been developed to promote state control and to prevent judges the opportunity for re-interpreting or changing laws. This marginalization of the judiciary helped extend state control of the economy. In contrast, the English common law had been created to protect private property and private freedom against the Crown. Thereby, a system of decentralized law-making with an independent judiciary where judges could interpret and change laws were implemented as effective checks on the government.

The consequences of these differing legal traditions on current economic performances have been broadly studied. For instance, La Porta et al. (1997, 1998) investigates the link between the law and finance. They show that the law in the civil law system has been designed to keep investors poorly motivated and the stock market less developed, contrary to the common law's protecting and motivating investors. This paper highlights the crucial links between the legal environment and finance, i.e., the nexus between legal institutions of the past and current economic ones. Also, in several studies conducted by LLSV jointly with others, they found that such outcomes as government ownership of banks (La Porta et al., 2002), the burden of entry regulations (Djankov et al., 2002), regulation of labor markets (Botero et al., 2004), and government ownership of the media Djankov et al. (2003b) vary across legal families. They argue that civil law is associated with more government ownership and regulation than common law. This has adverse impacts on markets, such as greater corruption, a larger unofficial economy, and higher unemployment. For instance, La Porta et al. (1999) studies such determinants of political institutions as government performance (provision of public good, effectiveness, government spending). They highlight some political theories to explain the quality of government

and assume that legal origin can be a good proxy for these political theories. They argue that the legal origin of law and regulation can predict "inefficient, interventionist and distortionary policies." They show that common law countries are less interventionist, better public good suppliers, more efficient and democratic than civil law countries. Besides, in other studies, the same authors have investigated the link between legal origin, property rights, and contract enforcement. For instance, Djankov et al. (2003a) have found that common law is less associated with formalism of judicial procedures than French civil law. In another paper, La Porta et al. (2004) have argued that common law countries enhance their judicial independence which is, in turn, associated with more freedom, better contract enforcement, and greater security of property rights[1]. In all, more than 100 papers have used legal origin as an explanatory variable, and LLSV's papers have been cited more than 2500 times. This chapter contributes to that literature by investigating the impact of legal origin on deforestation.

In this series of papers, LLSV and others have explained that legal origin is correlated with a wide range of institutions and policies which could be expected to produce higher rates of deforestation such as corruption, mis-defined property rights, or a weak rule of law in French civil law countries as opposed to common law ones. For this reason, the present chapter investigates the role of legal origin on deforestation assuming that the legal system matters in explaining deforestation. The main result is that civil law countries deforest significantly less than common law countries. Nevertheless, the implementation of the each legal system is not exogenous, except for previously colonized countries in which the legal system was transplanted by the colonizer. The differential impact of the French civil law remains significant for the previously colonized. Also, because of the close relationship between colonial history and legal origin, it is difficult to attribute the differences in environmental performance to legal origin as opposed to other aspects of colonial policy. In this sense, the differential impact of the the French civil law could be attributed to French colonial legacies. Fortunately, not all previously colonized countries with a French civil law inheritance were colonized by France, which allows of testing a specific French difference. Former French colonies tend to deforest less than former British, Spanish, or other colonies. This difference can be attributed to forest law legacies inherited from the 1827 French Forestry Code. Finally, since colonization strategies were not random and depended on geographical and climatic conditions, geographic features are controlled for. These results remain significant and robust.

The chapter is organized as follows. Section 2 describes the dataset and variables used in this chapter. Section 3 presents the main results and checks for the role of colonial legacies as well as geography. Section 4 provides concluding remarks and points to a interesting possible extension of this study.

[1]The seventeenth-century English revolutionary took control of the judiciary away from the Crown, and marginalised the role of the judiciary to prevent it from doing anything other than apply the existing law. The creation of laws and the administration of justice were then separated contrary to France. In this case, legislatures make laws, and independent judges enforce them, without interference from the legislature or the executive.

2.2 Data

The core dataset consists of 110 countries which had to meet one condition: having a French civil law origin, a common law origin, or a German civil law origin. However, two other different samples are used here to investigate more deeply the exogeneous role of legal origin and the influence of colonial legacies. The first one is a core dataset of 70 countries which had to meet two other conditions: (1) they are former colonies, (2) they are not located in Europe. The first criterion ensures that legal origin was exogenous and the second one excludes European countries to reflect the difficulty of classifying the colonial history of most European countries such as Italy or Finland for instance. The second sample is a core dataset of 47 countries which had to meet two other conditions: (1) being located in the tropics and (2) having a forest area above one million hectares in 1990.

Table 5.5 describes the variables. Table 2.8 indicates which countries are in the core dataset of 110 countries as well as in the two other sub-samples. Deforestation rates have been calculated from various Forest Resources Assessment (FRA) of the Food and Agriculture Organization (FAO). Although forest area data are available since 1960, only data since 1990 is used here, given the lack of reliability of the data before the 1990-FRA. This way, the dependent variable is the four-year average annual rate of deforestation on the sub-periods 1990–1993, 1994–1997, 1998–2001, and 2002–2005.

Legal origin was coded following two classifications. The first coding comes from LLSV's most recent coding (La Porta et al., 2008). The second is a revaluation of this coding in light of a variety of sources[2]. This coding differs from LLSV's coding for five countries which are here classified as "mixed legal origin"[3]. This alternative coding represents hybrid legal systems of the common and civil law whereas four countries were classified by LLSV as common law and one, the Philippines, as civil law. This coding could have had a large effect on the analysis, because all four classified common law countries had deforestation rates significantly higher whereas the Philippines had lower rates than average[4]. Nevertheless, as discussed further below, the main results remain valid even using LLSV's coding.

The colonial origin variables are coded by the dominant colonial power in the period 1750–2009. Though for most countries the coding was relatively straightforward, it was more complicated where the country was colonized by multiple countries. In this latter case, the assumption is that the last colonialist had had the biggest effect on institutional infrastructure at the time of independence[5]. Four categories of formerly colonized countries are created: the groups are

[2]Basically, the World Legal Systems Websites (http://www.droitcivil.uottawa.ca/world-legal-systems/eng-monde.html) of the University of Ottawa, Canada, is examined.

[3]Four of these countries are former colonies: Zimbabwe, Sri Lanka, the Philippines, and South Africa. Also, Thailand is classified as "mixed legal origin" and as a non-colonized country.

[4]For instance, the average deforestation rate was 0.03% in the core dataset and 0.05% in the sub-sample of tropical countries. In contrast, the four common law countries had a mean deforestation rate of 0.08% whereas the Philippines had a deforestation rate of -0.08%.

[5]Some countries were colonized by joining colonial powers, such as Cameroon, and were coded according to the colonial power of the more populous part (French in the case of Cameroon).

the former colonies colonized by (i) France, (ii) England, (iii) Spanish and (iv) other countries (Belgium, the Netherlands, the Ottoman Empire, Portugal, and Spain, Japan or the U.S).

Table 2.1 shows that legal and colonial origin are highly correlated. First, all common law countries are former British colonies whereas all former French colonies are of French legal origin. Nevertheless, the correlation between legal and colonial origin is not perfect so that some deviations could be exploited. For instance, all former Spanish colonies have French legal origin countries. These heterogeneities help to investigate whether legal traditions or colonial legacies have a greater influence on current deforestation in former colonized countries.

Table 2.2 presents descriptive statistics of deforestation rates between 1990–2005 along the identity of the former colonizer[6]. As can be seen, countries with different legal systems and colonial histories differ significantly in terms of deforestation performance. First, it is found that French civil law countries have deforested less between 1990–2005 than common law ones. Second, the former French colonies have deforested less between 1990 and 2005 than the other former colonies[7]. These results seem to highlight that legal and colonial legacies could have influenced some current features which, in turn, influence current deforestation.

2.3 Econometric Results

2.3.1 Main results

Table 2.3 presents the results of regressions using the core dataset of 110 countries as well as the sample of 70 former colonies. In all regressions, the dependent variable is the four-year average annual rate of deforestation on the sub-periods 1990–1993, 1994–1997, 1998–2001, and 2002–2005. In the first two columns, the only independent variables are legal origin dummy variables and the omitted category is that of French legal origin.

As in Table 2.2, common law countries deforest 0.4% more, on average, than French civil law countries, and this difference is significant at the 1% level (column 1). This result holds in only previously colonized countries in which the implementation of the legal system is more exogenous (column 2)[8]. These countries tend to deforest 0.3% more than French civil law countries.

The third column reports a regression with only colonial origin dummies as independent variables on the sample of former colonies (the omitted category is French former colonies). Former British colonies deforest 0.5% more than former French colonies, and this difference is statistically significant at the 1% level. Since all former British colonies are common law

[6]The sample used is of 65 countries formerly colonized by France, Great Britain, Spain or Portugal. The five other former colonies, not presented but in the sample of colonized countries, are: the Democratic Republic of the Congo, Eritrea, Ethiopia, South Korea and Indonesia.

[7]However, the mean of deforestation in former French colonies is not statistically and significantly different from that of the former Spanish colonies.

[8]Non colonized countries (included United States, Canada, Australia and New Zealand) were excluded because they are not former colonies so that their legal origin is not exogenous.

ones countries, this result does not allow of concluding about the role of legal origin or colonial legacies on deforestation. In addition, former Spanish and other colonies deforest more than former French colonies. This result is important, because all of these countries had received a version of the French civil law from Spain, Belgium, the Netherlands, the Ottoman Empire, or Portugal. Hence, since these former colonies deforest significantly more than former French colonies, it is obvious that legal origin does not suffice to explain the effects of inherited legacies on deforestation. This fact suggests that other aspects of colonial policy are likely to have been more important than legal origin.

Column 4 presents the results of a regression with both legal and colonial origin on the core dataset of 110 developed and developing countries. The coefficient on the common law dummy remains significant whereas the coefficient on the former British colony variable is now non-significant, although positive. These results seems to suggest that legal origin, not colonial origin matters. Moreover, the coefficient of both former Spanish and other colonies remains significantly positive. In this case, colonial origin seems to matter and some French colonial legacies allow of reducing deforestation compared to Spanish colonial legacies for instance.

Table 2.4 presents the same regressions and adds the five commonly used explanatory variables of deforestation[9]: the lag of forested areas, the log of GDP[10], the rural population density, the population growth and the relative price of timber (see Table 5.5 for more information). All variables are four-year averages, the sub-periods being 1990–1993, 1994–1997, 1998–2001 and 2002–2005. The core dataset is reduced to 87 countries and the former colonies sample regroups, now, only 61 countries. The previous results concerning the effect of legal and colonial origins remain robust to the introduction of all these variables. All common law countries (previously colonized countries) deforest 0.7% (0.08%) more than French civil law countries between 1990 and 2005.

Table 2.5 replicates key regressions from Table 2.4 using the alternative coding. This coding differs from LLSV's coding and uses hybrid legal systems of the common and civil law for five countries. The results remain identical to those in Table 2.4. Common law countries experience deforestation rates higher than French civil law countries (0.7% higher), and that difference remains significant when colonial origin is controlled for (column 3). Again, the coefficient on the former British colony variable is positive but non-significant, suggesting that legal origin, not colonial origin, mattered.

Finally, Table 2.6 replicates key regressions from Table 2.4 using the third sample of tropical countries. The results remains identical to those in Table 2.4. Common law countries deforest 0.08% more than French civil law countries, and that difference remains significant when colonial origin is controlled for (column 4). Again, the coefficient on the former British colony variable is positive but non-significant, suggesting that legal origin, not colonial origin, mattered in

[9]The results do not change with other control variables such as corruption or the rule of law index provided by ICRG or the World Bank (World Governance Indicators). Results available upon request.

[10]The introduction of the squared term of GDP to test the presence of the environmental Kuznets curve does not change the results. Results available upon request.

developing countries with a significant tropical forest.

2.3.2 The role of geography

The colonization was not randomly implemented by colonial powers. It was done in accord with imperial aims and relative power which varied over time and between colonial powers (Engerman & Sokoloff, 2000; Joireman, 2001; Lange, 2004).

To capture this feature, settler mortality data provided by Daron Acemoglu (Acemoglu et al., 2001)[11] is used. These figures give an indication of the extent to which a particular place was suitable for European settlement. In that study, the authors argue that European colonizers adopted different colonization strategies with correspondingly different institutions, depending on the conditions in the colonies. They explain that the feasibility of European settlement, characterized by the mortality rates of colonizers, determined the colonization strategy. More precisely, the conditions in colonies (the disease environment and the density of population) conditioned the European strategies. Besides they argue that institutions of the past have persisted over time so that current effects of present institutions on economic development could be explained by institutions of the past designed by Europeans in their colonies. They show econometrically that former "extractive colonies" characterized by a high level of mortality of settlers experienced bad institutions which impeded their current ones and so their level of development. Unlike these extractive colonies, the "settler colonies" had good institutions brought by the colonizer which have persisted over time, encouraging economic development in these former colonies.

The fact is that Britain colonized all or nearly all the most favorable countries. A mean comparison test shows that former French colonies had higher settler mortality compared to former British colonies.

Moreover, the geographical position of each country could influence deforestation rates. Also, French civil law countries are farther from the equator than common law countries. To control for that, the geographic position (latitude) of each country is used, to be sure that the results are not driven by the geographic location of the country[12].

Table 2.7 reports the regressions concerning the effects of the settlers' strategies and the latitude. The dataset for the first three columns is only for former colonies for which settler mortality data is available. This dataset, covering 54 countries, is slightly different than the sample of former colonies used previously, of 70 countries[13]. The results concerning the superiority of French civil law compared to common law are identical. However, the positive effect of

[11] Acemoglu et al. (2001) provide data for sixty-two former colonies with the maximum settler mortality for Mali.

[12] The literature of the role of geography on economic development is substantial. See for instance Engerman et al. (2002) and Easterly & Levine (2003).

[13] Given that all countries are previously colonized ones, in the third column with both legal and colonial origin, the former British colonies variable dummy has been removed because of its collinearity with the common law dummy variable.

former Spanish colonies becomes non-significant[14]. These results could suggest that the initial superiority of the French colonial legacies are better attributed to colonial strategies.

Columns 4–7 add the control for the distance from the equator. The previous results persist concerning the positive effect of common law origins, and Spanish colonial legacies on deforestation.

2.4 Conclusion

Recent empirical work demonstrates that countries whose legal systems are based on French civil law differ systematically from those whose legal systems are based on English civil law. The hypothesis of this chapter was that differences in the legal system can explain differences in environmental performance, measured through the loss of forest area between 1990 and 2005.

The main result of this chapter is that French civil law countries deforest significantly less than English common law countries. This result is robust in all samples and with the commonly used explanatory variables of deforestation. This result is particularly significant for the sample of previously colonized countries for whom the legal system is mainly an exogenous feature, and of developing countries with a substantial tropical forest. Also, since the choice of colonization strategy was not random, geographical features were controlled for. These results remain significantly robust. Also, former French colonies deforest less than former British colonies, though this result does not persist when legal origin is controlled for. Thus legal origin, not colonial origin, matters for explaining the loss of forest area. Also, former French colonies deforest less than other former colonies in the civil law area, such as formerly Spanish colonies. These results suggest that more than the legal origin on law and regulation, some French colonial legacies have reduced deforestation in the developing countries which had been colonized by France[15].

As a conclusion, it is worth noting that the French civil law seems to matter in reducing deforestation in previously colonized countries, by comparison with English common law. This study highlights the superiority of the French civil law over the English common law in preserving forested areas in developing countries. Moreover, because of the close relationship between colonial history and legal origin, it is difficult to attribute the differences in environmental performance to legal origin as opposed to other aspects of colonial policy. Anyway, one can attribute this effect of the French civil law on deforestation to French colonial or legal legacies such as the forest law legacies inherited from the French Forestry Code of 1827. This result is confirmed by the fact that former French colonies tend to deforest less than former British colonies, reinforcing the hypothesis on the presence of French forest law legacies which is both

[14]The sole Spanish colony removed is Equatorial Guinea, whereas none of the former French colonies have been removed. Thus, the results are not driven by a change in the sample.

[15]Though these results, mainly for former Spanish colonies, are not robust when controlling for "geographic" variables, thus suggesting that the superiority of the French colonial legacies could be attributed to French colonial strategies compared to Spanish ones.

a colonial origin and a legal origin.

This research can be extended to try to explain more precisely the differential impact of the French civil law. Another way to extend this article is to analyze whether English common law could, in such cases, allow of reducing deforestation since common law is associated to less corruption, better rule of law, and well defined property rights, all associated with low levels of deforestation. In this sense, legal origin could condition the effect of the institutional background on deforestation.

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2.5 Tables of results

Table 2.1: Number of countries according to former colonial status and legal origin

	French civil law	Common law	German civil law	Total
Non-colonized countries	19	8	13	40
Former French colonies	18	0	0	18
Former British colonies	0	25	0	25
Former Spanish colonies	16	0	0	16
Former other colonies	10	0	1	11
Total	63	33	14	110

Table 2.2: Legal origin, colonial origin, and deforestation rate (1990–2005)

Core dataset (110 countries)				
Legal origin	French	Common	German	
	0.0022	0.0073***	- 0.0025***	
Number of countries	63	33	14	
Only previously colonized countries (65 countries)				
Colonial power	French	British	Spanish	Portuguese
	0.0034	0.0091***	0.0051	0.0070*
Number of countries	18	25	16	6

Note: Asterisks indicate results of t-tests. The null hypothesis is that the mean is the same as the mean for French legal origin countries/Former French colonies. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 2.3: Legal origin, colonial origin, and deforestation (1990–2005)

Dependent variable: Rate of deforestation				
	Legal origin	Legal origin	Colonial origin	Both
	All sample	Previously Colonized	Previously Colonized	All sample
VARIABLES	(1)	(2)	(3)	(4)
Common law	0.004***	0.003**		0.004***
	(0.001)	(0.001)		(0.001)
German civil law	0.0005	0.006***		0.001
	(0.001)	(0.001)		(0.001)
Former British colonies			0.005***	0.002
			(0.002)	(0.001)
Former Spanish colonies			0.006***	0.007***
			(0.002)	(0.002)
Former other colonies			0.004*	0.005**
			(0.002)	(0.002)
Constant	0.002	0.005*	0.004	0.0008
	(0.002)	(0.003)	(0.003)	(0.002)
Observations	436	278	278	436
Countries	110	70	70	110
Adjusted R2	0.26	0.092	0.108	0.278
F statistic	33.358	26.002	12.912	26.071

Note: OLS robust standard errors in parentheses. In all regressions, regional and year dummies are introduced (omitted region is Asia). The omitted category is French legal origin, and/or Former French colony. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 2.4: Control variables, legal origin, colonial origin, and deforestation (1990–2005)

Dependent variable: Rate of deforestation				
	Legal origin	Legal origin	Colonial origin	Both
	All sample	Previously Colonized	Previously Colonized	All sample
VARIABLES	(1)	(2)	(3)	(4)
Common law	0.007***	0.008***		0.006***
	(0.002)	(0.002)		(0.002)
German civil law	0.005**	0.016***		0.005***
	(0.002)	(0.002)		(0.002)
Former British colonies			0.008***	0.003
			(0.002)	(0.002)
Former Spanish colonies			0.004	0.005*
			(0.003)	(0.003)
Former other colonies			0.005*	0.005**
			(0.003)	(0.002)
Lag forest Area	0.0002	-.00003	-.0002	0.00002
	(0.0005)	(0.0008)	(0.0009)	(0.0006)
Log GDP	-.003***	-.002***	-.002***	-.002***
	(0.0005)	(0.0007)	(0.0007)	(0.0005)
Rural density	-1.71e-06	-4.54e-06*	-3.58e-06	-2.48e-06
	(1.86e-06)	(2.37e-06)	(2.27e-06)	(1.96e-06)
Pop. growth	0.005***	0.006***	0.006***	0.005***
	(0.001)	(0.001)	(0.002)	(0.001)
Timber	0.003	0.002	0.001	0.002
	(0.002)	(0.003)	(0.003)	(0.002)
Constant	0.005	0.008	0.006	0.005
	(0.007)	(0.011)	(0.012)	(0.007)
Observations	348	244	244	348
Countries	87	61	61	87
Adjusted R2	0.341	0.24	0.236	0.35
F statistic	18.217	12.696	8.191	15.557

Note: OLS robust standard errors in parentheses. In all regressions, regional and year dummies are introduced (omitted region is Asia). The omitted category is French legal origin, and/or Former French colony. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 2.5: Alternative coding: Legal origin, colonial origin, and deforestation (1990–2005)

Dependent variable: Rate of deforestation			
	Legal origin	Legal origin	Both
	All sample	Previously Colonized	All sample
VARIABLES	(1)	(2)	(3)
Common law	0.007***	0.008***	0.006***
	(0.001)	(0.002)	(0.002)
Mixed legal origin	0.018***	0.02***	0.017***
	(0.003)	(0.003)	(0.003)
German civil law	0.007***	0.018***	0.007***
	(0.002)	(0.002)	(0.002)
Former British colonies			0.002
			(0.002)
Former Spanish colonies			0.003
			(0.003)
Former other colonies			0.003
			(0.002)
Lag Forest Area	0.0005	0.0004	0.0004
	(0.0005)	(0.0008)	(0.0005)
Log GDP	-.003***	-.003***	-.003***
	(0.0006)	(0.0007)	(0.0006)
Rural density	-1.99e-06	-5.43e-06***	-2.49e-06
	(1.54e-06)	(1.81e-06)	(1.67e-06)
Pop. growth	0.006***	0.007***	0.006***
	(0.001)	(0.002)	(0.001)
Timber	0.003	0.002	0.003
	(0.002)	(0.003)	(0.002)
Constant	0.0002	0.003	0.0004
	(0.007)	(0.01)	(0.007)
Observations	348	244	348
Countries	87	61	87
Adjusted R2	0.409	0.326	0.408
F statistic	18.685	12.879	15.78

Note: OLS robust standard errors in parentheses. In all regressions, regional and year dummies are introduced (omitted region is Asia). The omitted category is French legal origin, and/or Former French colony. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 2.6: Tropical countries: Legal origin, colonial origin, and deforestation (1990–2005)

Dependent variable: Rate of deforestation				
	Legal origin	Legal origin	Colonial origin	Both
VARIABLES	(1)	(2)	(3)	(4)
Common law	0.008***	0.008***		0.008**
	(0.002)	(0.002)		(0.003)
German civil law	-.012***			-.004
	(0.004)			(0.004)
Former British colonies			0.011***	0.003
			(0.002)	(0.003)
Former Spanish colonies			0.003	0.003
			(0.004)	(0.004)
Former other colonies			0.014***	0.014***
			(0.003)	(0.003)
Lag Forest Area	-.002***	-.002***	-.004***	-.004***
	(0.0006)	(0.0006)	(0.0006)	(0.0006)
Log GDP	-.001*	-.001	-.001	-.001
	(0.0008)	(0.0008)	(0.0008)	(0.0008)
Rural density	-5.68e-06***	-6.57e-06***	-6.63e-06***	-6.57e-06***
	(1.66e-06)	(2.02e-06)	(1.81e-06)	(1.81e-06)
Pop. growth	0.003**	0.003**	0.003**	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)
Timber	-.001	-.0006	-.001	-.001
	(0.002)	(0.002)	(0.002)	(0.002)
Constant	0.032***	0.032***	0.04***	0.041***
	(0.01)	(0.011)	(0.01)	(0.01)
Observations	176	168	168	176
Countries	44	42	42	44
Adjusted R2	0.253	0.164	0.301	0.375
F statistic	18.568	5.361	7.806	17.549

Note: OLS robust standard errors in parentheses. In all regressions, regional and year dummies are introduced (omitted region is Asia). The omitted category is French legal origin, and/or Former French colony. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 2.7: Geography, legal origin, colonial origin, and deforestation (1990–2005)

Dependent variable: Rate of deforestation							
VARIABLES	Legal Origin (1)	Colonial Origin (2)	Both Origins (3)	Legal Origin (4)	Legal Origin (5)	Colonial Origin (6)	Both Origins (7)
Common law	0.01***		0.011***	0.007***	0.008***		0.006***
	(0.002)		(0.002)	(0.002)	(0.002)		(0.002)
German civil law	0.011***		0.012***	0.006***	0.022***		0.006***
	(0.003)		(0.003)	(0.002)	(0.003)		(0.002)
Former British colonies		0.011***				0.008***	0.002
		(0.002)				(0.002)	(0.002)
Former Spanish colonies		0.002	0.003			0.005*	0.005**
		(0.003)	(0.003)			(0.003)	(0.002)
Former other colonies		0.004	0.005*			0.004*	0.005*
		(0.003)	(0.003)			(0.002)	(0.002)
Lag Forest Area	0.0003	-1.00e-05	-.0001	0.0002	-.0004	-.0005	0.00006
	(0.0008)	(0.0009)	(0.0009)	(0.0005)	(0.0007)	(0.0008)	(0.0006)
Log GDP	-.002***	-.002**	-.002**	-.003***	-.002***	-.002***	-.002***
	(0.0008)	(0.0009)	(0.0009)	(0.0005)	(0.0007)	(0.0007)	(0.0005)
Rural density	-4.22e-06	-4.24e-06	-4.79e-06*	-2.94e-06	-7.03e-06***	-5.06e-06**	-3.51e-06*
	(2.67e-06)	(2.71e-06)	(2.71e-06)	(1.86e-06)	(2.36e-06)	(2.22e-06)	(1.94e-06)
Pop. growth	0.007***	0.007***	0.007***	0.005***	0.006***	0.006***	0.005***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
Timber	0.002	0.001	0.002	0.002	0.002	0.001	0.002
	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.002)
Log settler mortality	0.003***	0.003***	0.003***				
	(0.0008)	(0.0008)	(0.0009)				
Latitude				-.009	-.020***	-.014**	-.008
				(0.006)	(0.007)	(0.007)	(0.006)
Constant	-.013	-.018	-.013	0.007	0.015	0.011	0.007
	(0.012)	(0.013)	(0.013)	(0.006)	(0.01)	(0.011)	(0.007)
Observations	216	216	216	348	244	244	348
Countries	54	54	54	87	61	61	87
Adjusted R2	0.296	0.294	0.301	0.345	0.258	0.243	0.353
F statistic	10.875	7.501	9.946	16.31	11.443	7.038	14.275

Note: Columns 1 to 3 (4 to 6) report the results with settlers mortality (latitude) as control variable. OLS robust standard errors in parentheses. In all regressions, regional and year dummies are introduced (omitted region is Asia). The omitted category is French legal origin, and/or Former French colony. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

2.A Appendix

2.A.1 List of countries

Table 2.8: List of countries

Core Dataset of 110 Countries
Algeria, Angola, Argentina, Australia, Austria, Belize, Benin, Bhutan, Bolivia, Botswana, Brazil, Bulgaria, Burkina Faso, Cameroon, Canada, Central African Rep., Chad, Chile, China, Colombia, Democratic Rep. Congo, Congo Rep., Costa Rica, Ivory Coast, Croatia, Czech Republic, Dominican Rep., Ecuador, Equatorial Guinea, Eritrea, Estonia, Ethiopia, Fiji, France, Gabon, Georgia, Germany, Ghana, Greece, Guatemala, Guinea, Guinea-Bissau, Guyana, Honduras, Hungary, India, Indonesia, Iran, Italy, Japan, Kazakhstan, Kenya, South Korea, Laos, Latvia, Liberia, Lithuania, Macedonia, Madagascar, Malawi, Malaysia, Mali, Mexico, Mongolia, Morocco, Mozambique, Namibia, Nepal, New Zealand, Nicaragua, Niger, Nigeria, Pakistan, Panama, Papua New, Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Russia, Saudi Arabia, Senegal, Serbia, Sierra Leone, Slovakia, Slovenia, Solomon Islands, Somalia, South Africa, Spain, Sri Lanka, Sudan, Suriname, Switzerland, Tanzania, Thailand, Turkey, Turkmenistan, Uganda, Ukraine, United Kingdom, United States, Uruguay, Uzbekistan, Venezuela, Vietnam, Zambia, Zimbabwe.
70 Past Colonized Countries
Algeria, Angola, Argentina, Belize, Benin, Bhutan, Bolivia, Botswana, Brazil, Burkina Faso, Cameroon, Central African Rep., Chad, Chile, Colombia, Democratic Rep. Congo, Congo Rep., Costa Rica, Ivory Coast, Dominican Rep., Ecuador, Equatorial Guinea, Eritrea, Ethiopia, Fiji, Gabon, Ghana, Guatemala, Guinea, Guinea-Bissau, Guyana, Honduras, India, Indonesia, Kenya, South Korea, Laos, Madagascar, Malawi, Malaysia, Mali, Mexico, Morocco, Mozambique, Namibia, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Senegal, Sierra Leone, Solomon Islands, Somalia, South Africa, Sri Lanka, Sudan, Suriname, Tanzania, Uganda, Uruguay, Venezuela, Vietnam, Zambia, Zimbabwe.
47 Tropical Countries
Angola, Argentina, Benin, Bolivia, Brazil, Burkina Faso, Cameroon, Central African Republic, Chad, Chile, China, Colombia, Democratic Rep. Congo, Costa Rica, Ivory Coast, Ecuador, Ethiopia, Gabon, Ghana, Guatemala, Guinea, Honduras, India, Indonesia, Laos, Madagascar, Malawi, Malaysia, Mozambique, Nepal, Nicaragua, Nigeria, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Senegal, Sierra Leone, Sri Lanka, Sudan, Tanzania, Thailand, Uganda, Vietnam, Zambia, Zimbabwe.

2.A.2 Data descriptions and sources

Table 2.9: Data descriptions and sources

Code	Variables and Definition	Source
Deforest	Deforestation: Log forested areas in $t-1$ minus log forested areas in t.	FAO
Log(Forest$_{t-1}$)	Initial Forest Areas: Log forested areas in $t-1$.	FAO
GDP	Log GDP per capita, constant 2000 US$.	WDI 2008
Popgr	Annual population growth rate (percentage).	WDI 2008
Rural	Rural population density per km^2 of arable land.	WDI 2008
Timber	The relative price of timber.	FAO/WDI 2008
Legalor	Legal origin of law and regulation with common, French civil law, German and Scandinavian law.	(La Porta et al., 2008)
Colony	Colonial dummies indicating whether a country had been a British, French, Spanish, or other (German, Italian, Belgian, Dutch or Portuguese) colony.	(La Porta et al., 1999)
Mortality	Log of the fourth mortality estimated by Acemoglu et al. (2000, Appendix, Table A2).	(Acemoglu et al., 2001)

Chapter 3

Colonial origin, institutions and deforestation

3.1 Introduction

Development economics theorists have long studied whether the identity of the colonial power or the strategy used by them mattered for subsequent development in previously colonized countries (see Hanson (1989); Grier (1999); Bertocchi & Canova (2002)).

This chapter thus investigates whether colonial legacies have long term implications for deforestation through their effects on the institutional background. This chapter tries thereby to investigate how colonial legacies could affect deforestation in previously colonized countries by assuming that these effects could be based on current institutional performances. In this context, this chapter belongs to the literature on historical and comparative institutional analysis (HCIA) which states that the current institutional framework "is a reflection of an historical process in which past economic, political, social, and cultural features interrelate and have a lasting impact on the nature and economic implications of a society's institutions" (Greif, 1998, P.82). Inherited legacies such as colonial legacies are so considered as a main "indirect" factor of deforestation, and important to understand whether the effects of institutions on deforestation differs according to the colonial origin. This chapter thus studies the existence of institutional persistence (Acemoglu et al., 2001; Acemoglu & Johnson, 2005; Chong & Zanforlin, 2000; Lange, 2004)[1].

This chapter investigates the role of colonial legacies through institutional performances because the institutional background is view as a significant underlying cause of deforestation which shapes economic incentives of economic agents (Mendelsohn, 1994; Deacon, 1994; Geist & Lambin, 2002). Institutions are defined such as the rules of the game or constraints which structure political, economic and social interactions. They could be both formal rules (such as

[1]Legacies can be defined such as legal origin of law and regulation. The effects of these legacies on deforestation through institutions is provided in the next chapter.

constitutions, law and property rights) and informal constraints (such as customs, traditions or sanctions). Appropriate institutions allow for the reduction of uncertainty in exchange and then result in weaker transaction and production costs. Put differently, institutions represent the core of the incentive structures of an economy and, in turn, shapes the direction of economic growth or environmental performances (North, 1990, 1994). In turn, institutions are a tool to enhance allocative efficiency and the feasibility of engaging in long term economic activities such as the sustainable use of natural resources and better environmental quality (Bohn & Deacon, 2000).

In this chapter institutions are defined through three groups: (1) an overall measure of the quality of governance as well as a measure of the extent of democratic rules (civil liberties, political regime (autocratic, democratic), political liberties); (2) informal policies such as the functioning of the government through the extent of corruption, the government effectiveness and the quality of the government's business regulatory; (3) property rights regime such as the risk of ownership, the quality of the legal structure and the quality of the rule of law. The first group is a global measure of governance quality to have an index of institutional vulnerability and a measure of democracy. The global institutional framework is thus apprehended in this first group in an attempt to compute a "global" effect of institutions. The second category is used to represent policy climate defined such as policies that result in unintended deforestation, due to the failure of government institutions to function effectively. Corruption is the main feature of this policy climate with the quality of the government functioning through the quality of governmental business regulatory and the quality of governmental services and policies. The third group is used to analyse the role of miss-defined property rights which is found to have an important positive effect on deforestation by increasing the opportunity costs for providing long term activities such as forestry activities. In a context of open access and miss defined property rights, deforestation through the conversion of forested areas into agricultural plots allows for the establishment of land titling (Mendelsohn, 1994; Barbier & Burgess, 1997; Araujo et al., 2009). In turn, deforestation is likely to occur in poorly property rights regime defines by miss-defined property rights and open access to forested land. Property regime thus is an important element of institutions having a strong effect on deforestation. The role of colonial legacies on these effects appear, therefore, important.

This chapter thus has the aim to investigate whether moving from French to British colonial legacies may do to influence the level of deforestation and whether the quality of institution may do affect this relationship. For instance, at our knowledge only Novoa (2007) investigates this issue and argues that former British colonies do relatively better than former Spanish ones in terms of avoiding deforestation because former British colonies have inherited better property rights than Spanish ones.

The effects of institutional persistence on deforestation through colonial legacies are estimated on a core dataset of 60 countries which had to meet two conditions: (1) they are former colonies, (2) they are not located in Europe. The second criterion excludes European countries

to reflect the difficulty of classifying the colonial history of most European countries such as Italy or Finland for instance.

The main result of this chapter is that the role of institutions on deforestation should be understood at the light of the past experiences of each country, i.e., the effects of institution are conditioned to colonial origins. An improvement of the quality of institutions is found to better dampen deforestation in countries previously colonized by Spain or Great Britain compared to these colonized by France. By contrast, Former French colonies tend to deforest less than former Spanish and British colonies in a context of bad governance. This result suggests to more puzzle out the role of colonial origins for combating deforestation. This study proposes that, in a context of poor governance (such as poor property rights, corruption, autocracy, low level of government functioning), previous French colonies are relatively better than other former colonies. This suggests, in turn, the presence of some French colonial legacies helping to preserve the forest. Finally, since colonization strategies were not random and depended on geographical and climatic conditions, geographic features are controlled for. These results remain significant and robust[2]. These results question, in turn, the validity of political recommendations in terms of governance which do not take into account the past experiences of each country, and underlie the significance of the relativism in the understanding of the effect of institutions[3].

The rest of the chapter is organized as follow. Section 2 provides an overview of the literature on institutional persistence through colonial legacies and provides a link with deforestation. Section 3 introduces the econometric approach and Section 4 shows and discusses main econometric results. Section 5 provides concluding remarks and points to policy recommendations.

3.2 Colonial legacies, institutions and deforestation

In this chapter colonial legacies are assumed to have affected early institutions which have persisted over time to represent the basis of current institutions influencing, now, the deforestation in previously colonized countries. In this section, this hypothesis is discussed by first discussing the nature, the emergence and the persistence of institutions, and then by explaining the link with deforestation.

3.2.1 Institutional persistence

Over the past few years, several studies have investigated the persistence of both politic and economic institutions. These studies investigate how this persistence over time have shaped economic development. The starting point is that institutions could persist over time through legacy or cultural heritage provided almost by colonization. For instance, Acemoglu et al. (2001)

[2]Results are less robust for former British colonies but overall the results suggest that colonial strategies matter in understanding the role of institutions on deforestation.

[3]In this chapter, the notion of institutions and governance are confounded and are defined such as the incentive structure of an economy represented by legal and political rules but also by government practises.

argue that paths of institutional development relies on economic or political mechanisms which explain why institutions persist over time. In this study, Acemoglu and his co-authors argue that Europeans colonizers adopted several colonization strategies with separate associated institutions depending on conditions in colonies. Thus, this paper of Acemoglu et al. (2001), on the role of colonial origins in development process through institutions, highlights the importance of the issue of institutional persistence. They explain that the feasibility of European settlement characterized by the mortality rates of colonizer determined the colonization strategy. More precisely conditions in colonies (the disease environment and the density of population) had conditioned the European strategies. Besides they argue that past institutions have persisted over time so that current effects of present institutions on economic development could be explained by past institutions designed by Europeans in their colonies. They show econometrically that previous "extractive colonies" characterized by a high level mortality of settlers experienced bad institutions impeded their current ones and so their level of development. Unlike these extractive colonies, the "settler colonies" had good institutions brought by the colonizer which have persisted over time encouraging economic development in these past colonies.

Also, Lange et al. (2006) argue that differences between the British and Spanish colonial economic model had large consequences for the type of areas they preferred to settle, the extent of colonial institutional building they designed and so legacies they left after independence. Spanish and British colonizers pursued different levels in the colonial institutional founding due to factor endowments in pre-colonial areas. Spanish mostly settled and concentrated colonial institutions in the most populous, politically and economically developed colonies at the beginning of the colonial era whereas British limited settlement and institutional transformation in the more populous, politically and economically developed pre-colonial areas. Thereby, they find that the level of colonialism had opposite effects on long-run socio-economic development for the Spanish and British colonies. More extensive British colonialism introduced an effective administration and a rule of law promoting development after independence whereas more extensive Spanish colonialism produced inefficient markets and predatory states leaving stratified societies after independence. Thus, this study explains that colonialism depends on both the colonizer's identity and conditions within colonies arguing that these separate colonialisms shaped past political and economical institutions with current impacts on present institutions.

Lange (2004) also investigates the relationship between the form of colonialism and post-colonial democratization in 33 former British colonies. This paper uses the general framework of Acemoglu et al. (2001) suggesting that the form of colonialism was made up by the density of pre-colonial population and the disease factor. However, Lange (2004) focuses on two forms of dominations: an integrated one or directly ruled and an dispersed one or indirectly ruled. He finds that the legal-administrative institutions in the indirectly ruled dominations which linked the colonial administration to local people via chiefs enhancing their executive, legislative and judiciary powers, experienced bad current institutional performances (measured by the ICRG index and the democracy index of Freedom House) contrary to the direct ruled system based

on formal rules and a structured legal-administrative system.

Finally, Joireman (2001) compares the effectiveness of the rule of law inherited from French civil and English common legal systems in Africa. Besides, Grier (1999) investigates the relationship between the identity of the colonizing power and the current economic growth in former African colonies. He finds that former British colonies have better economic performances than French ones.

3.2.2 Institutions and deforestation

Among the determinants of deforestation, institutions are often held to play a leading role. Since institutions are defined as the incentive structure shaping economic human interactions, they can help for moving the system towards a sustainable forestry management and a sustainable economic development.

In fact, deforestation is often viewed as the result of competing land use, between maintaining the natural forest and conversion options such as agriculture (Barbier & Burgess, 1997, 2001; Arcand et al., 2008). In turn, conversion implies that potential timber and environmental benefits (resulting from the "keeping" forest option) are irreversibly lost and represent the "price" or opportunity cost of conversion (deforestation). Consequently, institutions can influence the importance of opportunity costs generated by deforestation. For instance, creating appropriate institutions helps to reduce uncertainty in exchange as well as transaction and production costs of long term activities such as timber of environmental protection. The poor quality of institutions in developing countries may thus constitute a major impediment for forest conservation.

In the literature on deforestation causes, there has been an attempt to find a relationship between deforestation and political institutions although the type of institutional variables used varies. In the literature, a broader view of institutions is often used and represent both institutional factors and policy (Geist & Lambin, 2002)[4]. However, three important categories of institutions can be proposed: (1) informal policies such as corruption, (2) property rights regime such as the ownership risk, and (3) political institutions shaping both informal policies and property rights regime such as the quality of the rule of law and political stability.

Informal policies such as corruption and illegal activities are an important element of institutions having a strong effect on deforestation. Defined such as an informal pro-deforestation policy, corruption promotes rent seeking activities and develops miss-management forestry productions which leads, in turn, to an over-extraction of resources (Amacher, 2006; Søreide, 2007; Karsenty et al., 2008) (for theoretical studies, see Eerola (2004); Barbier et al. (2005); Wilson

[4]Policy here refers to the quality of the functioning of the government, i.e., the governance. However, the government policies such as macroeconomic policies, including monetary and fiscal policies, domestic and international trade policies can have also adverse effects on the conservation (see for instance Anderson (1990); Arcand et al. (2008)) and use of natural resources but are non studied in this chapter. Here, the focus is made on the governance of the government in the promotion of sustainable practises particularly through sound governmental activities.

& Damania (2005); Bulte et al. (2007); Delacote (2008), and for empirical works, see Barbier & Burgess (2001); Barbier (2004); Barbier et al. (2005); Galinato & Galinato (2009)). In addition, Callister (1999) and Contreras-Hermosilla (2000) argue that the extent of corrupt activities in forestry is more important in the case of tropical deforestation for three main reasons. First, forest activities are often located in remote areas, far away from the press, political power and public (Hotte, 2001). Second, *timber* is not inventoried but only valuable so that it is very difficult to assess how much wood was illegally extracted. Third, in developing countries government officials are often badly paid and have often an important discretionary power which, combined with high valued timber-logs, favours corruption.

The role of property right regime on deforestation has also been widely studied (Mendelsohn (1994); Angelsen (1999); Hotte (2001, 2005) for theoretical studies and Southgate & Runge (1990); Deacon (1994, 1999); Bohn & Deacon (2000); Bhattarai & Hammig (2001); Culas (2007); Arcand et al. (2008) for empirical works[5]). This literature focuses mainly on the role of ownership risk. The main underlying hypothesis is that "poorly enforced ownership exposes standing forests and other kinds of capital to a form of confiscation or default risk and thereby discriminates against capital intensive land uses" (Deacon, 1994, p421). In addition, since deforestation is a low intensive capital extraction process, miss-defined property rights tend to lead to over extraction. In this case, the more the risk of losing ownership is, the more the discount rate will be and the lower future returns for forestry activities will be. Hence, an agent will prefer for instance to cut wood and develop noncapital intensive permanent agriculture activities rather than forestry ones because it is discounted heavily to maintain forestry activities. Put differently, sustainable harvesting of forest products is most sensitive to the existence of clear property rights and their enforcement relative to agricultural activities since the forest is equivalent to a stock of capital. However, in the literature, the measurement of insecure property rights differs while it could be grouped into two different variables. First is more direct indicators such as the enforceability of contracts (Culas, 2007). This indicator measures the relative degree to which contractual arrangements are honoured. Second relies upon measures of political instability such as coups, revolutions and political assassinations since insecure property rights might arise from a lack of government's stability to enforce laws of property (Deacon, 1994, 1999; Bohn & Deacon, 2000; Arcand et al., 2008).

Last is political institutions which refers to the literature which determine the quality of policies implemented to preserve forest by improving environmental rules and regulations as well as the allocation of environmental resources. This concerns mainly the quality of the rule of law, the political stability and the extent of political and civil rights. For instance, Bhattarai & Hammig (2001) use an aggregated index of civil and political liberties taken from Freedom House to capture the role of political institutions. They find that this index has a negative impact on deforestation. They argue that more democracy and freedom promote sound

[5]At the local level, see for instance Godoy et al. (1997) for Bolivia and Otsuki et al. (2002); Araujo et al. (2009) for Brazil.

environmental practises and better conservation of forest land in Africa and South America.

In addition, despite the important literature on the role of institutions on deforestation, this study has the aim to provide a new explanation for the role of institutions by taking into account the role of colonial legacies and so, in turn, by analysing the importance of the persistence of institutions. Thus, this approach is suitable for understanding the role of institutions on deforestation at the light of colonial legacies by taking into account the historical process.

3.3 Empirical framework

3.3.1 Dataset and variables

The core dataset consists of 60 countries which had to meet two conditions: (1) they are former colonies, (2) they are not located in Europe[6].

Table 3.7 describes the variables and Table 3.5 indicates which countries are in the core dataset of 60 countries. Deforestation rates have been calculated from various Forest Resources Assessment (FRA) of the Food and Agriculture Organization (FAO). Although forest area data are available since 1960, only data since 1990 are used here, given the lack of reliability of the data before the 1990-FRA. Thus, the dependent variable is the four-year average annual rate of deforestation on the sub-periods 1990–1993, 1994–1997, 1998–2001, and 2002–2005[7].

The colonial origin variables are coded by the dominant colonial power in the period 1750–2009. Though for most countries, the coding was relatively straightforward, it was more complicated where the country was colonized by multiple countries. In this latter case, the assumption is that the last colonialist had had the biggest effect on institutional infrastructure at the time of independence[8]. Four categories of formerly colonized countries are created: the groups are the former colonies colonized by (i) France, (ii) England, (iii) Spanish and (iv) other countries (Belgium, the Netherlands, the Ottoman Empire, Portugal, and Spain, Japan or the U.S).

3.3.2 Institutional variables

Institutional determinants are divided into three parts (see Table 3.7 for more details and a complete definition of each institutional variable).

First is used two measures of the global governance quality. The first one is an indicator which combines the six separate variables created by the World Bank Governance Indicators database (WBGI) into a single index[9]. These variable are: control of corruption, rule of law, voice and accountability, political stability and absence of violence, government effectiveness

[6]The sample used is shaped by the data for the relative price of timber, available for only 60 countries.

[7]In the regressions with the variables provided by the World Bank Governance Indicators, the data ranges from 1996 to 2005 so that the sub-periods are only 1994–1997, 1998–2001, and 2002–2005.

[8]Some countries were colonized by joining colonial powers, such as Cameroon, and were coded according to the colonial power of the more populous part (French in the case of Cameroon).

[9]See Kaufmann et al. (2008) for more details on the construction of these variables.

and regulatory quality. All the original indicators of governance are first reversed as follows:

$$WBGI_i = \frac{WBGI_i - min(WBGI_i)}{max(WBGI_i) - min(WBGI_i)}, \tag{3.1}$$

where $min(WBGI_i)$ and $max(WBGI_i)$ represent the minimum and the maximum of each indicator. This transformation implies range between 0 and 1. The aggregated index of governance is then the first principal component of the vector of the six indicators of governance which accounts for 78% of the overall covariance (see Table 3.8 for more details).

The second overall measure is an average index of democracy created by the Quality of Government Institute (University of Gothenburg in the Quality Data of Government) from Freedom House data on civil liberties and political rights, and from the Polity 2 index of the Polity IV project. The Freedom House data are a standardized averaged index of civil liberties (with value from 1 (most free) to 7 (least free)) and political rights ((with value from 1 (most free) to 7 (least free)) indices. The Polity2 variable captures the regime authority spectrum on a ranging from -10 (hereditary monarchies) to +10 (consolidated democracy) and the three component variables that record key qualities of executive recruitment, constraints on executive authority, and political competition. This average index of democracy is then standardized as follows:

$$Democracy_i = \frac{Democracy_i - min(Democracy_i)}{max(Democracy_i) - min(Democracy_i)}, \tag{3.2}$$

where $min(Democracy_i)$ and $max(Democracy_i)$ represent the minimum and the maximum of the average index of democracy. The new variable is so transformed to a scale 0 (autocracy)-1 (full democracy).

The second part of institutional variables represents measures of the quality of the government functioning. The composite indicator from the World Bank Indicators database is broken up to return to specific measures of quality of governance such as the level of corruption, the effectiveness of the government and the extent of the regulatory quality.

The third part is based on the quality of property rights. Two indices are used to measure the quality of property rights. The Legal Structure and Security of Property Rights index of Fraser Institute is first used. This index ranges from 0 to 1 where 0 corresponds to bad legal structure. The index is a general overview of the legal structure in a country and gathers judicial independence, impartial courts, protection of property rights, military interference in rule of law and the political process, integrity of the legal system, legal enforcement of contracts and regulatory restrictions on the sale of real property. The second is the Rule of Law index of the World Bank Governance Indicators database. The index ranges from 0 (worst rule of law) to -1 (better rule of law) and measures the extent to which law enforcement agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, the police and courts, as well as the likelihood of crime and violence.

However, these two variables are a measure of legal institutions, but not a measure of prop-

erty rights. Thereby, an index of ownership risk is calculated following the Bohn and Deacon's approach (Bohn & Deacon, 2000). These authors used an empirical model of investment on the relationships between ownership risk and investment decisions. Since the security of property rights affects the extent of investment and the efficiency with which inputs are allocated, ownership risk could be defined such as a probability of expropriation, i.e., a capture of all claims to investment projects. Captures can be acted by government, private parties, or "bad" courts. In the model, expropriation risk is empirically represented by (1) government stability (revolutions, guerilla warfare, purges, political assassinations and constitutional change), and (2) regime type (Parliamentary democracy; Non-parliamentary democracy; Strong executive; Military dictatorship; Monarchy; Others). The underlying assumptions of this model is that "investors have some underlying notion of a permanent, country-specific ownership risk that is better measured empirically by the long-run frequency of such events" and can "perceived risk which might rise temporarily after an event occurs" (Bohn & Deacon, 2000, p.538). These short and long run links are modelled by the country-specific average frequency of each political event and dummies for the temporal occurrence of individual events in the current or preceding year. Investment is also regressed on traditional economic variables such as output per worker, human capital per worker and openness (following Bohn & Deacon (2000)). The basic equation of investment is:

$$Invest_{i,t} = \theta_0 + \theta_1 GDP_{i,t-1} + \theta_2 H_{i,t-1} + \theta_3 Open_{i,t-1} + \theta_4 Regime_{i,t} + \theta_5 Stability_{i,t} + \varepsilon_{i,t}, \quad (3.3)$$

where $Invest$ represents the investment/output ratio in the country i in time t, GDP is the log of output per worker in $t-1$, H represents the human capital in $t-1$, *open* is the degree of openness in $t-1$, *regime* represents the first political attributes associated with political regime, *stability* is the government stability and $\varepsilon_{i,t}$ is the disturbance term.

An unbalanced panel dataset covering the 60 previously colonized countries in the core data set from 1990 to 2005 is used. The dependant variable is the total investment as percent of GDP and comes from the last version of the Penn World Table (Heston et al., 2009) as well as the output per worker. The human capital variable is the ratio of secondary-school enrolment to population provided by Banks (2008). The measure of openness follows Bohn & Deacon (2000) who use the sum of exports and imports divided by GDP provided by the last version of Penn World Table (Heston et al., 2009). Political data come from the Cross-national time-series data archive of Arthur S. Banks Banks (2008). Political instability are measured by revolutions, political assassinations, purges, guerilla warfare and major constitutional changes. The cross-national time-series data archive provides the number of these political events but dummy variables, defined to equal one if at least one such event occurred in a given country and year, represent them in the model following Bohn & Deacon (2000). Political regimes are created using the following three criteria: the type of chief executive (premier, president,

military officer, monarch and other), the method of selection the chief executive (direct election, indirect election, and non-elective,) and the existence or effectiveness of the legislature (effective, partially effective, ineffective, and non-existent). In turn, six political regimes are created: (1) a *parliamentary democracy* with an effective or partially-effective legislature and an executive directed by a premier directly elected; (2) a *non parliamentary democracy* with a non-premier elected at the head of executive with an effective or partially effective legislature; (3) a *strong executive regime* with an ineffective or in-existent legislature; (4) a *military regime*; (5) a *monarchy*; and (6) an *"other" regime* category. A constitutional change variable is used in the same way of Bohn & Deacon (2000). They specify that constitutional change can have a non linear effect on investment according to the regime type. The dummy variable representing constitutional change is then interacted with the regime type which is recoding as follows: the Parliamentary democracy and the Non-parliamentary democracy are gathered to create a democracy regime (called regime D) whereas strong executive, military dictatorship, monarchy and others represent a non-democracy regime (called regime A). Finally, when a constitutional change occurred during year t, such variable equals one for a given country in year t if the country began year t in regime D and ended it in regime A for instance. Finally, the index of ownership risk is then constructed by multiplying coefficients (of each political attribute, i.e., government stability and regime type) by each political attribute and summed. The index ranges from 0 (high ownership risk) to 1 (low ownership risk).

3.3.3 An econometric deforestation model

The empirical approach is given by an equation in which the rate of deforestation is explained by variables suggested by the literature. The basic assumption is that there is a steady-level of the logarithm of the forest cover in a country i at time t, $lnF^*_{i,t}$. Hence the steady state is determined by traditional factors of deforestation and the dynamic to go toward this steady-state is represented by a linear first-order difference equation given by $lnF_{i,t} = \theta lnF_{i,t-1} + \theta_0$ with θ_0 is a constant. A first-order Taylor approximation around the steady-state gives

$$lnF_{i,t} = lnF^* + (lnF_{i,t-1} - lnF^*_{i,t})\theta. \tag{3.4}$$

Subtracting $LnF_{i,t-1}$ from both sides to have a rate of deforestation and arranging, we have

$$-(lnF_{i,t} - LnF_{i,t-1}) = (1-\theta)LnF_{i,t-1} + (\theta - 1)lnF^*_{i,t}. \tag{3.5}$$

If we replace $(\theta - 1)lnF^*_{i,t}$ by $X_{i,t}\gamma$, with γ represents coefficients associated with the matrix of explanatory variables, X, we have

$$-(lnF_{i,t} - LnF_{i,t-1}) = (1-\theta)LnF_{i,t-1} + X_{i,t}\gamma + \zeta_{i,t}, \tag{3.6}$$

with $\zeta_{i,t}$, a disturbance term.

Thus, the level of forest cover in a country follows a pace determined by $(1-\theta)$ and the steady-state level is influenced by explanatory variables.

To study the role of colonial legacies on deforestation through institutional performances, interaction terms are used. Each institutional variable is interacted with each colonial dummy (British, Spanish, Other colony where the reference is French). However, although the use of interaction terms suggests two interpretations, the use of inherited legacies provides a reasonably one-way interpretation[10].

Hence, the following equation was estimated to test the hypothesis that institutions affect differently deforestation according to the colonial origins:

$$deforest_{i,t} = \alpha + \delta_1 INST_{i,t} + \phi_1 INST * LEG_{i,t} + \phi_2 LEG_i + X'_{i,t}\beta + \nu_r + \eta_t + \varepsilon_{i,t},$$

where i and t represent the country and the nonoverlapping 4–years period, respectively. ν_r and η_t represent the region and period fixed effects, respectively[11]. $INST$ is the institutional variable, $INST * LEG$ is the interaction term, and LEG_i is the additive term or the "direct" effect of inherited legacies. LEG is at the same time *British*, *Spanish* and *Othercolonies*. The strategy consists in identifying a differential effect of institution according to colonial legacies to test the presence of institutional persistence. This strategy allows us to rank the impact of institutions on deforestation. δ_1 captures the institutional effect in the former French colonies since legacies equal 0, i.e., when the dummies *British*, *Spanish* and *Othercolonies* equal 0. By contrast, ϕ_1 is the institutional effect when the dummies *British*, *Spanish* and *Othercolonies* equal 1, i.e., the effect of institutions in former British, Spanish and other colonies relatively to the former French ones. Besides, ϕ_2 represents the role of colonial legacies (i.e., British, Spanish and other colonies) in a world with bad institutions ($INST = 0$). ϕ_2 allows us to assume that colonial legacies could have some effects on deforestation through other variables since inherited colonial legacies represent more broadly the colonial strategies with political, economical and cultural specificities. Thus, this effect represents the consequences of colonial legacies on deforestation through others channels that institutions. The overall impact of colonial origins is so $\phi_1 + \phi_2$, and a test of the joint significance of the two coefficients is needed to validate the existence of nonlinearity due to the level of the quality of institutions.

[10]For instance, assume an interaction term between corruption (compute as high score for high corruption) and the past forested areas with a positive coefficient. This has two interpretations: (1) more the forested areas is important, more an increase in corruption raises deforestation (previous forested areas strengthen the positive effect of corruption on deforestation), (2) more the level of corruption is high (i.e., more the variable corruption increases), more will be the scarcity effect (the positive effect of forested areas on deforestation). In contract, an interaction term between corruption and a dummy coded as 1 for previously British colonies and 0 otherwise (the reference being former French colonies) would have the following interpretation: the corruption effect is less or more important in previously British colonies relatively to French ones.

[11]Regions are Asia, Sub-Saharan Africa, North Africa and Middle East, Latin America and Caribbean, and Oceania (only Fiji).

X is a matrix of control variables that includes the following[12]: the level of economic development (GDP)[13], the population growth and the rural density (Cropper & Griffiths, 1994), and the relative price of timber (see 3.7 for a complete definition of each variables and sources)[14].

3.4 Econometric results

3.4.1 Main results

Table 3.1 to Table 3.3 present the results of regressions using the core dataset of 60 countries. In all regressions, the dependent variable is the four-year average annual rate of deforestation on the sub-periods 1990–1993, 1994–1997, 1998–2001, and 2002–2005.

First, in Table 3.1, the aggregated governance index from the World Bank Governance Indicators, and the aggregated index of democracy from Freedom House and the Polity IV project are used to investigate the presence of institutional persistence on deforestation according to colonial origins. First of all, the poorer the country's governance quality or the country's index of democracy is, the more deforestation is important in former British and Spanish colonies compared to former French colonies. For instance, in the case of the aggregated governance index, former British (Spanish) colonies deforest 1.7% (3.5%) more, on average, than former French colonies, and this difference is significant at the 1% level (column 2). Moreover, the overall impact of British and Spanish colonies is positive and significant[15]. For instance, at the sample mean of the aggregated governance index, former British (Spanish) colonies deforest 0.08% (1.7%) more than former French colonies[16]. These results mean that colonial origins matter for explaining deforestation but also that French colonial legacies seem to be relatively better to preserve the forest compared to British and Spanish colonial legacies.

Second, it is found that an improvement of institutional quality or democracy does not help for reducing deforestation in previously colonized countries (in Columns 1 and 3, the coefficient of each institutional variable is not significant). However, in Columns 2 and 4, institutions are found to have a differential impact on deforestation according to colonial origins. Thus, an

[12]The following variable have been previously used as control variables but have been removed because they (i) have a non significant effect on deforestation and (ii) do not change the results of the institutional variable: the real effective exchange rate, the external debt, both agricultural and fuel exports, and the financial development (such as the percent of domestic credit provided by banking sector).

[13]The GDP squared term can be introduced to test the Environmental Kuznets Curve (EKC) defining a non linear effect of economic growth on deforestation so that the marginal effect can be positive for low income countries and become negative for high income economies (Bhattarai & Hammig, 2001; Culas, 2007). The squared term is not used because the sample used is relatively homogeneous in term of income. Results do not change with the squared term. Results available upon request.

[14]The relative price of timber is an important determinant in the trade-off between keeping forest or clearing it (Arcand et al., 2008).

[15]Table 3.1 reports the significance of the sum of the two coefficients associated with each colonial origin and this sum is always statistically significant in the case of former British and Spanish colonies.

[16]In all cases, the sample mean of the institutional variable represents alternatively the mean of the former British colonies sample and the former Spanish colonies sample.

enhancement of democracy or the quality of institutions allows for the reduction of deforestation only in former British and Spanish colonized countries contrary to former French colonized countries. For instance, a shift from the median toward the 75th percentile of the distribution of the aggregated democracy index (an increase from -0.5 to -0.26 for British, and from -0.31 to -0.20 for Spanish) would lead to a decrease of the positive overall impact of the British (Spanish) legacies on deforestation from 3% to 2.5% (6.5% to 5.8%). These results highlight that French colonies could inherited worst institutional features (compared to British colonies) which, in turn, do not help for dampening deforestation. More interestingly, an improvement of each institutional variable implies an increase of deforestation in former French colonies (sign of each additive variable of institutions in Columns 2 and 4).

Table 3.2 presents the same regressions but used more detailed information on the quality of government functioning such as the control of corruption, the effectiveness of government and the regulatory quality. Columns 1 and 2 report the results with the corruption variable. An improvement in the control of the corruption is positively associated with low deforestation suggesting that corruption is an impediment for combating deforestation in developing countries (Contreras-Hermosilla, 2000). However, this effect is differential according to the colonial origin. For instance, a decrease of corruption in former Spanish colonies allows to reduce deforestation compared to former French colonies. However, there is no differential impact between former British and French colonies in low corrupt countries but there is a one in high corrupt countries. In fact, the higher the corruption is, the more the deforestation is in former British colonies compared to former French colonies. This result hold also for former Spanish colonies. For instance, although former Spanish countries weakly corrupted deforest 3.9% less than former French colonies, former Spanish countries highly corrupted deforest 2.7% more than former French colonies. Moreover, the overall impact of British and Spanish colonies is still positive and significant[17]. At the sample mean of the corruption index, former British (Spanish) colonies deforest 0.09% (1.2%) more than former French colonies.

Columns 3 and 4 report the results with the government effectiveness variable. An enhancement in the effectiveness of the functioning of the government such as the quality of public services or the civil service or the credibility of the government's commitment to such policies is not significantly associated with low deforestation (Column 3). However, this effect is differential according to the colonial origin. For instance, an improvement of the quality of the functioning of the government in both former British and Spanish colonies allows to dampen deforestation compared to former French colonies (Column 4). However, in the case where the government effectiveness is low, deforestation is more important in former British and Spanish colonies compared to former French colonies. For instance, although former British (Spanish) countries with a high quality of the government functioning deforest 2.8% (5.5%) less than former French colonies, former British (Spanish) countries with a low quality of the govern-

[17] Table 3.2 reports the significance of the sum of the two coefficients associated with each colonial origin and this sum is always statistically significant in the case of former British and Spanish colonies.

ment functioning deforest 1.8% (3%) more than former French colonies. Moreover, the overall impact of British and Spanish colonies is still positive and significant. At the sample mean of the government effectiveness index, former British (Spanish) colonies deforest 1% (1.1%) more than former French colonies.

Columns 5 and 6 report the results with the quality of the business regulatory provided by the government. An enhancement of this index is not significantly associated with low deforestation (Column 5) but this effect is differential according to the colonial origin. As in the case of the government effectiveness, former British (Spanish) countries with a high quality of the regulatory deforest 2.8% (6.6%) less than former French colonies whereas former British (Spanish) countries with a low quality of the regulatory deforest 2.3% (5.1%) more than former French colonies. Moreover, the overall impact of British and Spanish colonies is still positive and significant. At the sample mean of the regulatory quality index, former British (Spanish) colonies deforest 1% (1.02%) more than former French colonies. These results confirm that colonial origins matter for explaining deforestation and that French colonial legacies seem to be relatively better to preserve the forest compared to British and Spanish colonial legacies.

Table 3.3 presents the same regressions but used more detailed information on the quality of property rights such as an index of ownership risk, the quality of the legal structure and the quality of the rule of law. Columns 1 and 2 report the results with the computed ownership risk index. A reduction is the ownership risk (an increase of the index) is not significantly associated with low deforestation (Column 1). However, this effect is differential according to the colonial origin. For instance, a decrease of the ownership risk in both former British and Spanish colonies leads to a reduction of deforestation compared to former French colonies (Column 2). However, in countries characterized by a high ownership risk, deforestation is more important in former British and Spanish colonies compared to former French colonies. For instance, although former British (Spanish) countries with a low ownership risk deforest 2.7% (3.4%) less than former French colonies, former British (Spanish) countries with a high ownership risk deforest 2% (2.4%) more than former French colonies. Moreover, the overall impact of British and Spanish colonies is still positive and significant at the sample mean of the ownership risk index. For instance, former British (Spanish) colonies deforest 0.9% (0.6%) more than former French colonies.

Columns 3 and 4 report the results with the index on the quality of the legal structure taken from the Fraser Institute[18]. The differential effect according to colonial origins hold with this variable. Former British (Spanish) countries with a high quality of the legal structure deforest 3.3% (5%) less than former French colonies whereas former British (Spanish) countries with a low quality of the legal structure deforest 0.5% (0.9%) more than former French colonies.

Columns 5 and 6 report the results with the rule of law index taken in the World Bank Governance Indicators database. The previous results hold. An enhancement of this index

[18]Six countries are dropped due to a lack of data for this index: Burkina Faso, Guinea, Laos, Sudan, Angola, Suriname.

is not significantly associated with low deforestation (Column 5) but this effect is differential according to the colonial origin. Former British (Spanish) countries with a high rule of law deforest 3% (5.9%) less than former French colonies while former British (Spanish) countries with a low quality of the regulatory deforest 1.9% (3.6%) more than former French colonies. Moreover, the overall impact of British and Spanish colonies is still positive and significant at the sample mean of the regulatory quality index. For example, former British (Spanish) colonies deforest 0.9% (1.2%) more than former French colonies. These results confirm that colonial origins matter for explaining deforestation and that French colonial legacies seem to be relatively better to preserve the forest compared to British and Spanish colonial legacies.

Overall, these results suggest that the institutional effect, such as the degree of democracy, the functioning of the government or the quality of property rights, on deforestation is significantly differential according to colonial origins. In badly governed countries, there are some French colonial legacies which allow for the protection of the forest compared to former British and Spanish colonies. However, sound government practises, democracy and more protected property rights are more prone to reduce deforestation in former Spanish and British colonized countries than in French ones.

3.4.2 The role of geography

The colonization was not randomly implemented by colonial powers. It was done in accord with imperial aims and relative power which varied over time and between colonial powers (Engerman & Sokoloff, 2000; Joireman, 2001; Lange, 2004).

Acemoglu et al. (2001) investigates the role of colonial strategies using settler mortality data. These figures give an indication of the extent to which a particular place was suitable for European settlement. In that study, the authors argue that European colonizers adopted different colonization strategies with correspondingly different institutions, depending on the conditions in the colonies. They explain that the feasibility of European settlement, characterized by the mortality rates of colonizers, determined the colonization strategy. More precisely, the conditions in colonies (the disease environment and the density of population) conditioned the European strategies. Besides they argue that institutions of the past have persisted over time so that current effects of present institutions on economic development could be explained by institutions of the past designed by Europeans in their colonies. They show econometrically that former "extractive colonies" characterized by a high level of mortality of settlers experienced bad institutions which impeded their current ones and so their level of development. Unlike these extractive colonies, the "settler colonies" had good institutions brought by the colonizer which have persisted over time, encouraging economic development in these former colonies.

Also, the fact is that Britain colonized all or nearly all the most favorable countries. A mean comparison test shows that former French colonies had higher settler mortality compared

to former British colonies.

Table 3.3 reports the regressions concerning the effects of the settlers' strategies[19]. The dataset is only for former colonies for which settler mortality data is available. The sample varies according to the choice of the institutional variable from 39 to 53 countries. The results concerning the differential impact of French colonial legacies compared to British and Spanish ones are identical. For instance, in former Spanish colonies with bad governance (coefficient of the additive "Spanish" variable), the deforestation is significantly higher than in former French colonies with bad governance. The result concerning former British colonies is less obvious and hold only for the aggregated governance index, the democracy index, and for the three property rights index. Concerning the differential impact of institutions, results hold for former Spanish colonies. The better country's governance quality is in former Spanish colonies, the lower deforestation is compared to former French colonies. However, the result is more mitigated in the case of former British colonies. The negative effect of an improvement of the quality of institutions on deforestation in former British colonies (compared to former French ones) is significant only for the democracy and the legal structure indices. These results could suggest that the institutional differential impact of the French colonial legacies compared to former British ones are better attributed to colonial strategies, captured by the settlers mortality variable. By the way, the more the level of settler's mortality was, the more deforestation is important. This result suggests that colonial strategies have an impact on deforestation, and this is not attributed to the identity of the colonizer or the current influence of institutions.

Finally, the overall impact of British and Spanish colonies on deforestation is still positive and significant at the sample mean of each institutional variable. These results confirm that colonial origins defined such as the identity of the past colonizer matter for explaining deforestation, and that French colonial legacies seem to be relatively better to preserve the forest compared to British and Spanish colonial legacies.

3.5 Conclusion

Differences in institutions, defined as social and political controls on human life, may explain differences in current social, political and economic performances. This chapter proposes to analyse the role of these institutional differences on deforestation in developing countries.

The main underlying theoretical hypothesis is that these differential effect of institutions could be explained by institutional persistence. As suggested by the literature on institutional persistence, legal, political and economic legacies had drawn the previous set of institutions in a country shaping the current institutional performances. Colonial legacies represent some of these legacies and are studied in this chapter since they are an exogenous characteristics. Put differently, this study tries to understand if institutions could have a differential impact on

[19] Acemoglu et al. (2001) provide data for sixty-two former colonies with the maximum settler mortality for Mali.

deforestation according to colonial legacies such as the identity of the colonizer.

The main result of this chapter is that the role of institutions on deforestation should be understood at the light of the past experiences of each country including colonial legacies. For instance, an improvement of the quality of institutions is to better reduce deforestation in countries previously colonized by Spain or Great Britain compared to these colonized by France. These results question the validity of some political recommendation in terms of institutions and suggests to make out the importance of the relativism in the understanding of the effect of institutions.

By contrast, Former French colonies tend to deforest less than former Spanish and British colonies in a context of bad governance. This result suggests to more puzzle out the role of colonial origins for combating deforestation. This study proposes that, in a context of poor governance (such as poor property rights, corruption, autocracy, low level of government functioning), previous French colonies are relatively better than other former colonies. This result points out the presence of some French colonial legacies helping to preserve the forest.

As a conclusion, it is worthy noticing that the colonial origins seem to matter in understanding the role of institutions in reducing deforestation in previously colonized countries. This study highlights the role of the past in the understanding of the present, including the understanding of the influence of the incentive structure characterized by institutions. Political recommendation in terms of an improvement of institutions should take into account the relativism rules about institutions. This research can be extended to try to explain more precisely why an improvement of institutions are relatively less efficient on deforestation in former French colonies compared to British and Spanish ones[20]. Maybe, an explanation can be proposed by the first chapter which has highlighted the French superiority in terms of forest law compared to the English forest law.

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[20] In some cases, the effect of institutions increases deforestations contrary to theoretical arguments suggesting that a better incentive structure reduces opportunity costs and so promotes sustainable activities such as the fight against deforestation.

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3.6 Tables of results

Table 3.1: Colonial origins, governance quality and deforestation

Dependent variable: Rate of deforestation				
	Aggregated index WBGI		Democracy index	
VARIABLES	(1)	(2)	(3)	(4)
Former British colonies	0.01***	0.017***	0.009***	0.019***
	(0.002)	(0.006)	(0.002)	(0.003)
Former Spanish colonies	0.007**	0.035***	0.006**	0.048***
	(0.003)	(0.007)	(0.003)	(0.009)
Former other colonies	0.005*	-.002	0.005**	0.004
	(0.003)	(0.005)	(0.002)	(0.005)
Institutions	-.007	0.01	0.004	0.018***
	(0.006)	(0.011)	(0.004)	(0.005)
Institutions*British		-.021		-.022***
		(0.014)		(0.006)
Institutions*Spanish		-.053***		-.054***
		(0.016)		(0.012)
Institutions*Other col.		0.028*		0.0003
		(0.014)		(0.009)
Lag Forest Area	-.001	-.001	-.0007	-.001
	(0.0009)	(0.0008)	(0.0008)	(0.0007)
Log GDP	-.002*	-.001*	-.003***	-.002***
	(0.0009)	(0.0008)	(0.0007)	(0.0007)
Rural density	-7.98e-06***	-6.14e-06***	-7.84e-06***	-6.99e-06***
	(2.47e-06)	(2.28e-06)	(2.36e-06)	(2.16e-06)
Pop. growth	0.005***	0.004***	0.006***	0.005***
	(0.002)	(0.002)	(0.002)	(0.001)
Timber	0.002	0.002	0.002	0.001
	(0.003)	(0.003)	(0.003)	(0.003)
Latitude	-.019**	-.014*	-.024***	-.022***
	(0.008)	(0.008)	(0.007)	(0.007)
Intercept	0.024**	0.016	0.019*	0.015
	(0.012)	(0.011)	(0.01)	(0.01)
Number of countries	60	60	60	60
Observations	176	176	240	240
Adjusted R2	0.257	0.348	0.274	0.349
F-stat	6.972	7.367	9.839	11.676
RMSE	0.01	0.009	0.01	0.009
F-stat British		9.38***		18.02***
F-stat Spanish		16.63***		14.79***

Note: OLS robust standard errors in parentheses. In all regressions, regional and year dummies are introduced (omitted region is Asia). The omitted colonial origin is Former French colony. Columns 1 and 2 report results with the overall aggregated index, and Columns 3 et 4 report results with an index of democracy from Freedom House and Polity 2. F-stat British (Spanish) reports the F-stat and the associated significance of the following test: H0: $\phi_1 + \phi_2 = 0$. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 3.2: Colonial origins, governmental quality and deforestation

Dependent variable: Rate of deforestation						
	Corruption WBGI		Governm. effectiveness		Regulatory quality	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Former British colonies	0.01***	0.013**	0.01***	0.012*	0.01***	0.019**
	(0.002)	(0.006)	(0.002)	(0.007)	(0.002)	(0.009)
Former Spanish colonies	0.007**	0.027***	0.007***	0.024***	0.008***	0.044***
	(0.003)	(0.006)	(0.003)	(0.008)	(0.003)	(0.011)
Former Other col.	0.005*	-.004	0.005*	-.011*	0.005*	-.010
	(0.003)	(0.006)	(0.003)	(0.006)	(0.003)	(0.009)
Institutions	-.011**	0.002	-.008	-.004	-.002	0.007
	(0.005)	(0.01)	(0.009)	(0.016)	(0.007)	(0.015)
Institutions*British		-.010		-.007		-.017
		(0.015)		(0.019)		(0.017)
Institutions*Spanish		-.039***		-.033*		-.052***
		(0.014)		(0.02)		(0.018)
Institutions*Other col.		0.034**		0.058***		0.034*
		(0.017)		(0.02)		(0.018)
Lag Forest Area	-.001	-.001*	-.001	-.001	-.001	-.001
	(0.0009)	(0.0008)	(0.0009)	(0.0009)	(0.0009)	(0.0008)
Log GDP	-.001*	-.002*	-.002	-.002	-.002**	-.002**
	(0.0008)	(0.0009)	(0.001)	(0.001)	(0.0008)	(0.0008)
Rural density	-7.43e-06***	-6.18e-06**	-8.17e-06***	-6.03e-06***	-8.10e-06***	-6.03e-06**
	(2.51e-06)	(2.42e-06)	(2.43e-06)	(2.34e-06)	(2.49e-06)	(2.38e-06)
Pop. growth	0.005***	0.004***	0.005***	0.005***	0.005***	0.005***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Timber	0.002	0.002	0.002	0.003	0.002	0.003
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Latitude	-.016**	-.013*	-.019**	-.014	-.021***	-.016**
	(0.008)	(0.008)	(0.009)	(0.009)	(0.008)	(0.007)
Intercept	0.022*	0.02*	0.023**	0.019*	0.025**	0.016
	(0.012)	(0.011)	(0.011)	(0.011)	(0.012)	(0.013)
Number of countries	60	60	60	60	60	60
Observations	176	176	180	180	180	180
Adjusted R2	0.264	0.321	0.261	0.331	0.258	0.359
F-stat	9.193	8.445	7.854	8.095	8.072	7.478
RMSE	0.01	0.009	0.01	0.009	0.01	0.009
F-stat British		8.11***		8.56***		9.33***
F-stat Spanish		9.16***		13.04***		15.59***

Note: OLS robust standard errors in parentheses. In all regressions, regional and year dummies are introduced (omitted region is Asia). The omitted colonial origin is Former French colony. Columns 1 and 2 reports results with the Corruption index of the World Bank Governance Indicators database, Columns 3 and 4 reports results with the indicator of government effectiveness of the World Bank Governance Indicators database, Columns 4 and 5 uses the Regulatory Quality index of the World Bank Governance Indicators database. F-stat British (Spanish) reports the F-stat and the associated significance of the following test: H0: $\phi_1 + \phi_2 = 0$. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 3.3: Colonial origins, property rights and deforestation

Dependent variable: Rate of deforestation						
	Ownership risk index		Fraser Institute index		Rule of law index WBGI	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Former British colonies	0.01***	0.019***	0.007***	0.017***	0.01***	0.016***
	(0.002)	(0.006)	(0.002)	(0.005)	(0.002)	(0.005)
Former Spanish colonies	0.006**	0.022**	0.005*	0.025***	0.007**	0.032***
	(0.003)	(0.009)	(0.003)	(0.004)	(0.003)	(0.006)
Former other colonies	0.005**	-.016**	0.005	-.0003	0.005*	-.007*
	(0.002)	(0.007)	(0.003)	(0.005)	(0.003)	(0.004)
Institutions	0.0007	0.009	-.006	0.018**	-.006	0.008
	(0.005)	(0.01)	(0.004)	(0.008)	(0.005)	(0.01)
Institutions*British		-.019		-.027***		-.016
		(0.012)		(0.01)		(0.014)
Institutions*Spanish		-.028*		-.044***		-.046***
		(0.015)		(0.011)		(0.014)
Institutions*Other col.		0.038***		0.034**		0.047***
		(0.014)		(0.015)		(0.015)
Lag Forest Area	-.0008	-.0001	-.0006	-.001	-.001	-.001*
	(0.0008)	(0.0008)	(0.0009)	(0.0008)	(0.0009)	(0.0007)
Log GDP	-.002***	-.003***	-.002***	-.002***	-.002**	-.002**
	(0.0007)	(0.0007)	(0.0008)	(0.0007)	(0.0008)	(0.0008)
Rural density	-7.60e-06***	-4.49e-06*	-6.63e-06***	-5.11e-06**	-8.19e-06***	-5.80e-06**
	(2.50e-06)	(2.52e-06)	(2.24e-06)	(1.98e-06)	(2.45e-06)	(2.27e-06)
Pop. growth	0.006***	0.006***	0.005***	0.005***	0.005***	0.004***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Timber	0.002	0.002	0.001	0.0007	0.002	0.002
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Latitude	-.022***	-.021***	-.015**	-.012*	-.020**	-.013*
	(0.007)	(0.007)	(0.007)	(0.006)	(0.008)	(0.007)
Intercept	0.018*	0.009	0.023*	0.02	0.025**	0.02**
	(0.011)	(0.012)	(0.012)	(0.013)	(0.011)	(0.01)
Number of countries	60	60	54	54	60	60
Observations	240	240	208	208	180	180
Adjusted R2	0.27	0.325	0.277	0.359	0.261	0.375
F-stat	9.498	8.146	7.668	10.995	8.212	9.389
RMSE	0.01	0.009	0.01	0.009	0.01	0.009
F-stat British		16.17***		7.10***		9.08***
F-stat Spanish		4.68***		19.72***		21.37***

Note: OLS robust standard errors in parentheses. In all regressions, regional and year dummies are introduced (omitted region is Asia). The omitted colonial origin is Former French colony. Columns 1 and 2 report results with the inverse of the ownership risk index, Columns 3 and 4 report results with the legal structure and property rights index of the Fraser Institute, and Columns 5 and reports results with the Rule of Law index of the World Bank Governance Indicators database. F-stat British (Spanish) reports the F-stat and the associated significance of the following test: H0: $\phi_1 + \phi_2 = 0$. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 3.4: Settler mortality, colonial origins, institutions and deforestation

Dependent variable: Rate of deforestation								
	Aggregated index	Democracy	Corruption	Gov. effectiv.	Regul. qual.	Ownership risk	Legal structure	Rule of law
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
British colonies	0.012**	0.017***	0.009	0.007	0.006	0.015**	0.018***	0.012**
	(0.006)	(0.003)	(0.006)	(0.007)	(0.01)	(0.007)	(0.005)	(0.006)
Spanish colonies	0.031***	0.043***	0.022***	0.022***	0.039***	0.019*	0.022***	0.03***
	(0.008)	(0.009)	(0.006)	(0.008)	(0.011)	(0.01)	(0.004)	(0.006)
Other colonies	-.002	0.006	-.003	-.010	-.008	-.011	-.002	-.004
	(0.005)	(0.005)	(0.006)	(0.006)	(0.009)	(0.007)	(0.005)	(0.004)
Institutions	0.005	0.013**	-.004	-.0004	0.003	0.005	0.017*	0.007
	(0.013)	(0.005)	(0.011)	(0.017)	(0.016)	(0.01)	(0.009)	(0.01)
Institutions*British	-.004	-.015**	0.007	0.01	0.008	-.009	-.029***	-.003
	(0.015)	(0.007)	(0.016)	(0.019)	(0.019)	(0.015)	(0.011)	(0.016)
Institutions*Spanish	-.045***	-.049***	-.030**	-.030	-.045**	-.022	-.039***	-.042***
	(0.016)	(0.012)	(0.015)	(0.02)	(0.018)	(0.017)	(0.011)	(0.014)
Institutions*Other col.	0.029**	-.002	0.033**	0.058***	0.03*	0.03*	0.03**	0.042***
	(0.014)	(0.009)	(0.015)	(0.019)	(0.018)	(0.015)	(0.013)	(0.015)
Lag Forest Area	-.001	-.001	-.001	-.0009	-.0007	-.0003	-.001	-.001*
	(0.0008)	(0.0007)	(0.0008)	(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0008)
Log GDP	-.001	-.002**	-.002	-.002**	-.002**	-.003***	-.003***	-.002**
	(0.0009)	(0.0008)	(0.001)	(0.001)	(0.0009)	(0.0009)	(0.001)	(0.0009)
Rural density	-6.24e-06**	-7.72e-06***	-6.29e-06**	-5.56e-06**	-6.13e-06**	-6.05e-06*	-5.78e-06***	-6.03e-06**
	(2.49e-06)	(2.33e-06)	(2.62e-06)	(2.60e-06)	(2.60e-06)	(3.11e-06)	(2.23e-06)	(2.50e-06)
Pop. growth	0.005***	0.005***	0.005***	0.005***	0.006***	0.006***	0.006***	0.005***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Timber	0.001	0.002	0.001	0.0005	0.001	0.003	0.002	0.0002
	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Latitude	-.013	-.024***	-.014*	-.015	-.015*	-.027***	-.018**	-.013*
	(0.008)	(0.008)	(0.008)	(0.01)	(0.008)	(0.008)	(0.007)	(0.008)
Settlers mortality	0.003***	0.003***	0.003***	0.003***	0.003***	0.002**	0.002*	0.003***
	(0.001)	(0.0009)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Intercept	-.001	-.002	0.001	0.004	-.002	0.0003	0.009	0.003
	(0.013)	(0.012)	(0.013)	(0.014)	(0.014)	(0.013)	(0.016)	(0.013)
Number of countries	52	53	52	53	53	53	46	53
Observations	155	212	155	159	159	212	184	159
Adjusted R2	0.38	0.374	0.363	0.369	0.386	0.334	0.39	0.395
F-stat	6.807	10.298	6.509	8.11	7.599	9.135	8.194	7.113
RMSE	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
F-stat British	10.10***	20.03***	10.33***	8.21***	8.98***	12.20***	7.38***	9.33***
F-stat Spanish	12.65***	12.35***	9.45***	7.43***	10.91***	3.20**	12.96***	16.32***

Note: OLS robust standard errors in parentheses. In all regressions, regional and year dummies are introduced (omitted region is Asia). The omitted colonial origin is Former French colony. Column 1 reports results with the overall aggregated index, Column 2 with an index of democracy from Freedom House and Polity 2, Column 3 with the Corruption index of the World Bank Governance Indicators database, Column 4 with the indicator of government effectiveness of the World Bank Governance Indicators database, Columns 5 uses the Regulatory Quality index of the World Bank Governance Indicators database, Column 6 reports results with the inverse of the ownership risk index, Column 7 reports results with the legal structure and property rights index of the Fraser Institute, and Column 8 and reports results with the Rule of Law index of the World Bank Governance Indicators database. F-stat British (Spanish) reports the F-stat and the associated significance of the following test: H0: $\phi_1 + \phi_2 = 0$. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

3.A Appendix

3.A.1 List of 60 countries

Table 3.5: List of 60 countries

Former 18 French Colonies
Algeria, Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Congo Republic, Ivory Coast, Dominican Republic, Gabon, Guinea, Laos, Madagascar, Mali, Morocco, Niger, Senegal, Vietnam
Former 19 British Colonies
Botswana, Fiji, Ghana, Guyana, India, Kenya, Malawi, Malaysia, Namibia, Nepal, Nigeria, Pakistan, Papua New Guinea, Sierra Leone, South Africa, Sri Lanka, Sudan, Uganda, Zimbabwe
Former 15 Spanish Colonies
Argentina, Bolivia, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, Venezuela
Former 8 other Colonies
Angola, Brazil, Congo Democratic Republic, Guinea-Bissau, Indonesia, Mozambique, Philippines, Suriname

3.A.2 Summary statistics

Table 3.6: Summary statistics

VARIABLES	Mean	(Std. Dev.)	Min.	Max.	N
Deforestation (mean annual rate)	0.01	(0.01)	-0.04	0.03	60
Log lag Forest Area	9.35	(1.31)	6.9	13.13	60
Log GDP per capita	6.7	(1.14)	4.69	8.88	60
Rural density	347.57	(361.9)	14.73	2137.18	60
Pop. growth	2.14	(0.71)	0.05	3.5	60
Price of Timber	1.01	(0.14)	0.70	1.34	60
Former French colonies	0.3	(0.46)	0	1	60
Former British colonies	0.32	(0.47)	0	1	60
Former Spanish colonies	0.25	(0.44)	0	1	60
Former Other colonies	0.13	(0.34)	0	1	60
Latitude	0.16	(0.1)	0	0.38	60
Settlers' mortality	4.9	(1.09)	2.43	7.99	53
Aggregated governance index	0.41	(0.14)	0.04	0.79	60
Corruption WBGI	0.37	(0.13)	0.09	0.77	60
Government effectiv. WBGI	0.36	(0.11)	0.08	0.68	60
Regulatory quality WBGI	0.57	(0.13)	0.19	0.9	60
Rule of law WBGI	0.4	(0.14)	0.07	0.81	60
Accountability WBGI	0.45	(0.19)	0.05	0.83	60
Political stability WBGI	0.52	(0.17)	0.09	0.84	60
Ownership risk index	0.5	(0.16)	0.16	0.88	60
Legal structure	0.37	(0.13)	0.08	0.65	54
Democracy index	0.58	(0.23)	0.08	0.97	60

3.A.3 Definition of variables and sources

Table 3.7: Definition of variables and sources

Code	Variables and Definition	Source
Deforestation	Log forested areas in $t-1$ minus log forested areas in t.	FAO
Lag(Forest$_{t-1}$)	Initial Forest Areas: Log forested areas in $t-1$.	FAO
Log GDP	Log GDP per capita, constant 2000 US$.	WDI 2008
Pop. growth	Annual population growth rate (percentage).	WDI 2008
Rural density	Rural population density per km^2 of arable land.	WDI 2008
Timber	The relative price of timber. the ratio of the price of hardwood logs in Sarawak, Malaysia (in $US/m3, source: IMF, International Financial Statistics) to the country-specific unit export values of agricultural goods (source: FAO)	FAODATA/IFS-IMF
Colonial origins	Colonial dummies indicating whether a country had been a British, French, Spanish, or other (German, Italian, Belgian, Dutch or Portuguese) colony.	(La Porta et al., 1999)
Mortality	Log of the fourth mortality estimated by Acemoglu et al. (2000, Appendix, Table A2).	(Acemoglu et al., 2001)
Corruption WBGI	Control of Corruption: capturing perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.	WBGI
Gov. effect. WBGI	Government Effectiveness: capturing perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.	WBGI
Regul. qual. WBGI	Regulatory Quality: capturing perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.	WBGI
Rule of law WBGI	Rule of Law: capturing perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.	WBGI
Account. WBGI	Voice and Accountability: capturing perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media.	WBGI
Political stab. WBGI	Political Stability and Absence of Violence: capturing perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including politically-motivated violence and terrorism.	WBGI
Civil liberties	Civil liberties allow for the freedoms of expression and belief, associational and organizational rights, rule of law, and personal autonomy without interference from the state.	Freedom House
Civil liberties FH	Civil liberties allow for the freedoms of expression and belief, associational and organizational rights, rule of law, and personal autonomy without interference from the state.	Freedom House
Political rights FH	Political rights enable people to participate freely in the political process, including the right to vote freely for distinct alternatives in legitimate elections, compete for public office, join political parties and organizations, and elect representatives who have a decisive impact on public policies and are accountable to the electorate.	Freedom House
Polity 2	The "Polity Score" captures the regime authority spectrum on a 21-point scale ranging from -10 (hereditary monarchy) to +10 (consolidated democracy).	Polity IV project
Legal structure FI	The index consists of judicial independence, impartial courts, protection of intellectual property, military interference in rule of law and the political process, integrity of the legal system. The higher score corresponds to "high judicial independence", "trusted legal framework exists", "protection of intellectual property", "no military interference in rule of law", and "integrity of the legal system".	Fraser Institute
Ownership risk index	The index is an ownership risk index calculated from an econometric investment model with political attributes following Bohn & Deacon (2000).	Author's calculation.

3.A.4 Results of the principal components analysis

Table 3.8: Aggregating governance variables: principal components analysis

VARIABLES	First eigenvector	Correlation
Control of corruption	0.408	0.953
Regulatory quality	0.408	0.928
Government effectiveness	0.427	0.969
Rule of law	0.441	0.980
Accountability	0.394	0.912
Political stability	0.367	0.867
Number of countries	67	
Eigenvalue	4.629	
Variance proportion	0.771	

Note: The first eigenvector resulting from the first principal component analysis of governance quality is reported as well as the correlation of the first principal component with the corresponding governance variable (in parentheses, below the different eigenvectors). The composite index is calculated by multiplying each eigenvector (of each governance variable) by the relative governance variable previously standardized.

Chapter 4

Legal origin, institutions and deforestation

4.1 Introduction

As shown in the second chapter, countries whose legal systems are based on French civil law are found to differ systematically from those whose legal systems are based on English common law in recent empirical work. This literature is based on the Legal Origin Theory of development, developed by La Porta, Lopez-Silanes, Vishny and Shleifer (LLSV–several papers La Porta et al. (1997, 1998, 2007)). This theoretical framework studies how legal origin of law and regulation can influence economic performances by defining this origin by political institutions (legal procedures,...), ideology, broader attitudes and philosophy. Overall, the Legal Origins Theory relies on three important conceptual ideas. First, by the eighteenth or nineteenth centuries, Continental Europe, particularly France, and Great Britain had developed separate styles of social control of economic activities as well as the underlying institutions supporting these styles. Second, both these styles and their legal institutions were transplanted by the origin countries to most of the world through colonization, rather "than written from scratch." Third, despite country specific changes, these styles have persisted in addressing the social control of economic life. Consequently, the current legal system and in a broader view the quality of the institutions of each country relies on the historical background and the historical institutional framework represented by the legal origin.

As noticed in the second chapter, the theory of legal origin points out that all law in a country is influenced by either the English common law or else the French civil law. The origin of this two main family of law is different. The French civil law originates in the Roman law but had been developed at the beginning of the nineteenth century after the French Revolution with Napoleon Bonaparte. This French law has been exported to many countries such as Spain, Portugal, Belgium, Italy, and the Netherlands through Napoleon's conquests. Moreover, the French civil law has been transposed to many countries in the world through colonization and conquest by France in the nineteenth century in Oceania, Indochina, Africa, and some Caribbean Islands. Besides, the influence of French civil law has also been implemented in Latin

South American countries in the nineteenth century after the independence of the Spanish and Portuguese colonies. Finally, French civil law is now present in many South American, African and Asian countries.The first one originates in the laws of England and has been transposed through conquest and colonization to England's colonies, including the United States, Canada, New Zealand, Australia, and many countries in Africa and Asia. In comparison, the English common law originates in the laws of England and has been transposed through conquest and colonization to England's colonies, including the United States, Canada, New Zealand, Australia, and many countries in Africa and Asia.

The main result of the Legal Origins Theory is a heavier role of government in the civil law countries compared with the common law ones. The reasons of this development in France is based on the necessity to promote state control and to prevent judges the opportunity for re-interpreting or changing laws. This marginalization of the judiciary helped extend state control of the economy. By contrast, the English common law had been created to protect private property and private freedom against the Crown. A system of decentralized law-making with an independent judiciary where judges could interpret and change laws were implemented as effective checks on the government. In turn, the consequences on current economic performances of these differing legal traditions have been broadly studied and this chapter contributes to that literature, as the second chapter, by investigating the impact of legal origin on deforestation through institutions.

In this literature, legal origin is found to be correlated with a wide range of institutions and policies which could be expected to produce higher rates of deforestation such as corruption, mis-defined property rights, or a weak rule of law in French civil law countries as opposed to common law ones. For this reason, the present chapter investigates the role of legal origin on deforestation assuming that the legal system matters in explaining deforestation through their effect on the institutional background. This chapter tries thereby to investigates how legal origin could affect deforestation by assuming that these effects could be based on current institutional performances. This chapter belongs then to the literature on historical and comparative institutional analysis (HCIA) (Greif, 1998, P.82) and considered legal origin as inherited legacies which can be viewed as main "indirect" factors of development. This indirect effect means that legal origin are important to understand how institutions (a main direct effect) shape economic or environmental performances. This chapter thus investigates the existence of institutional persistence through legal origin of law and regulation[1]. This chapter investigates finally whether moving from French civil law to English common law may do to influence the level of deforestation and whether the quality of institution may do affect this relationship.

Moreover, as in the third chapter, this one investigates the role of legal origin through institutional performances. The underlying motivations are the same than in the previous chapter. Due to the important role of institutions as incentive structure, and the importance of legacies on institutions, the effect of institutions on deforestation can be different according to the le-

[1]Institutional persistence have also been studied through colonial legacies such as in chapter 3.

gal origin of law and regulation. Also, as in the previous chapter, the focus is made on three measures of institutions: (1) an overall measure of the quality of governance as well as a measure of the extent of democratic rules (civil liberties, political regime (autocratic, democratic), political liberties); (2) informal policies such as the functioning of the government though the extent of corruption, the government effectiveness and the quality of the government's business regulatory; (3) property rights regime such as the risk of ownership, the quality of the legal structure and the quality of the rule of law.

The effects of institutional persistence on deforestation through legal origin are estimated on a core dataset of 82 countries having a French civil law origin, a common law origin, or a German civil law origin from 1990 to 2005. Besides, to investigate more deeply the exogeneous role of legal origin, a core dataset of 60 countries of former colonies not located in Europe is used.

The main result of this chapter is that the role of institutions on deforestation should be understood at the light of the past experiences of each country. The main differences between the French civil law and the common law origin suggest that an improvement of the quality of the government functioning mainly through the control of corruption is more likely to dampen deforestation in French civil law countries whereas better democratic rules and less ownership risk is more prone to reduce deforestation in common law countries. By contrast, some institutions such as the quality of the legal structure and the rule of law have not a differential effect according to the legal origin. More precisely an enhancement of each of these two indicators is significantly associated with less deforestation whatever the legal origin. In addition, French civil law countries are found to deforest less than common law countries in a context of bad governance. This result stresses, in turn, the importance of puzzling out the role of the origin of the legal system for combating deforestation. This study proposes that, in a context of poor governance (such as poor property rights, corruption, autocracy, low level of government functioning), French civil law countries are relatively better than common law countries, and suggests, in turn, the presence of some French legacies helping to preserve the forest. These results question, as in the previous chapter, the validity of some political recommendations in terms of governance, and stresses the importance of making out the significance of the relativism in the understanding of the effect of institutions.

The rest of the chapter is organized as follow. Section 2 provides an overview of the literature on institutional persistence through legal origins and provides a link with deforestation. Section 3 introduces the econometric approach and Section 4 shows and discusses main econometric results. Section 5 provides concluding remarks and points to policy recommendations.

4.2 Legal origin, institutions and deforestation

In this chapter, legal origin of law and regulation is assumed to affect deforestation though the quality of institutions. The theoretical hypothesis underlying this issue relies on the fact that

the nature of the origin of the legal system have shaped early institutions which persisted over time to represent the basis of current institutions influencing, now, the deforestation. In the same way than in the previous chapter, it is first discussed the nature, the emergence and the persistence of institutions through legal origin, and after proposed the link with deforestation.

4.2.1 Institutional persistence

Over the past few years, several studies have investigated the persistence of both politic and economic institutions through legacy or cultural heritage provided almost by colonization through legal origin of law and regulations and colonial strategies.

The literature on inherited legal system is a part of the literature on institutional persistence. It investigates the trade-off between civil law and common law system and has been conceptualized mainly by La Porta, Lopez-Silanes, Vishny and Shleifer with the Legal Origins Theory of development. In this theory, the legal system is defined by La Porta et al. (2007) such as "the style of social control on economic life" representing by political institutions (legal procedures,...), ideology, broader attitudes and philosophy, which is, in turn, influenced by the legal origin.

The consequences of these differing legal traditions on current economic performances have been broadly studied. The role of legal origin on finance (La Porta et al., 1997, 1998), government ownership of banks (La Porta et al., 2002), the burden of entry regulations (Djankov et al., 2002), regulation of labor markets (Botero et al., 2004), and government ownership of the media Djankov et al. (2003b) have been investigated.

Moreover, some papers have studied the role of legal origin on institutional performances. La Porta et al. (1999) studies such determinants of political institutions as government performance (provision of public good, effectiveness, government spending). They highlight some political theories to explain the quality of government and assume that legal origin can be a good proxy for these political theories. They argue that the legal origin of law and regulation can predict "inefficient, interventionist and distortionary policies." They show that common law countries are less interventionist, better public good suppliers, more efficient and democratic than civil law countries. Besides, in other studies, the same authors have investigated the link between legal origin, property rights, and contract enforcement.

Djankov et al. (2003a) have investigated the role of legal origin on the functioning of the justice. They find that common law is less associated with formalism of judicial procedures than French civil law.

La Porta et al. (2004) have argued that common law countries enhance their judicial independence which is, in turn, associated with more freedom, better contract enforcement, and greater security of property rights. This result is explained by historical facts. The seventeenth-century English revolutionary took control of the judiciary away from the Crown, and marginalised the role of the judiciary to prevent it from doing anything other than apply the existing law. The

creation of laws and the administration of justice were then separated contrary to France. In this case, legislatures make laws, and independent judges enforce them, without interference from the legislature or the executive.

Besides, Mahoney (2001) investigates the role of legal origin on growth through property rights and contract rights using legal tradition as a reflection of different philosophies of government. He argues that the common law system promotes personal freedom to aim to individual claim whereas the civil law framework emphasises mainly the government's freedom in order to pursue collective ends. He shows then econometrically that common law system enhances property rights and contract rights. He noticed that "the common law and civil law, in this view, proceed from different views about the relative role of collective and individual action. These associations have to do with possibly chance connections between the judiciary and specific political problems of seventeenth-century England and eighteenth-century France, but once established, they have had continuing effects on institutional arrangements. Judges are invested with greater prestige and insulated more from political influence in common-law systems. Administrative bodies are insulated more from judicial influence in civil-law systems. These differences result in stricter protection for property and contract rights against government action in the common-law tradition" Mahoney (2001, p.523).

Some papers also focuses on the effect of inherited legal system on institutions in African countries. For example, Joireman (2001) compares the effectiveness of the rule of law of inherited civil and common legal systems in Africa. She finds that civil law systems appear to be worse at providing the rule of law (measured with the ICRG Rule of Law index) compared to the common law. She brings some explanations linked to the inherited legal systems from colonisation. Firstly, she gives an historical discussion on the colonial law in African and explains that "the lack of a powerful or even a stable legal profession and judiciary in most African countries at independence, combined with the impetus for the concentration of power in the executive, made authoritarian rule an inevitability in post-colonial Africa." (Joireman, 2001, p.581). The effectiveness and the formation of a politically active bar after the independence were a crucial element in the performance of the legal system. Joireman (2001) explains also that the two metropole (English and French) were neglectful in training a qualified indigenous bar. However, she highlights that in the common law system, the lawyers play a more important role than in the civil law one so that after the independence, in common law countries, "lawyers and strong associations can provide an important alternative locus of power to the state" (Joireman, 2001, p.575). However, the relative better independence of lawyer is a recent feature of common law African countries as noted by (Joireman, 2001, p.590). In fact, since 1990 the gap of the ICRG Rule of Law ratings increases between common law and civil law African countries due to the effectiveness and politically power of the legal profession. Finally, Joireman (2001) discusses the issue of bureaucratic effectiveness which can conditioned their results. Indeed, she suggests that common law countries, relying on the process rather than the application of a code, is less dependent on an effective bureaucracy to give a proper application

of the law. This argument is closer to the thesis of the Peruvian economist, Hernando de Soto (de Soto, 2000), on the necessity of an efficient legal system to reduce the opportunity costs and increase investment. A low effective application of the law due to an inefficient bureaucracy can create more transactions costs (pecuniary, time,...). To conclude, Joireman (2001)'s study suggests that inherited legal system in Africa has shaped crucial features influencing the current legal performance. Finally, this study illustrates the close relationship between colonial history and legal origin, and provides evidences of the difficulty to attribute the differences in environmental performance to legal origin as opposed to other aspects of colonial policy.

4.2.2 Institutions and deforestation

Institutions are the rule of the game and the incentive structure shaping economic human interactions. In turn, institutions help for moving the system towards a sustainable forestry management by creating appropriate institutions which allow for the reduction of uncertainty in exchange and result in reduced transaction and production costs of long term activities such as timber of environmental protection. The poor quality of institutions in developing countries may thus constitute a major impediment for forest conservation.

As in the previous chapter, institutions are grouped into three important categories[2]: (1) informal policies such as corruption, (2) property rights regime such as the ownership risk, and (3) political institutions shaping both informal policies and property rights regime such as the quality of the rule of law and political stability.

Informal policies such as corruption are defined such as an informal pro-deforestation policy which promotes rent seeking activities and develops miss-management forestry productions which leads, in turn, to an over-extraction of resources (Amacher, 2006; Søreide, 2007; Karsenty et al., 2008).

Property rights regime has also a leading role on deforestation (Mendelsohn (1994); Angelsen (1999); Hotte (2001) for theoretical studies and Southgate & Runge (1990); Deacon (1994, 1999); Bohn & Deacon (2000); Bhattarai & Hammig (2001); Culas (2007); Arcand et al. (2008) for empirical works. The ownership risk based on the quality of the property rights regime discriminates against capital intensive land uses such as forestry. Put differently, sustainable harvesting of forest products is most sensitive to the existence of clear property rights and their enforcement relative to agricultural activities since the forest is equivalent to a stock of capital. However, as mentioned in the previous chapter, the measurement of insecure property rights differs in the literature and can be grouped into two different variables. First is more direct indicators such as the enforceability of contracts (Culas, 2007). This indicator measures the relative degree to which contractual arrangements are honoured. Second relies upon measures of political instability such as coups, revolutions and political assassinations since insecure

[2]A broader view of institutions is used and represent both institutional factors and policy where policy refers to the quality of the functioning of the government, i.e. the governance.

property rights might arise from a lack of government's stability to enforce laws of property (Deacon, 1994, 1999; Bohn & Deacon, 2000; Arcand et al., 2008).

Last is political institutions which refers to the literature which determine the quality of policies implemented to preserve forest by improving environmental rules and regulations as well as the allocation of environmental resources. This concerns mainly the quality of the rule of law, the political stability and the extent of political and civil rights.

In addition, as in the previous chapter, this study provides a new explanation for the role of institutions by taking into account the role of legal origin and so, in turn, by analysing the importance of the persistence of institutions. Thus, this approach is suitable for understanding the role of institutions on deforestation at the light of legal origin by taking into account the historical process.

4.3 Empirical framework

4.3.1 Dataset and variables

The core dataset consists of 82 countries which had to meet one condition: having a French civil law origin (47 countries), a common law origin (25 countries), or a German civil law origin (10 countries). However, a core dataset of 46 countries is used to investigate more deeply the exogeneous role of legal origin in a context of substantial tropical forested areas. This dataset had to meet two other conditions: (1) being located in the tropics and (2) having a forest area above one million hectares in 1990. The first criterion ensures that legal origin was exogenous since all tropic countries are former colonies (except Thailand)[3] and the second one excludes countries with small forested areas. Thus, the sample used regroups only the French civil law origin (31 countries) and the common law origin (15 countries)[4].

Table 4.9 describes the variables. Table 4.7 indicates which countries are in the core dataset of 82 countries as well as in the sub-sample. Deforestation rates have been calculated from various Forest Resources Assessment (FRA) of the Food and Agriculture Organization (FAO). Although forest area data are available since 1960, only data since 1990 is used here, given the lack of reliability of the data before the 1990-FRA. Thus, the dependent variable is the four-year average annual rate of deforestation on the sub-periods 1990–1993, 1994–1997, 1998–2001, and 2002–2005[5].

Legal origin was coded following two classifications as in the second chapter. The first coding comes from LLSV's most recent coding (La Porta et al., 2007). The second is a revaluation

[3]Tropical forest are investigated because it is located in developing countries and to exclude mainly European countries to reflect the difficulty of classifying the colonial history, and in turn the exogeneity of the legal origin, of most European countries such as Italy or Finland for instance.

[4]China can meet the two conditions but has been removed because China is the sole German civil law country.

[5]In the regressions with the variables provided by the World Bank Governance Indicators, the data ranges from 1996 to 2005 so that the sub-periods are only 1994–1997, 1998–2001, and 2002–2005.

of this coding in light of a variety of sources[6]. This coding differs from LLSV's coding for five countries which are here classified as "mixed legal origin"[7]. This alternative coding represents hybrid legal systems of the common and civil law whereas four countries were classified by LLSV as common law and one, the Philippines, as civil law. This coding could have had a large effect on the analysis, because all four classified common law countries had deforestation rates significantly higher whereas the Philippines had lower rates than average (see chapter 2 for more details). Nevertheless, as discussed further below, the main results remain valid even using LLSV's coding.

4.3.2 Institutional variables

As in the chapter 3, institutional variable are divided into three parts (see Table 4.9 for more details and a complete definition of each institutional variable). The calculation of each variable is provided in chapter 3 or can be seen in the subsection 4.A.2 in the appendix (page 138).

Two global governance quality are first used: (1) an indicator which combines the six separate variables created by the World Bank Governance Indicators database (WBGI) into a single index from an ACP analysis (see Table 4.10) and (2) an overall measure of democracy created by the Quality of Government Institute (University of Gothenburg) from Freedom House data on civil liberties and political rights, and from the Polity 2 index of the Polity IV project.

The quality of the government functioning represents the second part of institutional variables. The composite indicator from the World Bank Indicators database is broken up to return to specific measures of quality of governance such as the level of corruption, the effectiveness of the government and the extent of the regulatory quality.

The quality of property rights is the third group of institutions defined by two indices: (1) the Legal Structure and Security of Property Rights index of Fraser Institute and (2) the Rule of Law index of the World Bank Governance Indicators database. However, as in the third chapter, an index of ownership risk is calculated following the Bohn and Deacon's approach (Bohn & Deacon, 2000). This index of ownership risk is constructed from an investment model explained by economic and political attributes. The index ranges from 0 (high ownership risk) to 1 (low ownership risk).

4.3.3 An econometric deforestation model

The same econometric deforestation model of the previous chapter is used. The basic assumption is that there is a steady-level of the logarithm of the forest cover in a country i at time t, $lnF^*_{i,t}$. Hence the steady state is determined by traditional factors of deforestation and the

[6]Basically, the World Legal Systems Websites (http://www.droitcivil.uottawa.ca/world-legal-systems/eng-monde.html) of the University of Ottawa, Canada, is examined.

[7]Four of these countries are former colonies: Zimbabwe, Sri Lanka, the Philippines, and South Africa. Also, Thailand is classified as "mixed legal origin" and as a non-colonized country.

dynamic to go toward this steady-state is represented by a linear first-order difference equation given by $lnF_{i,t} = \theta lnF_{i,t-1} + \theta_0$ with θ_0 is a constant. A first-order Taylor approximation around the steady-state gives

$$lnF_{i,t} = lnF^* + (lnF_{i,t-1} - lnF^*_{i,t})\theta. \tag{4.1}$$

Subtracting $LnF_{i,t-1}$ from both sides to have a rate of deforestation and arranging, we have

$$-(lnF_{i,t} - LnF_{i,t-1}) = (1-\theta)LnF_{i,t-1} + (\theta - 1)lnF^*_{i,t}. \tag{4.2}$$

If we replace $(\theta - 1)lnF^*_{i,t}$ by $X_{i,t}\gamma$, with γ represents coefficients associated with the matrix of explanatory variables, X, we have

$$-(lnF_{i,t} - LnF_{i,t-1}) = (1-\theta)LnF_{i,t-1} + X_{i,t}\gamma + \zeta_{i,t}, \tag{4.3}$$

with $\zeta_{i,t}$, a disturbance term.

Thus, the level of forest cover in a country follows a pace determined by $(1-\theta)$ and the steady-state level is influenced by explanatory variables such as institutions.

To study the role of legal origin on deforestation through institutional performances, interactions terms are used. Each institutional variable is interacted with each legal origin dummy (common law and German civil law where the reference is French civil law). Hence, the following equation was estimated to test the hypothesis that institutions affect differently deforestation according to the legal origin:

$$deforest_{i,t} = \alpha + \delta_1 INST_{i,t} + \phi_1 INST * LEGOR_{i,t} + \phi_2 LEGOR_i + X'_{i,t}\beta + \nu_r + \eta_t + \varepsilon_{i,t},$$

where $INST$ is the institutional variable, $INST{*}LEGOR$ is the interaction term, and LEG_i is the additive term or the "direct" effect of inherited legacies. $LEGOR$ is at the same time *Common* and *German*. The strategy consists in identifying a differential effect of institution according to the legal origin to test the presence of institutional persistence in the same way than in the third chapter. This strategy ranks the impact of institutions on deforestation. δ_1 captures the institutional effect in the French civil law countries since $LEGOR$ equals 0, i.e., when the dummies *Common* and *German* equal 0. By contrast, ϕ_1 is the institutional effect when the dummies *Common* and *German* equal 1, i.e., the effect in either common law countries or German civil law ones relatively to French civil law countries. Besides, ϕ_2 represents the role of the common law origin and the German civil law one in a world with bad institutions ($INST = 0$). ϕ_2 allows to assume that legal origin could have some effects on deforestation through other variables since legal origin represent more broadly the past institutional influences (such as colonial origins in the previous chapter). In turn, ϕ_2 is the consequences of legal origin on deforestation through others channels. The overall impact of

legal origin is so $\phi_1 + \phi_2$.

X is a matrix of control variables that includes the following: the level of economic development (GDP)[8], the population growth and the rural density (Cropper & Griffiths, 1994), the relative price of timber[9], the percentage of domestic credit provided by banking sector measuring the level of financial development, and the agricultural and fuel exports (see 4.9 for a complete definition of each variables and sources).

4.4 Econometric results

4.4.1 Main results

Table 4.1 to Table 4.3 presents the results of regressions using the core dataset of countries. In all regressions, the dependent variable is the four-year average annual rate of deforestation on the sub-periods 1990–1993, 1994–1997, 1998–2001, and 2002–2005.

First, in Table 4.1, the aggregated governance index from the World Bank Governance Indicators, and the aggregated index of democracy from Freedom House and the Polity IV project are used to investigate the differential impact of institutions on deforestation according to the legal origin. In all regressions, the French civil law origin is the reference. Results suggest that the effect of institutions differs whether the legal origin is French, German or English. Despite the absence of difference between the French civil law and the common law in the case of the aggregated governance index of the World Bank Governance Indicators, there are differences between this two legal origin in the case of the democracy index. As expected, an improvement of the democratic rights is expected to reduce deforestation in common law countries (Column 4). However, the coefficient of the dummy variable related to the common law origin is positive and significant in the column 4 suggesting that in countries with bad level of democracy, the common law origin is a significant determinant of deforestation compared to the French civil law origin. In this case, the deforestation is 1% more important in common law countries than in French civil law ones. Also, the overall impact of the common law origin on deforestation compared to the French civil law is positive and significant at the sample mean of the two institutional variables[10]. For instance, at the sample mean of the aggregated governance index, common law countries deforest 1.4% more than French civil law countries. These results mean that legal origin matters for explaining deforestation but also that the French civil law origin is to better preserve the forest compared to common law countries.

[8]The GDP squared term can be introduced to test the Environmental Kuznets Curve (EKC) defining a non linear effect of economic growth on deforestation so that the marginal effect can be positive for low income countries and become negative for high income economies (Bhattarai & Hammig, 2001; Culas, 2007). Results do not change with the squared term. Results available upon request.

[9]The relative price of timber is an important determinant in the trade-off between keeping forest or clearing it (Arcand et al., 2008).

[10]Table 4.1 reports the significance of the sum of the two coefficients associated with each legal origin and this sum is always statistically significant.

Table 4.2 presents the same regressions but used more detailed information on the quality of government functioning such as the control of corruption (Columns 1 and 2), the effectiveness of government (Columns 3 and 4) and the regulatory quality (Columns 5 and 6). In all regressions, without controlling for a differential impact of legal origin (i.e., without the interactions terms), an improvement of the control of corruption (Column 1), of the government effectiveness (Column 3) and of the regulatory quality (Column 5) allows for the decrease of deforestation. Moreover, in each case, common law countries deforest 0.7% more, on average, than French civil law countries, and this difference is significant at the 1% level (Columns 1, 3 and 5). However, the results differ with the introduction of the interactions terms. The relative superiority of the French civil law seems to be linked to the quality of the three institutional variables. In fact, the coefficient of the additive institutional variable is negative and significant in all regressions suggesting that an improvement of these indicators of the quality of the government functioning are tools to reduce deforestation in French civil law countries. These results mean that in the case of environmental performance, French civil law origin is more prone to facilitate the positive effect of an improvement of the quality of the government functioning on the preservation of forested areas. These results could also suggest that the French legal origin have influenced the quality of the government process allowing to reduce deforestation since the Legal Origin Theory suggests that these influences dampen the economic performances such as economic investment and finance. Moreover, the overall positive impact of the common law origin is still positive and significant at the sample mean of each institutional variable[11]. At the sample mean of the corruption index, common law countries deforest 0.08% more, on average, than French civil law countries. In addition, at the sample mean of the government effectiveness index, common law countries deforest 0.07% more, on average, than French civil law countries and 0.6% more at the sample mean of the regulatory quality index. These results confirm that legal origin matters for explaining deforestation and that the French civil laws seem to be relatively to better preserve the forest compared to the common law origin.

Table 4.3 presents the same regressions but used more detailed information on the quality of property rights such as an index of ownership risk (Columns 1 and 2), the quality of the legal structure (Columns 3 and 4) and the quality of the rule of law (Columns 5 and 6). Columns 1 and 2 report the results with the ownership risk index. A reduction of the ownership risk (an increase of the index) is not significantly associated with a low deforestation (Column 1). However, this effect is differential according to the legal origin. For instance, a decrease of the ownership risk in both common law and German civil law countries allows to reduce deforestation compared to French civil law countries (Column 2). However, in countries characterized by a high ownership risk, deforestation is more important in common law and German civil law countries compared to French civil law countries. For instance, although common law (German

[11] Table 4.2 reports the significance of the sum of the two coefficients associated with each legal origin and this sum is always statistically significant.

civil law) countries with a low ownership risk deforest 1.5% (4.5%) less than French civil law countries, common law (German civil law) countries with a high ownership risk deforest 1.3% (3.7%) more than French civil law countries. Moreover, the overall impact of common law and German civil law countries is negative and significant at the sample mean of the ownership risk index. For instance, common law and German civil law countries deforest 7.1% (2.4%) less than French civil law countries. As suggested by the Legal Origins Theory, common law countries are characterized by better property rights which, in turn, allow to dampen deforestation compared to the French legal origin.

However, these results do not hold for the two other property rights indices which measure more broadly the legal regime[12]. For instance, the French civil law seems to reduce deforestation through an improvement of both the quality of the legal structure and of the rule of law. In fact, the coefficient of the additive institutional variable is negative and significant in all regressions suggesting that an improvement of these indicators reduces deforestation in French civil law countries. These results suggest again that in the case of environmental performance, French civil law origin is more prone to facilitate the positive effect of an improvement of the quality of the legal structure and the rule of law on the preservation of forested areas. The French legal origin have influenced these indicators of institutions allowing to reduce deforestation tough, again, the Legal Origin Theory suggests that these influences dampen the economic performances such as economic investment and finance. Moreover, the overall positive impact of the common law origin is still positive and significant at the sample mean of the legal structure index. For instance, common law countries deforest 0.05% more, on average, than French civil law countries. In addition, at the sample mean of the legal structure index, common law countries deforest 0.7% more, on average, than French civil law countries and 0.6% more at the sample mean of the rule of law index. These results confirm that legal origin matters for explaining deforestation and that the French civil law seems to be relatively better to preserve the forest compared to the common law origin.

Overall, these results suggest that the institutional effect, such as the degree of democracy, the functioning of the government or the quality of property rights, on deforestation is significantly differential according to the legal origin. A closer study of the differences between the French civil law and the common law origin suggest that an improvement of the quality of the government functioning, the legal structure and the rule of law is more likely to dampen deforestation in French civil law countries whereas better democratic rules and less ownership risk is more prone to reduce deforestation in common law countries. Above all, the effect of institutions on deforestation should be understood at the light of the influence of the legal origin of law and regulation.

[12]In the regression with the Fraser Institute index, six countries are dropped due to a lack of data for this index: Burkina Faso, Guinea, Mongolia, Saudi Arabia, Sudan and Suriname.

4.4.2 The case of tropical forested areas

Table 4.4 to Table 4.6 present the results of regressions using the dataset of 46 countries with a substantial tropical forest and a legal system which is either a French civil law origin or a common law origin (the French civil law origin is the reference). In all regressions, the dependent variable is still the four-year average annual rate of deforestation on the sub-periods 1990–1993, 1994–1997, 1998–2001, and 2002–2005. This sample allows us to understand the exogeneous role of the legal origin of law and regulation since the legal origin has been implemented exogenously through mainly the colonization[13]

First, Table 4.4 reports regressions with the aggregated governance index from the World Bank Governance Indicators, and the aggregated index of democracy from Freedom House and the Polity IV project. Results remain robust concerning the absence of difference between the French civil law and the common law in the case of the aggregated governance index of the World Bank Governance Indicators, and on the differential impact of democracy. As in Table 4.1, an improvement of democracy is expected to reduce deforestation in common law countries (Column 4). Also, the coefficient of the dummy variable related to the common law origin is still positive and significant in the column 4 suggesting that in countries with bad level of democracy, the common law origin is a significant determinant of deforestation compared to the French civil law origin. In this case, the deforestation is 2% more important in common law countries than in French civil law ones. In addition, the overall impact of the common law origin on deforestation compared to the French civil law is positive and significant at the sample mean of the two institutional variables[14]. For instance, at the sample mean of the democracy index, common law countries deforest 3.5% more than French civil law countries. These results mean that legal origin matters for explaining deforestation but also that the French civil law origin seems to be relatively better to preserve the forest compared to common law countries.

Table 4.5 reports the regressions with indicators on the quality of government functioning such as the control of corruption (Columns 1 and 2), the effectiveness of government (Columns 3 and 4) and the regulatory quality (Columns 5 and 6). In all regressions, as in Table 4.2, without controlling for a differential impact of legal origin (i.e., without the interactions terms), an improvement of the control of corruption (Column 1), of the government effectiveness (Column 3) and of the regulatory quality (Column 5) allows for the decrease of deforestation whereas common law countries deforest 0.8% more, on average, than French civil law countries, and this difference is significant at the 1% level. In addition, as in Table 4.2, the results change when the interaction term is introduced. However, in this sample, the relative superiority of the French civil law is due to the quality of the control of corruption whereas an improvement of both the government effectiveness and the quality of the regulatory policies is no longer associated with

[13]In all regressions, "timber", "fuel export" and "agricultural export" variables have been removed to increase the sample. Consequently, seven countries, which are not in the sample of 82 countries, are in this sample: Angola, Chad, Ethiopia, Laos, Sierra Leone, Tanzania, and Zambia.

[14]Tables 4.4, 4.5 and 4.6 report the significance of the sum of the two coefficients associated with the common law origin and this sum is always statistically significant.

French civil law contrary to Table 4.2. The coefficient of the corruption variable is negative and significant in regressions suggesting that an improvement of the control of corruption is a tool to dampen deforestation in French civil law countries. This result suggests that French civil law origin is more prone to promote efficient control of corruption to preserve forested areas. By contrast, the effect of the interaction term in the three regressions is insignificant suggesting that an improvement of the quality of the government functioning is not useful to reduce deforestation in common law countries with an important tropical forested areas. Moreover, the overall positive impact of the common law origin is still positive and significant at the sample mean of each institutional variable. At the sample mean of the corruption index, common law countries deforest 0.08% more, on average, than French civil law countries. In addition, at the sample mean of the government effectiveness index, common law countries deforest 0.08% more, on average, than French civil law countries and 0.07% more at the sample mean of the regulatory quality index. These results confirm that legal origin matters for explaining deforestation and that the French civil law seems to be relatively better to preserve the forest compared to the common law origin after controlling for the differential effect of institutions.

Table 4.5 reports results with the index of ownership risk (Columns 1 and 2), the quality of the legal structure (Columns 3 and 4) and the quality of the rule of law (Columns 5 and 6[15]). The results concerning the ownership risk index holds with this sample. A reduction of the ownership risk (an increase of the index) is not significantly associated with low deforestation (Column 1) whereas this effect is different according to the legal origin. As in Table 4.3, a reduction of the ownership risk in common law countries is negatively associated with deforestation compared to French civil law countries (Column 2). As suggested by the Legal Origins Theory, common law countries are characterized by better property rights which, in turn, allow to dampen deforestation compared to the French legal origin. However, deforestation remains more important in common law countries characterized by a high ownership risk compared to the same type of French civil law countries. However, the overall impact of common law countries is now positive and significant at the sample mean of the ownership risk index. Common law countries deforest 0.08% more than French civil law countries.

Contrary to the results of the Table 4.3, the differential impact of an improvement of the quality of the legal structure is more likely to reduce deforestation in common law countries (Column 4). However, the effect of the additive variable is still negative (but insignificant), suggesting, in turn, that a better legal structure could dampen deforestation. Overall the results of Tables 4.3 and 4.6 suggest that an increase of the quality of the legal system, through better property rights, more judicial independence and more trust in the judicial system, is more prone to reduce deforested activities whatever the legal origin[16]. In addition, at the sample mean of

[15]In the regression with the Fraser Institute index, three countries are dropped due to a lack of data for this index: Burkina Faso, Guinea and Sudan.

[16]Remind that the index used is an aggregated index on the quality of the legal structure defining by the trust in the legal system, the quality of property rights and the extent of judicial independence. Each of this indicator can influence the results but overall this is the quality of the legal structure which matters for reducing

the legal structure index, common law countries deforest 0.7% more, on average, than French civil law countries.

Finally, as in Table 4.3, an enhancement of the rule of law is likely to dampen deforestation (Column 5) whatever the legal origin. By contrast, Column 6 reports no differential effect of the rule of law index according to the legal origin. Contrary to Table 4.3 which states a negative and significant effect of rule of law on deforestation only in French civil law countries, both the additive and interaction terms have negative but insignificant effect. The findings of Tables 4.3 and 4.6 implies almost that a better rule of law can reduce deforestation whatever the legal origin. In addition, at the sample mean of the law index, common law countries deforest 0.8% more, on average, than French civil law countries.

4.5 Conclusion

Differences in institutions may explain differences in economic performances. This chapter holds out that these institutional differences can explain deforestation in developing countries. This chapter investigates this issue through the influences of institutional persistence. As suggested by the literature on institutional persistence, inherited legacies had drawn the previous set of institutions in a country making the current institutional performances which can, in turn, shape the current environment performances. Legal origin represent some of these legacies and are studied in this chapter since they have been widely recognized to be important determinants of differences in institutional performances (La Porta et al., 2007). This chapter tries, finally, to understand if institutions could have a differential impact on deforestation according to legal origin.

The main result of this chapter is that the role of institutions on deforestation should be understood at the light of the past experiences of each country. A study of the differences between the French civil law and the common law origin suggests that an improvement of the quality of the government functioning mainly through the control of corruption is more likely to dampen deforestation in French civil law countries whereas better democratic rules and less ownership risk is more prone to reduce deforestation in common law countries. Above all, the effect of institutions on deforestation should be understood at the light of the influence of the legal origin of law and regulation. This questions the validity of some political recommendation in terms of institutions and underlies the importance of the relativism in the understanding of the effect of institutions. By contrast, some institutions such as the quality of the legal structure and the rule of law are not differential effect on deforestation according to the legal origin. An enhancement of each of these two indicators is significantly associated with less deforestation whatever the legal origin.

In addition, French civil law countries tend to deforest less than common law countries in a

deforestation.

context of bad governance. This result stresses the importance of puzzling out the role of the origin of the legal system for combating deforestation. This study proposes that, in a context of poor governance (such as poor property rights, corruption, autocracy, low level of government functioning), French civil law countries are relatively better than common law countries, and suggests, in turn, the presence of some French legacies helping to preserve the forest.

As a conclusion, this chapter stresses the importance of the past in the understanding of the present through the influence of the incentive structure characterized by institutions. Political recommendation in terms of an enhancement of institutions should consider the relativism rules about institutions. Finally, this research can be extended to try to explain more precisely why French civil law countries deforest less than common law ones after having controlled for the institutional quality. An explanation can rely on the French superiority in terms of forest law highlighted in the first chapter.

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4.6 Tables of results

Table 4.1: Legal origin, governance quality and deforestation

Dependent variable: Rate of deforestation				
	Aggregated index WBGI		Democracy index	
VARIABLES	(1)	(2)	(3)	(4)
Common law	0.007***	0.005	0.006***	0.01***
	(0.002)	(0.005)	(0.002)	(0.004)
German civil law	0.006**	-.024***	0.006***	-.017***
	(0.002)	(0.008)	(0.002)	(0.005)
Institutions	-.026***	-.033***	0.005	0.005
	(0.008)	(0.01)	(0.004)	(0.006)
Institutions*Common		0.005		-.009*
		(0.01)		(0.005)
Institutions*German		0.056***		0.026***
		(0.014)		(0.006)
Lag Forest Area	0.00006	0.0002	0.0006	0.001*
	(0.0006)	(0.0006)	(0.0006)	(0.0006)
Log GDP	-.0009	-.001	-.003***	-.004***
	(0.001)	(0.001)	(0.0007)	(0.0007)
Rural density	-3.19e-06	-4.73e-06*	-1.80e-06	-2.32e-06
	(2.59e-06)	(2.65e-06)	(2.43e-06)	(2.28e-06)
Pop. growth	0.006***	0.006***	0.006***	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)
Timber	0.002	0.002	0.001	-.0002
	(0.003)	(0.003)	(0.003)	(0.003)
Latitude	-.007	-.004	-.013*	-.008
	(0.007)	(0.007)	(0.007)	(0.006)
Fuel export	-.00004	-.00005	0.00002	6.16e-06
	(0.00004)	(0.00004)	(0.00003)	(0.00003)
Agr. export	-.00004	-.00003	-.00006	-.00007
	(0.00006)	(0.00006)	(0.00005)	(0.00005)
Credit	3.29e-07	-1.00e-05	9.86e-07	5.01e-06
	(1.00e-05)	(1.00e-05)	(1.00e-05)	(1.00e-05)
Intercept	0.007	0.014	0.006	0.007
	(0.009)	(0.01)	(0.008)	(0.008)
Number of countries	82	82	82	82
Observations	237	237	303	303
Adjusted R2	0.381	0.415	0.381	0.424
F-stat	10.744	11.187	12.56	16.193
RMSE	0.009	0.009	0.009	0.009
F-stat Common		5.85***		4.71***
F-stat German		16.31***		11.79***

Note: OLS robust standard errors in parentheses. In all regressions, regional and year dummies are introduced (omitted region is Asia). The omitted legal origin category is French civil law. Columns 1 and 2 report results with the overall aggregated index, and Columns 3 et 4 report results with an index of democracy from Freedom House and Polity 2. F-stat Common (German) reports the F-stat and the associated significance of the following test: H0: $\phi_1 + \phi_2 = 0$. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 4.2: Legal origin, governmental quality and deforestation

Dependent variable: Rate of deforestation						
	Corruption WBGI		Governm. effectiveness		Regulatory quality	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Common law	0.007***	0.003	0.007***	0.007	0.007***	0.004
	(0.002)	(0.004)	(0.002)	(0.004)	(0.002)	(0.007)
German civil law	0.006**	-.018***	0.006**	-.015**	0.006**	-.023*
	(0.002)	(0.007)	(0.002)	(0.007)	(0.002)	(0.014)
Institutions	-.020***	-.029***	-.019**	-.025***	-.019***	-.022**
	(0.005)	(0.006)	(0.008)	(0.009)	(0.007)	(0.009)
Institutions*Common		0.01		0.002		0.004
		(0.008)		(0.008)		(0.01)
Institutions*German		0.04***		0.034***		0.039**
		(0.009)		(0.009)		(0.016)
Lag Forest Area	0.0001	0.0002	0.0003	0.0004	0.0003	0.0003
	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)
Log GDP	-.001	-.001	-.001	-.001	-.001	-.001*
	(0.0009)	(0.0009)	(0.001)	(0.001)	(0.0008)	(0.0009)
Rural density	-2.44e-06	-3.39e-06	-2.45e-06	-4.12e-06	-2.60e-06	-3.42e-06
	(2.71e-06)	(2.76e-06)	(2.67e-06)	(2.79e-06)	(2.83e-06)	(2.91e-06)
Pop. growth	0.007***	0.006***	0.007***	0.006***	0.007***	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Timber	0.002	0.003	0.002	0.002	0.002	0.002
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Fuel export	-.00004	-.00005	-.00002	-.00003	-.00003	-.00003
	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)
Agr. export	-.00004	-.00005	-.00003	-.00003	-.00002	-.00002
	(0.00005)	(0.00005)	(0.00006)	(0.00006)	(0.00005)	(0.00005)
Credit	5.75e-07	-1.00e-05	5.74e-06	-4.31e-06	-2.08e-06	-7.34e-06
	(1.00e-05)	(1.00e-05)	(1.00e-05)	(1.00e-05)	(1.00e-05)	(0.00002)
Latitude	-.005	-.003	-.006	-.003	-.009	-.006
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Intercept	0.004	0.011	0.003	0.006	0.01	0.015
	(0.009)	(0.01)	(0.01)	(0.01)	(0.009)	(0.01)
Number of countries	82	82	82	82	82	82
Observations	237	237	240	240	240	240
Adjusted R2	0.388	0.425	0.372	0.393	0.375	0.386
F-stat	10.53	11.38	10.507	11.207	10.74	10.396
RMSE	0.009	0.009	0.009	0.009	0.009	0.009
F-stat Common		9.00***		6.64***		4.51***
F-stat German		18.67***		13.45***		10.86***

Note: OLS robust standard errors in parentheses. In all regressions, regional and year dummies are introduced (omitted region is Asia). The omitted category is Former French colony. Columns 1 and 2 reports results with the Corruption index of the World Bank Governance Indicators database, Columns 3 and 4 reports results with the indicator of government effectiveness of the World Bank Governance Indicators database, Columns 4 and 5 uses the Regulatory Quality index of the World Bank Governance Indicators database. F-stat Common (German) reports the F-stat and the associated significance of the following test: H0: $\phi_1 + \phi_2 = 0$. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 4.3: Legal origin, property rights and deforestation

Dependent variable: Rate of deforestation						
	Ownership risk index		Fraser Institute index		Rule of law index WBGI	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Common law	0.006***	0.013***	0.006***	0.006	0.007***	0.007*
	(0.002)	(0.004)	(0.002)	(0.004)	(0.002)	(0.004)
German civil law	0.006***	0.037***	0.005**	-.023***	0.006**	-.023***
	(0.002)	(0.009)	(0.002)	(0.006)	(0.002)	(0.008)
Institutions	-.005	0.006	-.011**	-.013**	-.014**	-.016**
	(0.004)	(0.006)	(0.005)	(0.005)	(0.006)	(0.007)
Institutions*Common		-.015**		-.0009		-.0005
		(0.007)		(0.006)		(0.007)
Institutions*German		-.045***		0.041***		0.04***
		(0.012)		(0.008)		(0.01)
Lag Forest Area	0.0007	0.0007	0.0006	0.0008	0.0001	0.0003
	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)
Log GDP	-.003***	-.003***	-.002***	-.003***	-.001	-.002*
	(0.0007)	(0.0007)	(0.0008)	(0.0008)	(0.001)	(0.001)
Rural density	-1.24e-06	-1.25e-06	-8.59e-07	-2.34e-06	-2.85e-06	-5.04e-06*
	(2.54e-06)	(2.36e-06)	(2.49e-06)	(2.48e-06)	(2.74e-06)	(2.84e-06)
Pop. growth	0.006***	0.006***	0.006***	0.006***	0.006***	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Timber	0.002	0.001	0.002	0.0007	0.001	0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Fuel export	-3.76e-06	3.52e-06	-1.00e-05	-.00002	-.00002	-.00003
	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00004)	(0.00004)
Agr. export	-.00004	-.00004	-.00002	-.00002	-.00002	-.00002
	(0.00005)	(0.00005)	(0.00006)	(0.00006)	(0.00006)	(0.00006)
Credit	4.00e-07	1.00e-05	5.49e-06	-1.00e-05	2.34e-06	-1.00e-05
	(1.00e-05)	(1.00e-05)	(1.00e-05)	(1.00e-05)	(0.00002)	(0.00002)
Latitude	-.011*	-.011*	-.010	-.009	-.007	-.005
	(0.006)	(0.006)	(0.007)	(0.006)	(0.007)	(0.007)
Intercept	0.007	0.003	0.004	0.011	0.008	0.013
	(0.008)	(0.008)	(0.009)	(0.01)	(0.009)	(0.01)
Number of countries	82	82	76	76	82	82
Observations	303	303	277	277	240	240
Adjusted R2	0.379	0.404	0.412	0.446	0.368	0.402
F-stat	13.291	13.291	12.845	13.214	10.51	11.044
RMSE	0.009	0.009	0.009	0.009	0.009	0.009
F-stat Common		16.17***		7.10***		9.08***
F-stat German		4.68***		19.72***		21.37***

Note: OLS robust standard errors in parentheses. In all regressions, regional and year dummies are introduced (omitted region is Asia). The omitted category is Former French colony. Columns 1 and 2 report results with the inverse of the ownership risk index, Columns 3 and 4 report results with the legal structure and property rights index of the Fraser Institute, and Columns 5 and reports results with the Rule of Law index of the World Bank Governance Indicators database. F-stat Common (German) reports the F-stat and the associated significance of the following test: H0: $\phi_1 + \phi_2 = 0$. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 4.4: Legal origin, governance quality and deforestation in tropical countries

Dependent variable: Rate of deforestation				
	Aggregated index WBGI		Democracy index	
VARIABLES	(1)	(2)	(3)	(4)
Common law	0.008***	0.015**	0.008***	0.02***
	(0.002)	(0.006)	(0.002)	(0.003)
Institutions	-.022**	-.014	0.008*	0.019***
	(0.009)	(0.01)	(0.004)	(0.005)
Institutions*Common		-.023		-.027***
		(0.022)		(0.007)
Lag Forest Area	-.003***	-.003***	-.002***	-.002***
	(0.0007)	(0.0007)	(0.0005)	(0.0005)
Log GDP	-.0006	-.0009	-.002***	-.002***
	(0.001)	(0.001)	(0.0007)	(0.0007)
Rural density	-9.15e-06***	-9.63e-06***	-9.13e-06***	-8.59e-06***
	(2.24e-06)	(2.32e-06)	(2.10e-06)	(1.93e-06)
Pop. growth	0.002	0.002	0.002	0.002*
	(0.002)	(0.002)	(0.001)	(0.001)
Latitude	-.022***	-.026***	-.028***	-.030***
	(0.007)	(0.009)	(0.007)	(0.007)
Credit	-.00003	-.00002	-.00004*	-.00004
	(0.00003)	(0.00003)	(0.00002)	(0.00002)
Intercept	0.051***	0.051***	0.042***	0.039***
	(0.012)	(0.012)	(0.009)	(0.009)
Number of countries	46	46	46	46
Observations	135	135	182	182
Adjusted R2	0.215	0.218	0.217	0.287
F-stat	6.483	5.464	7.059	8.086
RMSE	0.008	0.008	0.008	0.008
F-stat Common		9.37***		22.52***

Note: OLS robust standard errors in parentheses. In all regressions, regional and year dummies are introduced (omitted region is Asia). The omitted legal origin category is French civil law. Columns 1 and 2 report results with the overall aggregated index, and Columns 3 et 4 report results with an index of democracy from Freedom House and Polity 2. F-stat Common (German) reports the F-stat and the associated significance of the following test: H0: $\phi_1 + \phi_2 = 0$. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 4.5: Legal origin, governmental quality and deforestation in tropical countries

Dependent variable: Rate of deforestation						
	Corruption WBGI		Governm. effectiveness		Regulatory quality	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Common law	0.008***	0.011*	0.008***	0.014**	0.009***	0.018**
	(0.002)	(0.006)	(0.002)	(0.006)	(0.002)	(0.008)
Institutions	-.017***	-.015**	-.018**	-.013	-.012*	-.005
	(0.006)	(0.006)	(0.008)	(0.009)	(0.006)	(0.008)
Institutions*Common		-.009		-.018		-.019
		(0.019)		(0.02)		(0.016)
Lag Forest Area	-.003***	-.003***	-.003***	-.003***	-.003***	-.003***
	(0.0007)	(0.0007)	(0.0006)	(0.0006)	(0.0007)	(0.0007)
Log GDP	-.0008	-.0008	-.0006	-.0007	-.0009	-.001
	(0.0009)	(0.0009)	(0.001)	(0.001)	(0.001)	(0.001)
Rural density	-7.90e-06***	-8.14e-06***	-9.38e-06***	-9.78e-06***	-9.74e-06***	-1.00e-05***
	(2.18e-06)	(2.32e-06)	(2.20e-06)	(2.25e-06)	(2.26e-06)	(2.34e-06)
Pop. growth	0.002	0.002	0.002	0.002	0.002	0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Credit	-.00002	-.00002	-.00003	-.00002	-.00004	-.00004
	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)	(0.00003)
Latitude	-.019***	-.020***	-.023***	-.027***	-.028***	-.033***
	(0.007)	(0.008)	(0.007)	(0.009)	(0.007)	(0.009)
Intercept	0.048***	0.048***	0.051***	0.051***	0.055***	0.055***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Number of countries	46	46	46	46	46	46
Observations	135	135	138	138	138	138
Adjusted R2	0.217	0.212	0.214	0.215	0.206	0.212
F-stat	6.637	5.978	6.833	5.836	6.82	5.678
RMSE	0.008	0.008	0.008	0.008	0.009	0.008
F-stat Common		7.68***		8.65***		8.73***

Note: OLS robust standard errors in parentheses. In all regressions, regional and year dummies are introduced (omitted region is Asia). The omitted category is Former French colony. Columns 1 and 2 reports results with the Corruption index of the World Bank Governance Indicators database, Columns 3 and 4 reports results with the indicator of government effectiveness of the World Bank Governance Indicators database, Columns 4 and 5 uses the Regulatory Quality index of the World Bank Governance Indicators database. F-stat Common reports the F-stat and the associated significance of the following test: H0: $\phi_1 + \phi_2 = 0$. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

Table 4.6: Legal origin, property rights and deforestation in tropical countries

Dependent variable: Rate of deforestation						
	Ownership risk index		Fraser Institute index		Rule of law index WBGI	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Common law	0.007***	0.025***	0.007***	0.015***	0.009***	0.017***
	(0.002)	(0.005)	(0.002)	(0.005)	(0.002)	(0.006)
Institutions	0.005	0.022***	-.018***	-.010	-.017***	-.009
	(0.006)	(0.008)	(0.005)	(0.006)	(0.006)	(0.007)
Institutions*Common		-.037***		-.019*		-.023
		(0.01)		(0.011)		(0.016)
Lag Forest Area	-.002***	-.002***	-.003***	-.002***	-.003***	-.003***
	(0.0005)	(0.0005)	(0.0006)	(0.0006)	(0.0007)	(0.0006)
Log GDP	-.002***	-.002**	-.001	-.002	-.0008	-.001
	(0.0007)	(0.0007)	(0.001)	(0.001)	(0.0009)	(0.0009)
Rural density	-8.95e-06***	-5.66e-06***	-9.94e-06***	-1.00e-05***	-9.47e-06***	-1.00e-05***
	(2.13e-06)	(2.10e-06)	(2.39e-06)	(2.67e-06)	(2.19e-06)	(2.35e-06)
Pop. growth	0.002*	0.002**	0.002*	0.002*	0.002	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Credit	-.00003	-7.79e-06	-.00005	-.00005*	-.00002	-.00002
	(0.00002)	(0.00002)	(0.00003)	(0.00003)	(0.00003)	(0.00003)
Latitude	-.025***	-.020***	-.018***	-.021***	-.023***	-.028***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.008)
Intercept	0.043***	0.025**	0.056***	0.055***	0.053***	0.054***
	(0.01)	(0.012)	(0.011)	(0.011)	(0.012)	(0.012)
Number of countries	46	46	43	43	46	46
Observations	182	182	153	153	138	138
Adjusted R2	0.196	0.273	0.257	0.27	0.225	0.239
F-stat	6.838	6.967	6.115	5.166	6.739	5.774
RMSE	0.008	0.008	0.008	0.008	0.008	0.008
F-stat Common		16.82***		5.41***		11.82***

Note: OLS robust standard errors in parentheses. In all regressions, regional and year dummies are introduced (omitted region is Asia). The omitted category is Former French colony. Columns 1 and 2 report results with the inverse of the ownership risk index, Columns 3 and 4 report results with the legal structure and property rights index of the Fraser Institute, and Columns 5 and reports results with the Rule of Law index of the World Bank Governance Indicators database. F-stat Common reports the F-stat and the associated significance of the following test: H0: $\phi_1 + \phi_2 = 0$. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%.

4.A Appendix

4.A.1 List of countries

Table 4.7: List of countries

Core Dataset of 82 Countries
Algeria, Argentina, Australia, Austria, Benin, Bolivia, Botswana, Brazil, Bulgaria, Burkina Faso, Cameroon, Canada, Central African Republic, Chile, China, Colombia, Congo, Rep., Costa Rica, Ivory Coast, Dominican Republic, Ecuador, Fiji, France, Gabon, Germany, Ghana, Greece, Guatemala, Guinea, Guinea-Bissau, Guyana, Honduras, Hungary, India, Indonesia, Iran, Italy, Japan, Kenya, Korea, Rep., Madagascar, Malawi, Malaysia, Mali, Mexico, Mongolia, Morocco, Mozambique, Namibia, Nepal, New Zealand, Nicaragua, Niger, Nigeria, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Russian Federation, Saudi Arabia, Senegal, South Africa, Spain, Sri Lanka, Sudan, Suriname, Switzerland, Thailand, Turkey, Uganda, Ukraine, United Kingdom, United States, Uruguay, Venezuela, Vietnam, Zimbabwe.
46 Tropical Countries
Angola, Argentina, Benin, Bolivia, Brazil, Burkina Faso, Cameroon, Central African Republic, Chad, Chile, Colombia, Democratic Rep. Congo, Costa Rica, Ivory Coast, Ecuador, Ethiopia, Gabon, Ghana, Guatemala, Guinea, Honduras, India, Indonesia, Laos, Madagascar, Malawi, Malaysia, Mozambique, Nepal, Nicaragua, Nigeria, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Senegal, Sierra Leone, Sri Lanka, Sudan, Tanzania, Thailand, Uganda, Vietnam, Zambia, Zimbabwe.

4.A.2 The creation of institutional variables

The first indicator is the aggregated index of governance created from the World Bank Governance Indicators database (WBGI) which combines the six separate variables (control of corruption, rule of law, voice and accountability, political stability and absence of violence, government effectiveness and regulatory quality) into a single index. All the original indicators of governance are first reversed as follows:

$$WBGI_i = \frac{WBGI_i - min(WBGI_i)}{max(WBGI_i) - min(WBGI_i)}, \tag{4.4}$$

where $min(WBGI_i)$ and $max(WBGI_i)$ represent the minimum and the maximum of each indicator. This transformation implies range between 0 and 1. The aggregated index of governance is then the first principal component of the vector of the six indicators of governance which accounts for 78% of the overall covariance (see Table 4.10 for more details).

The second overall measure is an average index of democracy created by the Quality of Government Institute (University of Gothenburg in the Quality Data of Government) from Freedom House data on civil liberties and political rights, and from the Polity 2 index of the Polity IV project. The Freedom House data are a standardized averaged index of civil liberties (with value from 1 (most free) to 7 (least free)) and political rights ((with value from 1 (most free) to 7 (least free)) indices. The Polity2 variable captures the regime authority spectrum on a ranging from -10 (hereditary monarchies) to +10 (consolidated democracy) and the three component variables that record key qualities of executive recruitment, constraints on executive authority, and political competition. This average index of democracy is then standardized as

follows:

$$Democracy_i = \frac{Democracy_i - min(Democracy_i)}{max(Democracy_i) - min(Democracy_i)}, \tag{4.5}$$

where $min(Democracy_i)$ and $max(Democracy_i)$ represent the minimum and the maximum of the average index of democracy. The new variable is so transformed to a scale 0 (autocracy)-1 (full democracy).

The second part of institutional variables represents measures of the quality of the government functioning. The composite indicator from the World Bank Indicators database is broken up to return to specific measures of quality of governance such as the level of corruption, the effectiveness of the government and the extent of the regulatory quality.

The third part is based on the quality of property rights. Two indices are used to measure the quality of property rights. The Legal Structure and Security of Property Rights index of Fraser Institute is first used. This index ranges from 0 to 1 where 0 corresponds to bad legal structure. The index is a general overview of the legal structure in a country and gathers judicial independence, impartial courts, protection of property rights, military interference in rule of law and the political process, integrity of the legal system, legal enforcement of contracts and regulatory restrictions on the sale of real property. The second is the Rule of Law index of the World Bank Governance Indicators database. The index ranges from 0 (worst rule of law) to -1 (better rule of law) and measures the extent to which law enforcement agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, the police and courts, as well as the likelihood of crime and violence.

However, these two variables are a measure of legal institutions, but not of property rights. Thereby, an index of ownership risk is calculated following the Bohn and Deacon's approach (Bohn & Deacon, 2000). These authors used an empirical model of investment on the relationships between ownership risk and investment decisions. Since the security of property rights affects the extent of investment and the efficiency with which inputs are allocated, ownership risk could be defined such as a probability of expropriation, i.e., a capture of all claims to investment projects. Captures can be acted by government, private parties, or "bad" courts. In the model, expropriation risk is empirically represented by (1) government stability (revolutions, guerilla warfare, purges, political assassinations and constitutional change), and (2) regime type (Parliamentary democracy; Non-parliamentary democracy; Strong executive; Military dictatorship; Monarchy; Others). The underlying assumptions of this model is that "investors have some underlying notion of a permanent, country-specific ownership risk that is better measured empirically by the long-run frequency of such events" and can "perceived risk which might rise temporarily after an event occurs" (Bohn & Deacon, 2000, p.538). These short and long run links are modelled by the country-specific average frequency of each political event and dummies for the temporal occurrence of individual events in the current or preceding year. Investment is also regressed on traditional economic variables such as output per worker, human capital per worker and openness (following Bohn & Deacon (2000)). The basic equation of investment is:

$$Invest_{i,t} = \theta_0 + \theta_1 GDP_{i,t-1} + \theta_2 H_{i,t-1} + \theta_3 Open_{i,t-1} + \theta_4 Regime_{i,t} + \theta_5 Stability_{i,t} + \varepsilon_{i,t}, \tag{4.6}$$

where $Invest$ represents the investment/output ratio in the country i in time t, GDP is the log of output per worker in $t-1$, H represents the human capital in $t-1$, *open* is the degree of openness in $t-1$, *regime* represents the first political attributes associated with political regime, *stability* is the government stability and $\varepsilon_{i,t}$ is the disturbance term.

An unbalanced panel dataset covering the 60 previously colonized countries in the core data set from 1990 to 2005 is used. The dependant variable is the total investment as percent of GDP and comes from the last version of the Penn World Table (Heston et al., 2009) as well as the output per worker. The human capital variable is the ratio of secondary-school enrolment to population provided by Banks (2008). The measure of openness follows Bohn & Deacon (2000) who use the sum of exports and imports divided by GDP provided by the last version of Penn World Table (Heston et al., 2009). Political data come from the Cross-national time-series data archive of Arthur S. Banks Banks (2008). Political instability are measured by revolutions, political assassinations, purges, guerilla warfare and major constitutional changes. The cross-national time-series data archive provides the number of these political events but dummy variables, defined to equal one if at least one such event occurred in a given country and year, represent them in the model following Bohn & Deacon (2000). Political regimes are created using the following three criteria: the type of chief executive (premier, president, military officer, monarch and other), the method of selection the chief executive (direct election, indirect election, and non-elective,) and the existence or effectiveness of the legislature (effective, partially effective, ineffective, and non-existent). In turn, six political regimes are created: (1) a *parliamentary democracy* with an effective or partially-effective legislature and an executive directed by a premier directly elected; (2) a *non parliamentary democracy* with a non-premier elected at the head of executive with an effective or partially effective legislature; (3) a *strong executive regime* with an ineffective or in-existent legislature; (4) a *military regime*; (5) a *monarchy*; and (6) an *"other" regime* category. A constitutional change variable is used in the same way of Bohn & Deacon (2000). They specify that constitutional change can have a non linear effect on investment according to the regime type. The dummy variable representing constitutional change is then interacted with the regime type which is recoding as follows: the Parliamentary democracy and the Non-parliamentary democracy are gathered to create a democracy regime (called regime D) whereas strong executive, military dictatorship, monarchy and others represent a non-democracy regime (called regime A). Finally, when a constitutional change occurred during year t, such variable equals one for a given country in year t if the country began year t in regime D and ended it in regime A for instance. Finally, the index of ownership risk is then constructed by multiplying coefficients (of each political attribute, i.e., government stability and regime type) by each political attribute and summed. The index ranges from 0 (high ownership risk) to 1 (low ownership risk).

4.A.3 Summary statistics

Table 4.8: Summary statistics

VARIABLES	Mean	(Std. Dev.)	Min.	Max.	N
Deforestation (annual rate)	0.003	(0.01)	-0.04	0.03	82
Log Lag forest area	9.35	(1.42)	6.9	13.6	82
Log GDP per capita	7.47	(1.51)	4.94	10.49	82
Rural density	293.25	(339.38)	5.46	2137.18	82
Pop. growth	1.61	(1)	-0.86	3.5	82
Price of timber	1.01	(0.14)	0.70	1.48	82
French civil law	0.57	(0.5)	0	1	82
Common law	0.3	(0.46)	0	1	82
German civil law	0.12	(0.33)	0	1	82
Latitude	0.26	(0.18)	0.01	0.67	82
Credit	57.04	(51.4)	-40.77	289.53	82
Fuel exports	14.47	(25.11)	0	96.83	82
Agr. export	7.33	(13.53)	0.03	74	82
Aggregated governance index	0.4	(0.15)	0.11	0.74	82
Corruption WBGI	0.47	(0.2)	0.2	0.97	82
Government effectiv. WBGI	0.45	(0.19)	0.16	0.93	82
Regulatory quality WBGI	0.65	(0.15)	0.33	0.96	82
Rule of law WBGI	0.51	(0.21)	0.17	0.99	82
Accountability WBGI	0.55	(0.23)	0.05	0.99	82
Political stability WBGI	0.61	(0.19)	0.15	0.97	82
Ownership risk index	0.57	(0.18)	0.1	0.95	82
Legal structure	0.48	(0.21)	0.15	0.95	76
Democracy index	0.67	(0.26)	0.01	1	82

4.A.4 Definition of variables and sources

Table 4.9: Definition of variables and sources

Code	Variables and Definition	Source
Deforestation	Log forested areas in $t-1$ minus log forested areas in t.	FAO
Lag(Forest$_{t-1}$)	Initial Forest Areas: Log forested areas in $t-1$.	FAO
Log GDP	Log GDP per capita, constant 2000 US$.	WDI 2010
Pop. growth	Annual population growth rate (percentage).	WDI 2010
Rural density	Rural population density per km^2 of arable land.	WDI 2010
Timber	The relative price of timber. the ratio of the price of hardwood logs in Sarawak, Malaysia (in $US/m3, source: IMF, International Financial Statistics) to the country-specific unit export values of agricultural goods (source: FAO).	FAODATA/IFS-IMF
Credit	Domestic credit provided by banking sector (% of GDP).	WDI 2010
Fuel export	Fuel export (% of merchandise exports).	WDI 2010
Agricultural export	Agricultural raw material export (% of merchandise exports).	WDI 2010
Legal origin	Legal origin of law and regulation with common, French civil law and German civil law.	La Porta et al. (2007)
Corruption WBGI	Control of Corruption: capturing perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.	WBGI
Gov. effect. WBGI	Government Effectiveness: capturing perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.	WBGI
Regul. qual. WBGI	Regulatory Quality: capturing perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.	WBGI
Rule of law WBGI	Rule of Law: capturing perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.	WBGI
Account. WBGI	Voice and Accountability: capturing perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media.	WBGI
Political stab. WBGI	Political Stability and Absence of Violence: capturing perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including politically-motivated violence and terrorism.	WBGI
Civil liberties	Civil liberties allow for the freedoms of expression and belief, associational and organizational rights, rule of law, and personal autonomy without interference from the state.	Freedom House
Civil liberties FH	Civil liberties allow for the freedoms of expression and belief, associational and organizational rights, rule of law, and personal autonomy without interference from the state.	Freedom House
Political rights FH	Political rights enable people to participate freely in the political process, including the right to vote freely for distinct alternatives in legitimate elections, compete for public office, join political parties and organizations, and elect representatives who have a decisive impact on public policies and are accountable to the electorate.	Freedom House
Polity 2	The "Polity Score" captures the regime authority spectrum on a 21-point scale ranging from -10 (hereditary monarchy) to +10 (consolidated democracy).	Polity IV project
Legal structure FI	The index consists of judicial independence, impartial courts, protection of intellectual property, military interference in rule of law and the political process, integrity of the legal system. The higher score corresponds to "high judicial independence", "trusted legal framework exists", "protection of intellectual property", "no military interference in rule of law", and "integrity of the legal system".	Fraser Institute
Ownership risk index	The index is an ownership risk index calculated from an econometric investment model with political attributes following Bohn & Deacon (2000).	Author's calculation.

4.A.5 Results of the principal components analysis

Table 4.10: Aggregating governance variables: principal components analysis

VARIABLES	First eigenvector	Correlation
Control of corruption	0.418	0.949
Regulatory quality	0.403	0.923
Government effectiveness	0.422	0.965
Rule of law	0.428	0.977
Accountability	0.397	0.917
Political stability	0.381	0.877
Number of countries	82	
Eigenvalue	5.175	
Variance proportion	0.863	

Note: The first eigenvector resulting from the first principal component analysis of governance quality is reported as well as the correlation of the first principal component with the corresponding governance variable (in parentheses, below the different eigenvectors). The composite index is calculated by multiplying each eigenvector (of each governance variable) by the relative governance variable previously standardized.

Part III

Demand for good governance and deforestation

Institutions and deforestation: the role of the demand for good governance

"(S)ustainable development depends upon good governance, good governance depends upon the rule of law, and the rule of law depends upon effective compliance. None are sufficient alone, but together they form an indivisible force that is essential for survival and for sustainable development". Zaelke et al. (2005, p.29-30)

After analysing the role of history in the understanding of deforestation, the second part of this thesis investigates the role of an important element of the institutional background: the demand for good governance. The starting point is the lack of studies on the role of demand for good governance as a potential tool for combating deforestation in developing countries. One of difficulties in the investigation of demand for good governance is the definition of this notion. The initial definition, actually proposed by the World bank, relies on government's accountability. The more public officials are accountable towards their people, the more these people are willing to demand more good governance.

Nevertheless, in this thesis, we decide to defined the demand for good governance such as environmental compliance with the law, related to the respect and the enforcement of the legal system. The choice of this definition, more explained in the following chapter, relies on the fact that deforestation in developing countries is mainly a rule of law crisis due to a lack of compliance. Moreover, rule of law is not only composed by compliance but also by regulatory policies as well as administrative and court process, i.e., supply for good governance.

As a consequence, interactions between the demand and supply side for good governance can be complex due to the fact that compliance (demand side) may be treated as an indivisible part of the rule of law (supply side). Compliance is thus important to improve the success of efforts to strengthen the rule of law, which in turn will improve the achievement of efforts to promote good governance allowing society to reach sustainable development such as preservation of woodland. In this context, improvements of the governance infrastructures, and more particularly norm–enforcement and compliance, are important.

The fifth chapter thus analyses the interactions between demand side and supply side for good governance in the case of forestry in developing countries. In this chapter, the demand for good governance is defined in terms of environmental compliance whereas the supply of good governance represents the degree of the efficiency of the governance infrastructure defined as judicial efficiency. Using a principal–agent model, the main proposition states that environmental compliance is a substitute of low judicial efficiency or a complement of high judicial efficiency in strengthening the forest stock.

Empirical estimates, using cross sectional data for 60 developing countries, support the main theoretical prediction. Thereby, the demand for good governance improves the sustainability of good governance reforms. The results also show that an enhancement of the efficiency of governance infrastructure can increase deforestation but only in the case of a lack of environmental compliance. Hence, the non–sustainability of good governance reforms in developing countries could be explained by a lack of demand for good governance. This chapter gives, in turn, an explanation of the non–sustainability of governance reforms and calls for more consideration of the role of the demand for good governance.

This part finally stresses out the importance to think about the demand side for good governance as a tool for insure the sustainability of supply side reforms in terms of forest preservation. Since the deforestation problem is mainly a problem a rule of law in developing countries, this part proposes thus a solution to resolve this issue.

Chapter 5

Environmental compliance, governance and deforestation*

5.1 Introduction

Deforestation of the tropics is the result of a forestry crisis characterized by a lack of efficient forestry management. The deforestation problem is above all a problem of the rule of law at both the national and local level (Segall, 2006). The forest is thus mainly seen as a source of political control and not as a natural resources worth preserving which leads to catastrophic exploitation (Contreras-Hermosilla, 2000). It displaces communities, increases both flood frequencies and soil erosion, undermines the economic possibilities of a sustainable forestry management, and reduces global biodiversity. In consequence, local communities become poorer and continue to degrade surroundings forests to survive, and kleptocratic governments can capture woodland through corrupt concession-awarding process.

Discovering and implementing proper legal structures for sustainable development (such as durable forestry management), i.e., good governance practises, is a way to better understand why forestry crisis in developing countries is almost a crisis of the rule of law (Segall, 2006). In this context, good governance is mainly the fruit of the quality of the rule of law which can be defined such as a set of rules applied fairly, efficiently and predictably by independent institutions in a framework of public–private interaction process. The way of combating the forestry crisis has to be found in the improvement of the rule of law process by improving (i) the mechanism of the supply side of good governance (administrative bodies, government functioning) and (ii) the level of the demand for good governance (the public officials' accountability toward their people) by leading toward a stronger civil society, more inclined to impose good governance practises, i.e., demand for good governance[1].

However, this last component of the rule of law has widely been ignored in the implementation of good governance reforms. This way, this chapter tries to investigate if the rule of law crisis resulting in a forestry crisis in developing countries can be explained by this component. Differently, this chapter investigates the forestry crisis as the failure of the interaction between the supply side and demand side for good governance.

*This chapter is an adapted version of an article co-authored with Gaoussou Diarra, submitted to *Environmental and Resource Economics*.

[1]The demand for good governance is a concept used by the World Bank and defined such as the level of how responsive government is to its people (Odugbemi & Jacobson, 2008, Part VI). The basic idea is that more people is inclined to have accountable public officials, more they are willing to demand good governance practises from their government.

In this chapter, the focus is made on the compliance with the law as an important element of the demand side for good governance. The reason of this choice is that compliance is related to the respect and the enforcement of the legal system. In other words, compliance assesses the degree in which people accepts to respect the system. As a result, compliance may be treated as an indivisible part of the rule of law: the rule of law cannot have meaning without compliance. In fact, the improvement of the functioning of courts as well as legislative and administrative bodies, i.e., good governance reforms, has no meaning without a lack of compliance. The result is that the degree in which people decides to comply with the law conditions their demand for good governance. Thus, it is assumed that people will be more inclined to have accountable government if they are more willing to comply with the law.

In consequence, the growing focus on compliance seems to be important to enhance the success of efforts to strengthen the rule of law, which in turn will improve the achievement of efforts to promote good governance, and thereby allow society to reach sustainable development. The importance of taking into account the demand side of good governance reforms requires thus an awareness of the interaction between the stakeholder's compliance with regulatory policies (Young, 1979; Odugbemi & Jacobson, 2008; McNeil & Malena, 2010) and these polices such as forestry ones.

Moreover, the analysis of deforestation through the interaction between the demand and supply side for good governance is an attempt to deal with two important issues concerning the forestry crisis in developing counties: corruption and sustainability of governance reforms. Firstly, corruption phenomena can be apprehended such as the result of the interaction between compliance (demand) and regulatory policies (supply). Low level of good governance practises in the both sides can lead to corruption. Failures in the functioning of the regulatory policies at local level (i.e., inspector) or state level (i.e., government) can lead to corrupt practices (bribery) with agents such as forestry firms.

Secondly, the sustainability of governance reforms refers to the success of these reforms. The main issue is that most of good governance reforms in developing countries (through better rule of law, better government functioning . . .) have not leaded to substantial improvements in terms of sustainable development such as durable forestry management. These failures necessitate to understand actually the persistence of some bad institutions such as self-sustaining corruption and a too small demand for good governance in some economies. Some attempts have been proposed to respond to these issues by explaining that as good governance reforms are gradual processes and necessitate investment in legal and administrative infrastructures, political instability is likely to create an environment under which corruption becomes more pervasive and tends to persist (Damania et al., 2004; Mishra, 2006). In this context, governments will be constrained in their ability to enforce compliance with chosen policies and be vulnerable to lobbying activities. Moreover, corruption is conceived along different dimensions which are interlinked: grand versus petty corruption. Grand corruption, which involves the higher decision levels in a country, is conceptually quite different from petty corruption. It includes cases when politicians or high-ranking civil servants manipulate a country's management or regulation of infrastructure industries to gain exclusive benefits (Knack, 2006; Kenny & Soreide, 2008). A main contrast between petty and grand corruption is related to monitoring mechanisms, which can be far better organized when petty corruption is the main issue. With grand corruption, elected politicians are often directly or indirectly controlling the supposed monitoring mechanisms, including the media as well as the judicial system.

Nonetheless, in these studies the role of bribery and other political-economy aspects of enforcement and compliance were under-investigated. This chapter proposes thus (i) to study the role of corruption within the interactions between the demand and supply side for good

governance, and (ii) to apprehend the problem of the sustainability of good governance reforms as a problem of a lack of demand for good governance.

Positioned in the same lineage as Damania et al. (2004) but without being primarily interested in the channel of political instability as the way through which corruption may affect environmental compliance, a theoretical model is developed to explain how environmental compliance and governance infrastructure interact to reduce environmental damages such as loss of forest stock. More precisely, a two-stage model is adopted where a profit-maximizing representative harvester selects the optimal amount of harvested land to be cleared given the available technology in forestry. In the second step, the logging firm is inspected by a bureaucrat (inspector) and might be willing to bribe this inspector in case of non-compliance. Firm–inspector interactions are shaped by judicial efficiency and the authorized harvest quota previously set. Indeed, the first step presents a model of policy-maker corruption, following Grossman & Helpman (1994). The policy maker designs the forest policy, i.e., the maximum harvest. The logger acts as a lobby so that the policy-maker maximizes a weighted sum of social welfare and received bribes.

Some positions predicting the interactions between the firm's environmental compliance, the governance infrastructures, and the environmental outcomes have been drawn. The main proposition states that environmental compliance is a substitute of low judicial efficiency or a complement of high judicial efficiency in strengthening the forest stock. Empirical estimates, using cross sectional data for 60 developing countries, support the main theoretical prediction. Thereby, the demand for good governance allows in insuring the sustainability of good governance reforms. However, the results show that an improvement of the efficiency of governance infrastructure can reduce the level of forest stock only in the case of a lack of environmental compliance. Hence, the non-sustainability of good governance reforms in developing countries could be explained by a lack of demand for good governance.

This chapter is organized as follows. Section 2 presents a political economy model. Section 3 provides econometrical evidence in support of the predictions of the model. Section 4 concludes and discusses policy implications.

5.2 The Baseline Model

A three-tier hierarchy agency model is used: firm-harvester/inspector/government (Tirole, 1986)[2]. We assume that all parties are risk neutral. The representative harvester has the right to cut timber in a given public forestland (like a concession). The harvester decides the volume to harvest knowing that an inspector will monitor the production.

The time sequence of actions and the specification of the model are first defined. Then, the firm–inspector interactions are studied to determine harvesting and reporting decisions as well as the optimal bribe. Finally, policy decisions are investigated.

5.2.1 Time Sequences of Decision

The model is a sequential finite-period stage game. The timing of events is given below:

- At date t = 0, the harvester determine its political contributions offered to the incumbent government. The level of these contributions is linked to the forest policy.

[2]An audit agency takes place in the game but only to monitor inspector's reported harvest production. Hence, the audit agency does not take part into the equilibrium process.

- At date t = 1, the incumbent government selects the forest policy to maximize their pay-off.
- At date t = 2, the harvester determines the harvest and reported effort.
- At date t = 3, the inspector controls the firm's production and an optimal level of bribe is determined with a probability to be discovered depending on the level of judicial efficiency, i.e., the quality of the audit agency.

A backward induction process is used for the resolution of the game. Hence, the forest policy is given for the harvester and inspector in the second stage.

5.2.2 Firm–Inspector Interaction

The policy-maker, i.e., the principal, designs a forest policy in order to reduce deforestation, to preserve biodiversity or to implement a durable forestry management. This policy consists of setting the maximum harvest effort, $\overline{e}$ required, i.e., a harvest quota. We assume that the harvester tends to produce more than the quota and to set $e > \overline{e}$ implying a positive level of non-compliance $v = (e - \overline{e})$. Given that harvest production results in environmental damage, the government, i.e., the policy maker, has to control harvest effort and assigns a bureaucrat (for instance an inspector) to monitor the firm. Moreover, the harvester has private information on their harvest production so that the principal has to use an inspector to monitor the firm's reported information.

However, the harvester may propose a bribe B to the inspector in the case of non-compliance. This corrupt behaviour is defined as petty corruption because it occurs between the firm and the inspector[3]. The harvester's bribe incites the inspector to declare that the quota is respected. In the model, inspection is not probabilized because it is assumed that the harvester is alone, which makes the inspection obvious. In other words, given that the inspector is risk-neutral, the bribe could be accepted or refused if its amount is not enough to optimize the pay-off. If the inspector accepts the bribe, the harvest effort is reported as $e \leq \overline{e}$. Moreover, the inspector is assumed to receive from the regulator (government) a fixed wage w and a variable wage R from the regulator (government). This last component of the inspector's remuneration, R, is considered as a reward for reporting the true harvester's effort. Then, R depends positively on the level of non-compliance (v, $\partial R/\partial v > 0$) but as public resources are scarce, R should not increase indefinitely with v ($\frac{\partial^2 R}{\partial v^2} > 0$). This award is a positive incentive used as a regulatory tool by the incumbent government to persuade the inspector to comply with the original purpose, i.e., to report the true harvest production.

However, knowing that the inspector could be bribed by the harvester, the regulator implements an audit of the harvest effort. The audit uncovers the true harvest effort with a probability $\lambda \in (0, 1)$. Therefore, the level of λ could be an indicator of the efficiency of the auditing process as noted by Damania et al. (2004). If $e > \overline{e}$, two fines are imposed: one on the harvester f^H and another on the inspector f^I. Thus, the fine for corruption is increasing and convex in non-compliance $f(v)(\frac{\partial f}{\partial v} > 0; \frac{\partial^2 f}{\partial v^2} > 0)$. Hence, the harvest effort will depend on the forest policy ($\overline{e}$) and the efficiency of the audit (λ), with penalties in the case of non-compliance. Thus, harvest effort will be $e = e(\overline{e}, \lambda)$ in the *cheat/bribe* strategy and $e^S = e(\overline{e}, \lambda)$ in the *safe* strategy (where $e^S = \overline{e}$).

[3]In contrast, corruption occurring between the harvester and the incumbent government is considered as grand corruption.

Let $H(e)$ be the net harvest function of the harvester from the harvest effort, with the land-holding cost and timber prices included. We assume that the logger is a price taker given that trading is on international market. The net harvest function depends on the logging effort (which is the logger's choice variable), and takes the form $H(e)$, with the standard properties: $H_e > 0, H_{ee} < 0$. The net harvest function is $H(\overline{e})$ in the safe case and $H(e)$ in the cheat strategy. Consequently, the strategies and their related pay-off are given in the following table 5.1.

Table 5.1: Strategies pay-off

Strategy	Harvester	Inspector
Safe	$H(\overline{e})$	$w + R(v)$
Cheat	$H(e) - [B + \lambda f^H(v)]$	$w + B - \lambda[f^I(v) + R(v)]$
Net	$\Psi^H(e, \overline{e})$ $= H(e) - [B + \lambda f^H(v)] - H(\overline{e})$	$\Psi^I(e, \overline{e})$ $= w + B - \lambda[f^I(v) + R(v)] - w - R(v)$ $= B - (1 + \lambda)R(v) - \lambda f^I(v)$

Following Damania et al. (2004) and Wilson & Damania (2005), we begin by determining the optimal level of bribe and effort intensity. The process of this game can be divided in two stages. First, the logger sets the effort level to maximize the joint pay-off ($\Psi^J \equiv \Psi^H + \Psi^I$). Then, the inspector and logger share the surplus through a Nash equilibrium process.

Therefore, taking the policy parameters as given $(\overline{e}, \lambda, f_v^H, f_v^I, R(v))$, the harvest effort is chosen to maximize the joint net pay-offs to the logger and inspector.

$$\max_e \Psi^J \equiv \Psi^H + \Psi^I = [H(e) - [B + \lambda f^H(v)] - H(e^s)] + [B - (1 + \lambda)R(v) - \lambda f^I(v)]. \quad (5.1)$$

The first order condition is

$$\Psi_e^J = H_e - \lambda f_e^H - \lambda f_e^I = 0. \quad (5.2)$$

The logger's optimal harvest effort $e^*(\overline{e}, \lambda, f_v^H, f_v^I, R(v))$ is implicitly given by equation 5.2 which, in equilibrium, specifies that the actual effort is set so that the marginal revenue from production equals the marginal expected penalty.

The equilibrium bribe is determined by a Nash bargaining between the harvester and bureaucrat. In this process, both parties share equally the benefit of the bribe strategy (non-compliance), i.e., they have the same bargaining power. To be successful, the bargaining has to respect the reservation values of the bureaucrat and logger. By the harvester's net pay-off, the bribe is paid by the firm, i.e., the bribe strategy is dominant if $B < H(e) - H(e^S) - \lambda f^H(v) \equiv \overline{B}$. By the inspector's net pay-off, the inspector accepts the bribe if $B > (1+\lambda)R(v) + \lambda f^I(v) \equiv \underline{B}$. Therefore, the optimal bribe is determined by the following Nash bargain

$$\max_B (\Psi^H \Psi^I). \quad (5.3)$$

The first order condition is

$$\partial(\Psi^H \Psi^I)/\partial B = [H(e) - H(e^S) + (1 - \lambda)R(v) - \lambda(f^H - f^I) - 2B] = 0. \quad (5.4)$$

Hence, the optimal bribe is

$$B^* = 1/2[H(e) - H(e^S) + (1 - \lambda)R(v) - \lambda(f^H - f^I)]. \quad (5.5)$$

The optimal bribe resulting from this process has to lie between $[\underline{B}, \overline{B}]$ so that the global benefit of the bribe strategy is higher than the global loss of this strategy.

5.2.3 Policy Determination

Having described the harvester–inspector interaction, we now turn to the political process. Recall that we proceed backwards so that the political process, which determines the forest policy takes place before the harvester–bureaucrat outcomes. The incumbent government has to draw the policy but the logger act as a lobby. Consequently, the threshold level of harvest quota ($\overline{e}$) is influenced by the harvester's lobbying.

Following Grossman & Helpman (1994), the incumbent government i receives political contribution S defined as grand corruption from the logger. We assume that the firm's political contribution depend on its level of non-compliance, and hence, is noted $S(v)$ with $S_v > 0$. In fact, a non-compliant firm could have a trade-off between the cost of bribing the incumbent government or the cost of bribing the inspector in the following stage. However, we assume that an optimal strategy for the firm would be to try to influence the government to have a well-set harvest quota.

Thus, the government derives utility from political contributions and also from the welfare of voters W. The incumbent government draws the level of forest policy in order to maximize its pay-off considering S as given. Consequently, the current utility of the policy-maker is a weighted sum of S and W:

$$U = (1-\alpha)\beta S(v) + \alpha W(H(e), e),$$

where β measures the degree of environmental compliance in the economy. Basically, this parameter allows of introducing into the model the degree of demand for good governance which shapes the weight of corruption in the government's utility. More compliance increases the weight of corruption in the government's utility because the rent seeking government is more inclined to deal with a compliant firm than with a non-compliant one. The intuition is as follows: a more compliant firm implies both less fiscal evasion in the second stage and more international recognition of the government through the compliance of the harvest quota.

α measures the weight of social welfare in the government's utility. Social welfare represents the sum of the utility of all agents in the economy in a given period. It is decreasing in the harvest effort ($W_e < 0$; $W_{ee} < 0$) which is associated to environmental damage (biodiversity losses,...) and increasing in the total harvested volumes ($W_H > 0$; $W_{HH} < 0$).

Following Grossman & Helpman (1994) and Dixit et al. (1997), the equilibrium in a common agency model maximizes the joint surplus of all parties. From Lemma 2 of Bernheim & Whinston (1986), the forest policy ($\overline{e}$) has to satisfy two necessary conditions, which are

$$CI: \quad \overline{e}^* \in \arg\max U, \tag{5.6a}$$

$$CII: \quad \overline{e}^* \in \arg\max \Pi + U. \tag{5.6b}$$

The expected profit Π of the logger is

$$\Pi = H(e) - B - \lambda f^H(v) - S(v).$$

Condition 5.6a states that the incumbent government determines the forest policy to maximize its own welfare (U), given the offered political contribution schedules (S). Condition 5.6b

states that the equilibrium forest policy maximizes the joint welfare of the harvester and the government.

The optimal forest policy ($\overline{e}^*$) maximizes (i) CI (equation 5.6a) and (ii) CII (equation 5.6b). Hence, the first order conditions satisfy

$$(1-\alpha)\beta S_v + \alpha W_H H_e + \alpha W_e = 0,$$

$$\alpha W_H H_e + \alpha W_e + H_e - \lambda f_v^H - \alpha\beta S_v = 0.$$

Thus, $\overline{e}^*$ is implicitly given by

$$H_e + \frac{\alpha}{\beta(1-\alpha)} W_H H_e + \frac{\alpha}{\beta(1-\alpha)} W_e - \lambda f_v^H = 0. \tag{5.7}$$

Having defined the political equilibrium of the model, we now turn to analyse the comparative static properties of the equilibria to examine interrelationships between forest policy ($\overline{e}$), judicial efficiency (λ) and environmental non-compliance (β).

Result 1 *An increase of judicial efficiency (λ) reduces the forest quota i.e the forest policy becomes more stringent. (see proof 5.A.1).*

This result implies that an improvement of judicial efficiency is a condition for weakening environmental damage. In fact, a more efficient audit agency arranges that the costs associated to the bribe strategy increase implying less petty corruption and finally less opportunity to violate the forest policy. Thereby, the principal, here the government, could implement a more stringent forest policy to reduce environmental damage knowing that the logger will be less incited to violate the forest policy. Thus, judicial efficiency allows of promoting sustainable environmental policies.

Result 2 *Conditioned on the level of judicial efficiency, an increase of compliance (a rise of β) tends to reduce the harvest quota, i.e., the forest policy becomes more stringent (see proof 5.A.1).*

These results imply that in countries with low judicial efficiency, an improvement of environmental compliance allows of reducing environmental damage as deforestation, i.e., the forest quota. Moreover, in a high judicial efficiency country, the effect of environmental compliance decreases the harvest quota only if fines paid by the firm are nil. Moreover, given that judicial efficiency is high, a firm has to be compliant to not a pay fine (because the probability to be detected increases with judicial efficiency). Hence, we have the following proposition concerning the effect of both environmental compliance and judicial efficiency on the forest stock.

Proposition 1 *Environmental compliance is a substitute of low judicial efficiency or a complement of high judicial efficiency in order to reduce the harvest quota (see proof 5.A.1).*

Thereby, environmental compliance is a good substitute of weak governance infrastructure or a good complement of strong governance infrastructure to reduce environmental damages.

5.3 Econometric Framework

5.3.1 Econometric Approach and Data

Econometric Specification

The theoretical model has highlighted interactions between environmental compliance, governance infrastructures (here judicial efficiency) and environmental damages (here losses of forest stock, i.e., deforestation). The econometric approach consists in testing whether environmental compliance and judicial efficiency are complementary or substitutable to preserve the forest stock, i.e., to dampen deforestation (Proposition 1).

To test proposition 1, the following regression is run:

$$Deforestation_i = \alpha_0 + \alpha_1 Compliance_i + \alpha_2 Judicial_i + \alpha_3 Compliance_i \times Judicial_i + \sum_k \alpha_k Z_i + \varepsilon_i, \tag{5.8}$$

where $Deforestation_i$ is the deforestation rate in the country i, $Judicial_i$ is the quality of the legal framework, $Compliance_i$ is the level of environmental compliance, Z_i are control variables, α are coefficients vector to estimate and ε_i is the error term.

Proposition 1 states that both α_1 and α_3 should be negative, i.e., preserve forest stock[4]. The sign of α_2 is not stated by the model. A negative sign means that judicial efficiency could preserve forest stock by dampening deforestation despite the fact that environmental compliance is low whereas a positive sign means that judicial efficiency lessens forest stock (increases deforestation) in country with weak environmental compliance. Moreover, a positive effect suggests that there is a threshold effect because the coefficient of the interaction term (α_3) and the additive term (α_2) have an opposite sign. Hence, the threshold effect is:

$$\frac{\delta Deforestation_i}{\delta Judicial_i} = \alpha 2 + \alpha 3 * EnvironmentalCompliance_i = 0 \Rightarrow EnvironmentalCompliance_i = -\frac{\alpha 2}{\alpha 3}.$$

Among control variables, the literature on factors of deforestation is substantial. First, the path of deforestation is often associated positively with the initial forest area (*Forest Lag*) for three main reasons: (i) the scarcity effect implies that any remaining forested lands are preserved more; (ii) logging or forest conversion activities are more expensive when forest areas are rare; (iii) non-forested lands (in proportion to total area) are more available to other land uses such as agriculture, cattle ranching, tree plantations or urbanization when forest lands are important. The introduction of the initial level of forest cover allows thus of testing for the forest transition hypothesis (Rudel et al., 2005; Serban & Scrieciu, 2007).

Second, the environmental Kuznets curve (EKC) approach states that the level of environmental degradation, measured by environmental indicators such deforestation, is linked to economic development (Bhattarai & Hammig, 2001; Culas, 2007). This relation implies a non-linear effect of economic growth on deforestation (*Log GDP per capita* and *Log GDP per capita squared*): the marginal income effect is positive for low income countries and becomes negative for high income economies.

[4] The marginal effect of compliance on deforestation is: $\frac{\delta deforestation}{\delta compliance} = \alpha 1 + \alpha 2 * Judicial.$

Third, demographical effects and more particularly population pressures are associated with greater deforestation. The common explanation advanced is that population growth encourages the conversion of forest land to other uses (such as agricultural uses) by increasing the need for arable land. The growth of population (*Pop*) and the extent of rural population (*Rural*) are introduced to control for these pressures on forest land (Cropper & Griffiths, 1994).

Fourth, a legal origin dummy is introduced to capture institutional differences due to different legal systems (La Porta et al., 1999). A *latitude* variable as well as region dummies are used to control for non-observed differences[5].

The Issue of Endogeneity

A naive estimation of the parameters of the model may lead to biased estimates if the issue of endogeneity is not taken into account. To tackle this issue, a selection on observables in adding a large number of control variables or a selection on unobservables measuring all other time-invariant determinants could be implemented. However, the first approach does not allow of controlling for all the bias, and the second could not be implemented in this chapter using cross-country data.

Thus, a third approach relies on the use of instrumental variables (IV) under three conditions. First, IV should be correlated with the supposed endogenous variable. Second, the error term in the instrumentation equations has to be uncorrelated with the measurement error in the structural equations. Third, the IV should not be correlated with the dependent variable, except through the endogenous variables or through the effect on the other variables that have been already controlled for. Estimation are made with the 2SLS estimator.

The choice of pertinent instruments for each one of the two variables of interest, i.e., environmental compliance and judicial efficiency, relies on the literature. As in Damania et al. (2004), environmental compliance could be instrumented by the level of *civic liberties* and the degree of *environmental education*. These two variables measure the extent of informal regulatory pressures in the society and are expected to influence positively environmental compliance.

Last, as instruments of judicial efficiency, the intensity of *constitutional changes* is used. Basically, we assume that judicial efficiency is negatively influenced by the frequency of changes in the legal system (Damania et al., 2004).

Dataset

Our sample consists of a cross-country of 60 developing countries[6]. We begin by a description of environmental compliance, judicial efficiency and deforestation. Table 5.4 summarizes the descriptive statistics, and Table 5.5 provides full data descriptions (definitions and sources).

The time-span analysis is 2005-2007 and motivated by the available data for compliance. In fact, in the literature, we found no data on environmental compliance at the country level. To address this issue, we built an index of environmental compliance from the data of several reports provided by the World Economic Forum. The compliance is the predicted value of corporate ethics[7] of firms in a given country which has been regressed on (i) a variable measuring

[5] Results remain robust when alternatively the relative price of timber or agricultural commodity export unit value are controlled for. These results are not presented because the size of the sample is reduced. Results available upon request.

[6] We cannot use a panel framework to test empirically our proposition due to just one period-time for available data concerning environmental compliance.

[7] Corporate ethics is the ethical behaviour in interactions with public officials, politicians, and other enterprises in a given country. The data are averaged over 2007-2009.

the burdens for businesses to comply with governmental administrative requirements (averaged over 2007-2009) and on (ii) a variable related to the stringency of environmental regulation (averaged over 2007-2009). We assess thus that the corporate ethics explained by these two variables could be a measure of the degree in which firms comply with environmental law.

Besides, as a measure of judicial efficiency and following Damania et al. (2004), the *Rule of Law* index developed by Kaufmann et al. (2008), "capturing perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence", is introduced (from -2.5 (low) to 2.5 (high), averaged over 2005-2008). This index could be reasonably expected to approach the degree to which laws are enforced.

Finally, the dependent variable is the deforestation rate between 2005 and 2007 (*minus* the difference in logarithms of forest area, expressed in thousands of hectares, when forest area is strictly positive, source: FAO). The average deforestation rate is positive (0.4%), which means that forests are being lost at a global scale. The sample goes from -2.23% (Uruguay) to 3.76% Nigeria.

5.3.2 Econometric Results

Proposition 1 of the model states that environmental compliance is a substitute, in preserving forest stock, for a low level of judicial efficiency, or a complement for a high level of judicial efficiency.

Table 5.2 displays the results related to Proposition 1. As a validity check, excluded instrumental variables for environmental compliance and judicial efficiency are used.

It is found that environmental compliance could help to increase the forest stock by dampening deforestation. In both specification, compliance has a negative effect which is only significant in the 2SLS specification[8]. Moreover, this effect is strengthened by the quality of the legal infrastructure. The interaction term (*Compliance*∗*Judicial Efficiency*) is negative and significant (in the 2SLS specification) suggesting that more judicial efficiency improves the positive effects of positive environmental compliance on forest stock, i.e., the negative effect on deforestation.

However, the additive coefficient of judicial efficiency is positive, suggesting that an improvement of the legal system could increase deforestation, but only in a society with low environmental compliance. This result highlights that good governance reforms provided by politics have to be appropriated by the demand side to become efficient.

Moreover, there is a threshold effect because the coefficient of the interaction term and this one of the additive term of judicial efficiency have opposite signs. From column 6, the threshold level of environmental compliance that ensures a negative marginal impact of judicial efficiency on deforestation stands at 3.42[9]. The majority (42 countries over the sample) of countries have levels consistent with an overall negative effect of judicial efficiency on deforestation. In these countries, compliance is high enough to allow a positive effect of judicial efficiency on the preservation of forest (i.e., the decrease of deforestation). However, there are 18 countries in the sample below the threshold value of compliance[10]. For these countries, the overall effect of judicial efficiency on deforestation is positive. This result suggests that the low level of environmental compliance in these countries could explain why good governance reforms, such

[8]The number of countries is 58 since there is no information concerning the variable, environmental education, for Suriname and Guyana.

[9]Environmental compliance ranges from 2.57 to 5.25 with a mean at 3.80.

[10]These countries are Algeria, Argentina, Bangladesh, Bolivia, Cameroon, Chad, Ivory Coast, Dominican Republic, Ecuador, Kazakhstan, Kyrgyzstan, Mongolia, Nepal, Peru, Suriname, Venezuela, Vietnam, Zimbabwe.

as judicial efficiency, may be become inefficient due to a lack of appropriation of these reforms by citizens.

Among control variables, only legal origin variables are found to be significant. French civil law countries deforest significantly less than common law countries as shown in the first part of this thesis. Socialist law countries are also found to deforest significantly less than common law countries[11].

Finally, for completeness Table 5.5 reports the first stage regressions.

5.4 Concluding Remarks

This chapter has provided explanations for the interactions between environmental compliance and the effectiveness of regulatory institutions in the specific case of forestry in developing countries.

Using a principal–agent model, an improvement in the efficiency of the governance infrastructure, defined as judicial efficiency, is found to allow of implementing a more stringent forest policy. Hence, the supply side of good governance can be necessary but not sufficient. Indeed, it is also highlighted that environmental compliance is a substitute of low judicial efficiency or a complement of high judicial efficiency in setting a more stringent forest policy, which in turn preserves the forest stock.

Empirical estimates, using cross sectional data for 60 developing countries, support the main theoretical prediction. Environmental compliance helps preserve the forest stock but this effect is strengthened by the legal system. In countries where the legal system is efficient in monitoring economic activities and resolving disputes, environmental compliance is a good complement to legal infrastructure in avoiding environmental damages. However, in countries where the legal system is too weak to prevent environmental losses, environmental compliance could be a good substitute. Also, in countries where environmental compliance is low, an improvement of the legal system could increase losses of the forest stock. In this context, the non-sustainability of good governance reforms could be explained by a lack of demand for good governance.

Finally, this chapter brings a new explanation to understanding the weak sustainability of good governance reforms in the environmental field and calls for more consideration of the appropriation of institutional reforms (compliance) by the main stakeholders, to move towards sustainable change.

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[11]Socialist law countries are Azerbaijan, Cambodia, China, Kazakhstan, Kyrgyzstan, Georgia, Mongolia and Vietnam.

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5.5 Tables of results

Table 5.2: Environmental compliance, judicial efficiency and deforestation

	OLS Regression			IV Regression		
	(1)	(2)	(3)	(4)	(5)	(6)
Envir. Compliance	-.004	-.00004	-.002	-.014**	-.011	-.011*
	(0.003)	(0.003)	(0.003)	(0.006)	(0.007)	(0.006)
Compliance*rule of law			-.006*			-.012***
			(0.003)			(0.004)
Rule of law		-.008**	0.015		0.001	0.041***
		(0.004)	(0.011)		(0.005)	(0.014)
Log Lag Forest	-.0006	-.0004	-.0005	-.001	-.0008	-.0007
	(0.0009)	(0.0009)	(0.0008)	(0.0008)	(0.0008)	(0.0007)
Log Gdp per capita	0.015	0.01	-.008	0.032	0.03	-.012
	(0.032)	(0.026)	(0.026)	(0.032)	(0.031)	(0.029)
Log Gdp per capita squared	-.001	-.0007	0.0006	-.002	-.002	0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Rural population	-.00008	-.00007	-.00009	0.00005	0.00002	-.00003
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Pop. growth	0.003	0.003	0.002	-.0002	0.0003	0.0003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
French Civil law	-.011***	-.011***	-.010***	-.015***	-.014***	-.012***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)
Socialist/Communist Laws	-.009	-.011*	-.012**	-.011	-.010	-.013**
	(0.007)	(0.006)	(0.006)	(0.008)	(0.008)	(0.006)
Latitude of capital	-.010	-.006	-.007	-.023	-.021	-.018
	(0.014)	(0.012)	(0.013)	(0.016)	(0.015)	(0.013)
America	0.003	0.001	0.00007	0.003	0.004	-.00009
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)
Asia	-.005	-.005	-.004	-.009**	-.008*	-.007
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Intercept	-.007	-.018	0.053	-.039	-.039	0.099
	(0.105)	(0.086)	(0.086)	(0.1)	(0.094)	(0.086)
Observations	60	60	60	58	58	58
Adjusted R2	0.239	0.305	0.342	0.07	0.174	0.279
F-stat	2.161	2.291	2.116	4.106	3.433	4.098
Compliance instrum. equation F-stat				4.21	6.15	7.58
Compliance*Judicial Eff. instrum. equation F-stat						9.72
Judicial Eff. instrum. equation F-stat					11.00	25.11
Hansen test				1.265	2.929	4.476
Hansen P-value				0.261	0.087	0.214

Note: Robust standard errors. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%. The omitted continent is Africa and the omitted legal origins is common law. The number of countries is 58 in the 2SLS regressions as there is no information concerning the variable, environmental education, for Suriname and Guyana. The dependent variable is the deforestation rate between 2005 and 2007.

Table 5.3: First stage regressions

	Deforestation equation				
Depend Variable	Compliance	Compliance	Judicial Efficiency	Compliance	Judicial Efficiency
Col. Table 5.2	col.4	col.5	col.5	col.6	col.6
	(1)	(2)	(3)	(4)	(5)
Excluded Instruments					
Environmental education	0.225**	0.226**	0.126**	0.205	0.249**
	(0.093)	(0.089)	(0.061)	(0.158)	(0.119)
Civic liberties	-.044	-.011	-.205***	-.037	-.018
	(0.088)	(0.09)	(0.054)	(0.223)	(0.153)
Constitutional change		-.822***	-.489***	-.741	2.119
		(0.31)	(0.17)	(3.667)	(1.875)
Environ. Education*Civic Liberties				0.007	-.039
				(0.052)	(0.039)
Environ. Education*Const. change				0.028	-.080
				(0.295)	(0.151)
Civic Liberties*Const. Change				-.042	-.529
				(0.669)	(0.355)
Included Instruments					
Log Lag Forest	-.048	-.048	0.006	-.047	0.014
	(0.057)	(0.056)	(0.036)	(0.059)	(0.038)
Log Gdp per capita	0.909	0.263	-.813	0.158	-1.442
	(1.635)	(1.734)	(1.271)	(2.251)	(1.353)
Log Gdp per capita squared	-.047	0.0001	0.084	0.007	0.126
	(0.118)	(0.124)	(0.092)	(0.159)	(0.097)
Rural population	0.007	0.012*	0.01**	0.012	0.01**
	(0.007)	(0.007)	(0.005)	(0.007)	(0.005)
Pop. growth	-.053	-.061	-.037	-.063	-.054
	(0.122)	(0.123)	(0.087)	(0.136)	(0.087)
French Civil law	-.101	-.137	0.073	-.133	0.093
	(0.196)	(0.173)	(0.138)	(0.187)	(0.142)
Socialist/Communist Laws	0.04	-.086	-.158	-.092	-.149
	(0.347)	(0.338)	(0.211)	(0.361)	(0.206)
Latitude of capital	-.692	-.411	0.344	-.379	0.308
	(0.793)	(0.812)	(0.62)	(0.883)	(0.633)
America	-.204	-.078	-.512***	-.073	-.508***
	(0.26)	(0.284)	(0.158)	(0.294)	(0.169)
Asia	-.232	-.169	0.001	-.179	0.014
	(0.24)	(0.265)	(0.145)	(0.281)	(0.168)
Intercept	-.638	1.187	0.763	1.649	2.366
	(5.435)	(5.793)	(4.129)	(7.490)	(4.286)
Observations.	58	58	58	58	58
Adjusted R2	0.277	0.322	0.616	0.274	0.61
Excluded instrument F-stat	6.19	7.73	18.93	3.81	15.67

Note: Robust standard errors. *** statistical significance at 1%, ** statistical significance at 5%, * statistical significance at 10%. The omitted continent is Africa and the omitted legal origins is common law.

5.A Appendix

5.A.1 Proofs of Results 1–2 and Proposition 2

Result 1

Proof.

$$\overline{e}^*_\lambda = \frac{\overbrace{f^H_v}^{>0}}{\underbrace{H_{ee} + \frac{\alpha}{\beta - \alpha\beta}\left(W_H H_{ee} + W_{ee}\right) - \lambda f^H_{vv}}_{<0}} < 0 \tag{5.9}$$

The sign of the numerator f^H_v is positive and the sign of the denominator is negative ($H_{ee} < 0$, $W_H > 0$ and $H_{ee} < 0$, $W_{ee} < 0$, f^H_{vv}). Hence, the sign of the marginal effect of λ on $\overline{e}^*$ is unambiguously negative. ■

Result 2

Proof.

$$\overline{e}^*_\beta = \frac{\overbrace{-\left(\frac{\alpha}{(1-\alpha)\beta^2}\right)\left[W_H H_e + W_e\right]}^{?}}{\underbrace{H_{ee} + \frac{\alpha}{\beta - \alpha\beta}\left(W_H H_{ee} + W_{ee}\right) - \lambda f^H_{vv}}_{<0}} \tag{5.10}$$

The sign of the denominator is negative because $H_{ee} < 0$, $W_H > 0$ and $H_{ee} < 0$, $W_{ee} < 0$, $f^H_{vv} > 0$. Hence, the sign of the marginal effect of β on $\overline{e}^*$ depends on the sign of the numerator which depends on the sign of $W_H H_e + W_e$ given that the sign of $\frac{\beta-\alpha\beta+\alpha}{(\beta-\alpha\beta)^2}$ is positive. However, $W_H H_e$ is positive and W_e negative, the sign of $W_H H_e + W_e$ is ambiguous.

From equation 5.7, we have $1 + \frac{\alpha}{\beta-\alpha\beta} > \frac{\alpha}{\beta-\alpha\beta}$ so that $W_H H_e$ must be lower than $-W_e + \lambda f^H_v$ or $W_H H_e + W_e < \lambda f^H_v$ and so the sign of $W_H H_e + W_e$ depends on λf^H_v.

If λ tends to zero, $W_H H_e + W_e < 0$ and the sign of $\overline{e}^*_\beta$ is negative (the numerator is positive).

If λ tends to 1, the sign of $W_H H_e + W_e$ depends on the level of f^H_v. In the case where the firm is compliant, f^H_v will be nil and the sign of $W_H H_e + W_e$ will be negative as well as the sign of $\overline{e}^*_\beta$. ■

Proposition 2

Proof. Given that from result 1, the effect of non-compliance β on $\overline{e}^*$ is conditioned on the level of judicial efficiency λ, and that from result 2 the effect of judicial efficiency λ on $\overline{e}^*$ is negative, we have Proposition 1. ■

5.A.2 List of countries

List of 60 Developing Countries				
Central and South America				
Argentina	Bolivia	Brazil	Chile	Colombia
Costa Rica	Dominican Republic	Ecuador	Guatemala	Guyana
Honduras	Mexico	Nicaragua	Panama	Paraguay
Peru	Suriname	Uruguay	Venezuela	
Africa				
Algeria	Benin	Botswana	Burkina Faso	Cameroon
Chad	Ivory Coast	Ethiopia	Ghana	Kenya
Madagascar	Malawi	Mali	Morocco	Mozambique
Namibia	Nigeria	Senegal	South Africa	Tanzania
Tunisia	Uganda	Zambia	Zimbabwe	
Asia				
Azerbaijan	Bangladesh	China	India	Indonesia
Georgia	Kazakhstan	Kyrgyzstan	Malaysia	Mongolia
Nepal	Pakistan	Philippines	Sri Lanka	Thailand
Turkey	Vietnam			

5.A.3 Descriptive statistics

Table 5.4: Summary statistics

Variable	**Mean**	**(Std. Dev.)**	**Min.**	**Max.**	**♯ of Countries**
Deforestation rate	0.0048	(0.0108)	-0.024	0.038	60
Envir. compliance	3.8	(0.6)	2.57	5.25	60
Judicial efficiency	-0.47	(0.58)	-1.69	1.21	60
Log forested areas in 2000	9.06	(1.36)	6.39	13.08	60
Log Gdp per capita	7.04	(0.81)	5.22	8.34	60
Log Gdp squared	50.18	(11.35)	27.25	69.59	60
Rural	51.14	(21.53)	7.33	87.33	60
Pop. growth	1.61	(0.88)	-1	3	60
French Civil law	0.54	(0.5)	0	1	60
Socialist/Communist Laws	0.13	(0.34)	0	1	60
Latitude of capital	0.21	(0.14)	0.01	0.53	60
Africa	0.38	(0.49)	0	1	60
America	0.3	(0.46)	0	1	60
Asia	0.32	(0.47)	0	1	60
Environ. education	4.57	(1.35)	2	9	58
Civil liberties	3.45	(1.31)	1	6	60
Constitutional change	0.06	(0.18)	0	1	60

5.A.4 Data sources

Table 5.5: Data descriptions and sources

Name	Variables and definition	Source
Dependent variable		
Deforestation	The deforestation rate between 2005 and 2007 (*minus* the difference in logarithms of forest area, expressed in thousands of hectares, when forest area is strictly positive).	FAOSTAT
Explanatory variables		
Compliance	A created variable from data provided by the World Economic Forum (WEF) (see table 5.6).	WEF
Judicial efficiency	The Rule of Law index scaled 0-6: a lower score associated with fewer rule of law (2005-2008).	WGI
Forest Lag	Initial Forest Areas: Log forested areas in 2000.	FAO
GDP	Log GDP per capita, ppp (2005-2007).	WDI
Pop. Growth	Annual population growth rate (percent) (2005-2007).	WDI
Rural	Rural population in percent of total population (2005-2007).	WDI
Latitude	Measure of the distance from the equator, i.e., latitude (0 to 1, 0 is the equator).	(La Porta et al., 1999)
Legalor	Legal origins on law and regulation, i.e., common law, French civil law and Socialist law.	(La Porta et al., 2007)
Instrumental Variables		
Environ. Education	The extent of environmental concerns for basic, secondary and tertiary education as well as for research and development (from 1 (low) to 10 (high), 2006).	Bertelsmann Transformation Index
Civic Liberties	Freedoms of expression and belief, associational and organizational rights, rule of law, and personal autonomy without interference from the state (1: most free to 7: least free, 2005).	Freedom House
Constitutional Changes	The number of basic alterations in a state's constitutional structure.	Arthur S.Banks

Table 5.6: Data used to create the index of compliance

Variables and definition	Sources
Corporate Ethics How would you compare the corporate ethics (ethical behavior in interactions with public officials, politicians, and other enterprises) of firms in your country with those of other countries in the world? (1 = among the worst in the world; 7 = among the best in the world) (2008-2009) weighted average.	GCR, WEF
Burdensome to comply How burdensome is it for businesses in your country to comply with governmental administrative requirements (e.g., permits, regulations, reporting)? (1 = extremely burdensome; 7 = not burdensome at all) (2008-2009) weighted average.	GCR,WEF
Stringency of Environmental Regulation How stringent is your country's environmental regulation? (1 = lax compared with most countries, among the world's most stringent) (2007-2008).	T-T, WEF

Sources: GCR: Global Competitiveness Report, World Economic Forum (WEF); T-T: Tourism and Trade Report, World Economic Forum (WEF).

Part IV

Deforestation in Brazil

Institution and deforestation at micro level: the Brazilian case

"*Le Brésil est la terre des forêts vierges par excellence; leur aspect imposant saisit d'admiration le voyageur qui y pénétre*" Alfred Maury in *Histoire des Grandes Forêts* (Maurry, 1850, p.31).

After having analysed the role of institutions from a macro level, the third part of this thesis investigates this role as an underlying cause shaping the effects of more proximate causes of deforestation. This is made with two micro-economics applications in Brazil. More precisely, this last part proposes to understand the effect of agricultural productivity in the Brazilian Legal Amazon (chapter 6), and of a fiscal tool, the ICMS ecologíco (ICMS-E) in the state of Paraná (chapter 7), on deforestation.

The choice of Brazil is obvious due to the weight of this country in the current sustainable development agenda. Brazil is one of the most active emerging countries with a strong economic growth. However, Brazil is also the most important countries in terms of biodiversity and carbon sequestration due to its huge tropical Amazonian forest. This great environmental ecosystem is a wonderful biodiversity hotspot and its trees are obviously strongly important in the fight against global warming. Consequently, Brazil wishes to become a leader country in the promotion of sustainable development by developing strong impediments for reducing and combating the disastrous deforestation thereto occurring. However, Brazil has a strong economic growth characterized by a development of agricultural and industrial activities against the promotion of environmental practises. The Brazil thus faces a great challenge concerning the balancing between environmental preservation and economic development. As a consequence, this thesis makes an attempt to understand the mechanism underlying this balancing according to micro application studies.

One of the main causes of deforestation in the Brazilian Amazon is the agricultural expansion. The seventh chapter thus analyses the impact of agricultural technical efficiency on the propensity of farmers to convert natural land into agricultural plots, i.e., deforestation. This analysis is made in the Brazilian Legal Amazon (BLA) which is, beyond its great biodiversity hotspot, characterized by a poor institutional background, i.e., a weak environmental valuation of the Brazilian forest, an uneven land distribution, and a problem of the *de facto* openly accessed forested and "unproductive" lands.

This chapter gives a new explanation of economic drivers of deforestation at the farm level by investigating whether there exists a clear and unambiguous link between agricultural efficiency as proximate causes and deforestation in the specific Brazilian context. Put differently, this chapter studies the trade-off between economic efficiency, in terms of agricultural productive efficiency, and environmental efficiency, in terms of preservation of forested land, to know whether efficient agricultural producers in the Brazilian Legal Amazon (BLA) also have sound environmental practices. The underlying motivation is that a potential increase of productivity could create incentives to convert more natural land when an efficient farmer is (i) in a context of relatively poor environmental valuation implying that this kind of farmer does not internalize the social cost of forest into their production decisions, and (ii) in a de facto openly accessed "unproductive" private lands which pushes farmers to exploit their extensive margins before their intensive ones.

A two step econometric approach is adopted. A bootstrapped translog stochastic frontier that is a posteriori checked for functional consistency is used in order to estimate technical efficiency, estimates of which are put into a land use model to assess the impact of produc-

tivity on deforestation. Regressions are estimated on census-tract-level data from the Censo Agropecuario 1995–1996 in the BLA (Acre, Amazonas, Amapa, Para, Rondõnia, Roraima and Tocantins (North region), Mato Grosso (Center-West region), and Maranhão (North-East region)).

Results suggests that technical efficiency has a **U**-shaped effect: less and more efficient farms use more land for agricultural activities and so they have a positive effect on deforestation. However, the majority of farms are on the ascendant slope so that efficiency implies more deforestation in the BLA. This result could be thus explained by the poor environmental valuation of Brazilian tropical forest land, resulting in a lack of internalization of the social value of forested land into farmers' production decisions, and *de facto* openly accessed "unproductive" private lands which pushes farmers to exploit their extensive margins before their intensive ones.

Besides, an important challenge in the sustainable development agenda is to find financial resources to incite local actors in the production local public good, such as environmental parks, having strong global benefits. In this sense, Brazil has tried to implement, since twenty years, a new tool for inciting municipalities to preserve and promote conservation units. As a consequence, the eighth chapter has the aim to analyse the efficiency of a such mechanism, namely the ICMS-E, through the presence of spatial interactions between counties in the State of Paraná.

This fiscal mechanism is of special interest because he influences directly the Brazilian municipalities' land use and, thus, explains land cover change through strategic interactions between municipalities. The general principle underlying the ICMS-E is as follows: each Brazilian State collects VAT from the consumption of goods and services, and then they transfer one fourth of the collected amount to municipalities. This implies then a choice in land uses, between the development of economic activities and the creation of conservation units. Also, since only a fixed pool of money is available in any given year, the municipalities compete with each other to receive the money.

It is assumed that there can be positive or negative spatial interactions, i.e., each municipality could prefer to choose economic activities than conservation ones according the behviors of their neighbors. From a land use based deforestation model and a spatial Bayesian tobit estimator, negative spatial interactions between municipalities are found. This result suggests that municipalities use land for economic activities if their neighbors have created conservation units. The assumption of profitability is thus validated. A municipality, with neighbors allocating their lands for ecological purposes, prefers to develop their plots for agricultural or industrial activities to attract economic agents of neighboring municipalities.

Chapter 6

Agricultural technical efficiency and deforestation*

6.1 Introduction

The depletion of the Brazilian forest has drawn attention for a long time and been the subject of numerous studies (Pfaff, 1999; Andersen et al., 2002; Chomitz & Thomas, 2003; Margulis, 2003; Araujo et al., 2009; Pacheco, 2009a). This is of particular importance since most Brazilian policy makers are aware that Brazil's future is closely linked with environmental issues. To date, serious concerns exist that are related to the loss of biodiversity, climate change, local ecological disturbances, degradation of fresh water sources, degradation of soil fertility, and erosion.

This chapter contributes to the inquiry into the economic drivers of deforestation at the farm level by examining whether there exists a clear and unambiguous link between agricultural efficiency and deforestation. Put differently, this chapter studies the trade-off between economic efficiency, in terms of agricultural productive efficiency, and environmental efficiency, in terms of preservation of forested land, to know whether efficient agricultural producers in the Brazilian Legal Amazon (BLA) also have sound environmental practices. Many papers have analyzed the effect of efficiency and have revealed that inefficient farms (i.e., with an extensive production) deforest more. But this analysis has been performed without empirically estimating the effect of productivity (Otsuki et al., 2002; Bulte et al., 2007; Keil et al., 2007). For instance, Godoy et al. (1997, p. 978) explain that an "increase [of] the productivity of land (...) create(s) incentives to cut less forest." However, a potential increase of productivity could create incentives to convert more natural land when an efficient farmer is in a context of relatively poor environmental valuation, as in the Brazilian Amazon, implying that this kind of farmer does not internalize the social cost of forest into their production decisions. This lack of internalization reduces the costs associated to the conversion option and efficient agricultural producers exploit extensive margins when they exist, before turning to intensive margins.

Moreover, Angelsen (1999) theoretically explains that in an open economy and an open access model where property rights are defined by forest clearance, such as in the case of the Brazilian Amazon, an increase in output productivity enhances agriculture expansion, i.e., deforestation. For instance, Pacheco (2009b, p. 40) argues that "wealthier farmers not only tend to deforest more in absolute terms but also show a slightly greater propensity to deforest whatever their production system" in the state of Pará in the Brazilian Eastern Amazon. Therefore, this study estimates a potential impact of productivity defined as technical efficiency

*This chapter is an adapted version of an article submitted to *Ecological Economics*.

on agricultural expansion, i.e., on deforestation, in the specific case of the Brazilian Legal Amazon, characterized by an open access to forested and "unproductive" lands as well as land concentration and an active regional development policy. As far as I know, only Jones et al. (1995) have empirically analyzed this effect in the Brazilian context. They find that the stock of cleared land is lower in farms with a higher productivity in cattle and cultivated land but that productivity has no effect on the pace of land clearing (Jones et al., 1995, p.179-180).

Thus, this chapter contributes to the understanding of the determinants of deforestation at the farm level. Browder et al. (2004) provide a review of the literature on these determinants at the farm level according to three different models: the neoclassical economic tradition (NET), the household life cycle (HLC) (Walker & Homma, 1996; Perz & Walker, 2002), and the political ecology approach. This study is more linked to the first model in which a farmer manages production in order to maximize utility under some constraints. In this model, agricultural land use (i.e., the level of deforestation) depends on the profitability of land conversion explained by some production variables (such as productivity, farm size, or output composition).

In this chapter, the effect of agricultural productivity on deforestation is estimated on census-tract-level data from the Censo Agropecuario 1995–1996[1]. This census permits of analyzing the behavior of each farm present in the BLA[2] between 1995–1996 and to avoid an aggregation bias. This data allows of estimating the level of technical efficiency thanks to the dis-aggregated data on agricultural activities. Then, to assess the link between deforestation and productivity, a two step method is implemented. In the first step, the technical efficiency is estimated from a stochastic production frontier model (Aigner et al., 1977). In the second step, the estimated technical efficiency is considered as a determinant of deforestation in a land use model following Chomitz & Gray (1996) and Chomitz & Thomas (2003). In this model, the effects of the determinants of land use are studied so that an increase in agricultural land is associated to deforestation.

This chapter is organized as follows. Section 2 briefly describes the Brazilian Legal Amazon and its historical background. The data, the stochastic production frontier model, and the land use model are discussed in Section 3. Section 4 analyzes the econometric results and is followed by a summary and concluding remarks in Section 5 which discusses the main results and tries to make some explanations linked to the Brazilian context.

6.2 Environmental efficiency and economic efficiency: the role of the institutional background

The Brazilian Legal Amazon (BLA) is an administrative area created in 1953 to reduce the relevant economic, demographic and natural heterogeneities in Brazil: in 2000, the BLA had 20 million inhabitants out of 170 million Brazilians in total (source: IBGE) on more than half of the territory, and contributed to only 6% of the Brazilian GDP (in 1995)[3]. These heterogeneities were more important before the implementation of development policies in the 60s. For instance, the BLA represented only 10% of the total population in 1980 against 13%

[1]The Brazilian Institute of Geography and Statistics (IBGE) conducted a more recent census in 2006 but data at the representative farm level is not yet available.

[2]The Brazilian Legal Amazon is an administrative area created in 1953 which regroups nine states: Acre, Amazonas, Amapa, Para, Rondõnia, Roraima and Tocantins (North region), Mato Grosso (Center-West region), and Maranhão (North-East region).

[3]Author's calculations from data provided by IPEADATA. See Andersen et al. (2002, pp. 50–54) for an overview of the GDP distribution within the BLA.

in 2007, and 5% of the GDP in 1980 against 8% in 2008. This relatively faster development of the BLA is mainly a result of regional development policies.

Regional development policies have mainly consisted of building roads, colonization, and land titling projects[4]. However, the regional development policy has been very much criticized due to an important deforestation. As a consequence of this policy, some 35 million ha were deforested between 1970 and 1995. In the mid-nineties, nearly 10% of the BLA area was deforested, compared to 2.5%, in 1975. During this period, according to the Brazilian National Institute of Space Research (INPE, Instituto Nacional de Pesquisas Especiais), the growth of deforestation was 18,000 km^2 per year, and the average annual land clearing was between 12,000 and 16,000 km^2. Moreover, the annual area cleared increased from 18,226 (in 2000) to 27,379 km^2 (in 2004) according to the INPE whereas, since 2005, the annual surface cleared decreases: from 18,759 (2005) to 11,224 km^2 (2007).

Brazilian regional development policy has influenced the economic behavior of farmers. However, the question is not so much whether this policy has increased agricultural efficiency but rather how this policy has changed conditions, i.e., how the opportunity cost associated to agricultural activities has been modified. By the way, beyond increasing deforestation by a colonization project, road networks, or infrastructure projects, regional development policies affect agricultural productivity by influencing agricultural modernization, the relation between agricultural inputs (Reis & Blanco, 1997), and so the trade-off between economic efficiency, i.e., productivity, and environmental efficiency, i.e., the preservation of forested plots. Several channels can be highlighted to explain this effect. For instance, improvements in market accessibility, lower rural wages, or a reduction in the prices of agricultural inputs (such as fertilizer and credit availability) modify the profitability of the agricultural option as well as the degree of substitutability/complementarity of the inputs. These changes can enhance extensive shifting cultivation and so deforestation, because agricultural activities are more profitable than conservative forestry activities.

Though development policies have influenced productive efficiency, two other specific features of the BLA have obviously shaped the relations between economic and environmental efficiency. First, forest land has a particular legal status. According to the 1988 Brazilian Constitution from the Statute of the Land of 1964, squatters, i.e., farmers with no legal titles, have the right to settle on undeveloped public or private lands (i.e., "unproductive" land or forest land), and to make private exploitation of them. In the Brazilian case, though public forest lands are actually *de jure* state property, they are *de facto* open access resources because of a lack or weakness of institutional arrangements to enforce government regulations (Fearnside, 2001). More precisely, squatters, using public land, by performing agricultural activities for at least one year can receive a right of usufruct, and are able to get full property rights after five years of continuing occupation. Moreover, squatters, exploiting private lands for five consecutive years without legal opposition from landowners, are able to obtain formal property titles (Cleary, 1993; Araujo et al., 2009). In this case, forest clearing and cultivation give farmers some claims to the land so that deforestation is viewed as an investment by farmers in open access forest resources. Agricultural lands and pasture are less vulnerable to invasions by squatters than forested lands in the BLA (Alston et al., 2000). In consequence, for a less efficient farmer, land is the input relatively more available, inciting him to use the more abundant factor (the land). This kind of problem could also influence the behavior of an efficient farmer with no constraint on using labor and capital inputs. He can actually increase land use in order to improve his profitability, given that the natural environment is less valued, i.e., he

[4] Andersen et al. (2002, Chap. 2) provide a complete review of the historical evolution of development policies in the BLA from the first phases in the 60s and 70s to the latest ones in the 90s and the 00s.

does not internalize the social value of the forest, due to the specific status of "unproductive" land, i.e., forest land. In this case, more efficiency could increase deforestation because land is a complement of labor and capital. Alternatively, in the context of a more valued environment, the internalization of the social value of the forest in farmers' production decisions increases the costs associated to the clearing option so that land is less used, though labor and capital can be increased for an efficient farmer. Therefore, in this context, the intensive margin will be used before the extensive one (Angelsen, 1999).

Second, another important issue in the Brazilian Legal Amazon which could influence land use choices and so the trade-off between economic efficiency and environmental efficiency is land concentration (Walker & Homma, 1996; Pereira, 2003). Until 1995, in the BLA, land distribution relied mainly on political connections so that, as noticed by Helfand & Levine (2004, pp. 247) "large farms may hold large amounts of undeveloped land for speculation, as a hedge against inflation or for prestige, and therefore do not use it efficiently for production"[5]. Alternatively, Pereira (2003) argue that small farmers do not have the right political connections for acquiring land, so that they must cultivate their plots in order to acquire them. Pereira (2003) argue that this situation relies on the fact that "land in Brazil has traditionally been not merely a factor of production but a reward for service and proximity to power, as well as a foundation for the accumulation and maintenance of more power and privilege." The system of land allocation thus creates an uneven land distribution in the BLA which, in turn, indirectly affects land use choices through actual farm sizes and agricultural productivity.

To resume, the Brazilian case, characterized by both an open access to forest resources and "unproductive" private plots, and land market imperfections, could shape and explain the relations between productive efficiency and environmental efficiency, i.e., the preservation of the forest.

6.3 Methodology and conceptual framework

6.3.1 Estimated technical efficiency with a stochastic production frontier model

Technical efficiency derives from a production frontier under the hypothesis that a non-optimal use of production factors by agricultural farmers, i.e., an X-inefficiency (Leibenstein, 1966), is the effect of labor and credit constraints[6].

Assuming that a farmer i uses inputs X to produce a single or a multiple output Y, a production function can be written to represent a particular technology: $Y_i = f(x_i)$, where $f(x_i)$ is a production frontier. On the frontier, the farmer produces the maximum output for a given set of inputs or uses the minimum set of inputs to produce a given level of output.

[5]In 1995, President Fernando Enrique Cardoso (1995–2002) launched an agrarian reform, continued by President Luiz Inácio Lula da Silva since 2002. This reform consists in "maintaining and stimulating a modern agricultural sector that finally produces for the best interests of the larger society, while using welfare programs, including land reform, to ameliorate the worst social effects of agricultural modernization and provide some relief to a conflict-ridden countryside" (Pereira, 2003, p.48). The policy's aim was to modernize the agricultural sector by allowing landless or small landowners to have or secure land.

[6]Farm productivity can be generally decomposed into two elements: a dynamic and a static one. The first element is related to technical progress and the second one to productive efficiency. To analyze the first element, it is necessary to have time series. The dataset does not allow us to have a temporal dimension so only the farm's productive efficiency can be analyzed. In fact, the 1985 census could have been used to give a temporal dimension but the 1995 census was completely different from previous censuses (see Andersen et al. 2002, pp. 45–47 for more details).

In standard microeconomic theory, there is no inefficiency in the economy implying that all production functions are optimal and all firms produce at the frontier. But if markets are imperfect, farmers can be pulled beneath the production frontier.

This output-oriented measure of technical efficiency (more output with the same set of inputs) gives the technical efficiency of a farmer i as follows:

$$TE_i(x, y) = [\max \phi : \phi y \leq f(x_i)]^{-1}, \tag{6.1}$$

where ϕ is the maximum output expansion with the set of inputs x_i.

This output-oriented measure of technical efficiency is estimated under three auxiliary hypotheses. Firstly, (6.1) is applied to an econometric model (Kumbhakar & Lovell, 2000, p.64):

$$Y_i = f(X_i; \beta).e^{-U_i}, \tag{6.2}$$

where Y_i is a scalar of output, X_i is a vector of inputs used by farmers $i = 1, \ldots, N$, $f(X_i; \beta)$ is the production frontier[7] and β is a vector of technology parameters to be estimated. U_i are non-negative unobservable random variables associated with technical inefficiency which follow an arbitrary distribution[8].

Secondly, a stochastic production frontier is used so that the error term has two components: random shocks V_i (not attributed to the relationship between inputs and output) and an inefficiency term U_i (Aigner et al., 1977; Meeusen & van den Broeck, 1977). Eq. (6.2) becomes

$$Y_i = f(X_i; \beta).e^{-U_i}.e^{V_i}, \tag{6.3}$$

where V_i represent random shocks which are assumed to be independent and identically distributed random errors with a normal distribution of zero mean and unknown variance. Under that hypothesis, a farmer beneath the frontier is not totally inefficient because inefficiencies can also be the result of random shocks (such as climatic shocks).

Since TE_i is an output-oriented measure of technical efficiency, a measure of TE_i is:

$$TE_i = \frac{Prod_{obs}}{Prod_{max}} = \frac{f(X_i; \beta).e^{-U_i}.e^{V_i}}{f(X_i; \beta).e^{V_i}} = e^{-U_i}. \tag{6.4}$$

Technical efficiency is then estimated using the stochastic frontier model given by (6.3) and (6.4).

Thirdly, the production function is modeled using a transcendental logarithmic ("translog") specification (Diewert, 1971). The translog specification is preferred to the Cobb–Douglas form because of its flexibility implying no restrictions on a coefficient's substitutability (factor substitutability is equal to one in the Cobb–Douglas case)[9].

[7] The production frontier has the traditional properties of monotonicity, continuity and concavity (Fuss & McFadden, 1978, p.226-227).

[8] It can be either a half-sided normal distribution or an exponential one.

[9] A likelihood ratio test (LR) was implemented in order to test the functional form of the production function. In all tests, restrictions can be rejected at a very low confidence level so that the translog specification can be preferred. Details available upon request.

The general form of the traditional translog is as follows (Christensen et al., 1971)[10]:

$$ln(Y_i) = \beta_0 + \sum_{j=1}^{4} \beta_j ln(X_{ij}) + \frac{1}{2} \sum_{j=1}^{4} \sum_{k=1}^{4} \beta_{jk} ln(X_{ji}) ln(X_{ki}) - U_i + V_i, \tag{6.5}$$

where $i = 1, \ldots, N$ are the farmer unit observations; $j, k = 1, 2, \ldots, 4$ are the applied inputs; $ln(Y_i)$ is the logarithm of the output of farmer i; $ln(X_{ij})$ is the logarithm of the jth input applied of the ith individual; and β_j, β_{jk} are parameters to be estimated[11].

The final empirical model estimated in the translog case is:

$$\begin{aligned} Output_{i,c} = \beta_0 + \beta_1.Labor_{i,c} + \beta_2.Land_{i,c} + \beta_3.Livestock_{i,c} + \beta_4.Purchased_{i,c} \\ + \beta_5.Labor^2_{i,c} + \cdots + \beta_9.Labor_{i,c} * Land_{i,k} + \cdots + \lambda - U_{i,c} + V_{i,c}, \end{aligned} \tag{6.6}$$

which represents the relationship between the output and inputs of farmer i in county c and where λ is a state fixed effect to control for common features shared by farmers in the same state (land quality, climate, policy...)[12].

The output is an aggregated output variable from animal production (cattle, chickens...), to crop production (soybean, corn, coffee...) and plant production (forestry, horticulture...). It is the gross value of agricultural output (for more details see 6.A.1)[13].

Four inputs are taken into account (see the descriptive statistics in Table 6.5, p.187, and 6.A.1 for *Labor* and *Livestock* inputs). *Labor* includes all the persons who work on the farm. There are both family and hired labor and all are measured in full-time equivalent units. *Livestock* is the stock of animals in cattle equivalents. *Land* represents the total area (in hectares) of the farm. All kinds of land are aggregated: crops, pasture, productive land that was not being used (fallow), but also land which was not used for agricultural purposes (forest, woodland, and useless land). *Purchased* inputs are expenditures on feed and medicine for animals, fertilizers, chemicals (such as pesticides and herbicides), seeds, and fuels[14].

Finally, the maximum likelihood estimator is used to estimate the technical efficiency both under a half-normally distributed efficiency and under an exponentially distributed one[15]. Moreover, there could be proximity effects in such survey data implying correlations between farmers' behaviors within the same area. Thus, error terms may be spatially correlated, so that the coefficients may be biased. To avoid this, the error terms are bootstrapped (200 replications) (Wooldridge, 2002, p. 378-379).

[10] A negative sign is used in order to show that the term $-U_i$ represents the difference between the best efficient farm (on the frontier) and the observed farm.

[11] Similarity conditions are imposed, i.e., $\beta_{jk} = \beta_{kj}$. Moreover, the production frontier requires monotonicity (first derivatives, i.e., elasticities between 0 and 1 with respect to all inputs) and concavity (second derivatives negatives). These assumptions should be checked *a posteriori* by using the estimated parameters for each data point.

[12] County fixed effects would have been a better way to control for common factors but the estimation of the stochastic frontier model does not work with too many variables.

[13] This is not the added value but the output because intermediary inputs are used in the model.

[14] The number of tractors (in equivalent 75 hp) had been introduced but then removed since it does not respect theoretical assumptions of monotonicity and concavity. However, the results do not change with this input. Results available upon request.

[15] Estimations are made using Stata 10 and the command *frontier*.

6.3.2 A land use based deforestation model

The analysis of deforestation is done following a land conversion model (Chomitz & Gray, 1996). The basic assumption of this model is that each farmer allocates their plot either to an agricultural activity or leaves it uncleared, i.e., under forest. Therefore, the use may be agricultural (annual or peri-annual harvest, livestock, fallow, or planted forest) or natural (the land remains natural, i.e., natural forest or natural pasture).

Under that hypothesis, the propensity to clear land, i.e., the proportion of deforested land (p), depends on the potential profits ($\pi(X)$) per hectare from converting natural land to agricultural use. The potential profit depends on X, a vector of farm level explanatory variables.

The following equation is the reduced form of the model which is estimated using a Tobit estimator (Chomitz & Gray, 1996; Dolisca et al., 2007):

$$p^*_{i,c} = \alpha X_{i,c} + \vartheta_{i,c}, \tag{6.7}$$

where $p^*_{i,c}$ is a latent variable: the propensity to convert natural land into agricultural ones for farmer i in county c explained by $X_{i,c}$, a set of explanatory variables influencing the potential profit. $\alpha = (\alpha_1 \dots \alpha_k)'$ is a vector of unknown parameters and $\vartheta_{i,c}$ is the error term. The dependent variable is latent, i.e., cannot be observed for $p^*_{i,c} < 0$, so we have[16]:

$$p_{i,c} = 0 \quad if \quad p^*_{i,c} \leq 0$$
$$p_{i,c} = p^*_{i,c} \quad otherwise,$$

where $p_{i,c}$ is the observed dependent variable.

Finally, the estimated model is

$$p_{i,c} = \alpha_0 + \alpha_1 TE_{i,c} + \alpha_2 TE^2_{i,c} + \alpha_3 Size_{i,c} + \sum \alpha_k X^k_{i,c} + \varepsilon_{i,c}, \tag{6.8}$$

where the observed dependent variable, $p_{i,c}$, is the agricultural land ratio of farmer i in county c defined as the ratio between agricultural land uses (crops, cattle, planted pasture, short fallow) and all land uses. When $p_{i,c}$ equals 1, the farmer uses all the land for agriculture. TE is the technical efficiency estimated from the stochastic production frontier model. *Size* represents the average size of each individual farm in the representative farm. It is a coded variable defined in the Table 6.3, p.186[17]. X is a set of covariates (see the descriptive statistics in Table 6.5, p.187): *land tenure* (owners (62%), sharecroppers (26%), renters (9%) and occupants (3%), see Table 6.4, p.186 for more details), *output composition* (peri-annual crops, annual crops, plant production, animals...), *public goods* (cooperative, financing, technical assistance, and electricity) and the last category focuses on *technology* (artificial insemination, irrigation, soil conservation...). This last category allows of controlling for some credit and capital market imperfections.

The effect of TE on agricultural land uses has not been unambiguously established in the literature. It is often concluded that intensive farms deforest less that extensive ones. However, in the Brazilian case, even an efficient farm could exploit at the extensive margin before the intensive margin. Thereby, a more efficient agricultural unit deforests more than a less efficient one. Hence, TE could increase the ratio of agricultural use, i.e., α_1 could be positive. However,

[16] Farmers with unprofitable areas belong to the same group, i.e., the observed dependent variable is censored at 0.

[17] All farms in the 16th code (only 0,02% of all farms) are dropped because these farms do not declare their size.

if the sign is negative (other things equal, including agricultural land), it is expected that increasing efficiency curtails deforestation. In other words, an inefficient farm would have an extensive production.

Moreover, the relationship between technical efficiency and deforestation may be a **U**-shape in the Brazilian context characterized by a *de facto* open accessed "unproductive" private plots and forested land: i) a poorly efficient farm compensates for these inefficiencies by increasing the relatively more abundant factor, i.e., land; ii) a more efficient farmer could use this efficiency to invest and acquire new land. This non-linear effect is introduced with the term TE_i squared. A positive α_2 induces a **U**-shaped effect and therefore a strong effect on deforestation both when efficiency (inefficiency) is low (high) and high (low). In this case, the relevant question is actually to know whether an efficient farmer with an intensive production will stop expansion or accelerate deforestation (Angelsen & Kaimowitz, 2001) and so whether extensive margins, when they exist, are exploited before turning to intensive margins. This kind of situation could occur in the Brazilian case characterized by an openly accessed forest land as well as "unproductive" land in which an increase in agricultural technical efficiency enhances agriculture expansion, i.e., deforestation (Angelsen, 1999).

Among the control variables, the effect of farm size could be expected to be negative in the Brazilian context. Indeed, small farmers could have a high discount rate which induces them to use more land[18]. Agricultural producers use the most abundant factor if they are relatively more constrained in the use of other factors (Boserup, 1965; Angelsen & Kaimowitz, 2001). Moreover, another interesting explanation of this negative effect could be found in the specific Brazilian context of an uneven land distribution driven by the political scheme (Pereira, 2003; Andersen et al., 2002). In fact, large farmers can receive land from the state without paying for it, then they receive fiscal incentives to produce, but they produce anything and they simply hold the land without paying for it (Pereira, 2003, p.56). In this context, small farmers have to acquire land titles by developing the land, living on it, and cultivating it (Andersen et al., 2002, p.32).

However, there is another important issue concerning land quality which could affect both technical efficiency and the farmer's choices of how much to deforest. To control for land quality, the propensity for a farmer to use irrigation and conservation, which could indirectly be correlated with land quality, is used. County fixed effects also allow of controlling for this, since land quality is more a spatial feature shared between farmers in the same area (here, the county). Moreover, county fixed effects are also introduced in order to control for transportation costs, climate features (for instance, precipitation levels), and the abundance of land, which can differ for farmers due to their spatial location.

Finally, two statistical problems arise in the estimation of these land use determinants: spatial correlation and generated regressor bias. Firstly, spatial correlations could emerge in such survey data analysis (Deaton, 1997). Indeed, households in a single cluster (for example the county) live near one another, and are often interviewed at the same time (survey teams are often in one county at the same time). Moreover, farmers in the same county are engaged in comparable agricultural activities because of comparable soil qualities, pests, weather effects, and so on. Estimates are thus liable to this spatial correlation: inefficient estimation may be suspected. A clustering approach allows of considering that all farmers in the same county are spatially correlated. So, this allows of dealing with the similarity between people within the same cluster (municipality). In addition, county fixed effects are used. Secondly, the use of the estimated technical efficiency creates a potential generated regressor bias which could downward bias the standard errors estimated. However, Pagan (1984) (Theorem 7, p.233)

[18] These farmers do not take into account the negative long term effects of an extensive land use on productivity.

shows that estimates of the variance of the residuals used, such as the regressor (here technical efficiency), are correct, i.e., the standard errors of technical efficiency are efficient[19].

6.3.3 The dataset

The dataset comes from the *Censo Agropecuário* that was conducted between 1995 and 1996 by the Brazilian Institute of Geography and Statistics (IBGE-Instituto Brasileiro de Geografia e Estatística). The census covers the Legal Amazon made up of all the states in the Northern region of Brazil plus parts of the states of Maranhão and Mato Grosso. However, though some states are fully covered by tropical forest (such as Amazonas and Acre) and others are partially covered by tropical woods (Mato Grosso and Maranhão), every agricultural conversion of a natural area is considered as deforestation[20]. Though there is not the same impact in terms of cleared trees, there is the same consequences in terms of biodiversity because "transitional areas are just [as] valuable as the dense forest in terms of both biodiversity and biomass record stored" (Andersen et al., 2002, p.12-13).

The dataset consists of "representative farms" established at the county level and of which the characteristics vary according to size (15 classes) and land tenure (owner, sharecropper, renter, or occupant). More precisely, all farms having both the same size and the same land tenure, and being located in the same county, are grouped together. The construction of representative farms reduces the total number of farms from 893,129 to 14,724.

6.4 Results

6.4.1 Technical efficiency estimation

The first part of the study concerns the econometric estimation of technical efficiency with a translog specification. In order to use technical efficiency in the land use model, two assumptions have to be fulfilled. The first one relies on the relevance of the model and the second one on the significance of technical efficiency.

First, the model has to be relevant. Hence, the theoretical consistency of the estimated efficiency model is checked by verifying that the marginal products are positive and decreasing (monotonicity). In other words, if these theoretical criteria are jointly empirically validated, then the obtained efficiency estimates are consistent with microeconomic theory and can be used as determinants in the land use model. As the coefficients of the translog functional form do not allow of any direct interpretation of the magnitude and significance of individual output elasticities, the latter were computed for all inputs at the sample mean (from the coefficients of column 6)[21]. Brazilian agricultural production depends more strongly on purchased inputs (0.65) and labor (0.39). These findings suggest that efficiency gains are most likely with respect

[19] Two conditions are necessary: i) the residuals of the two equations have to be independent, and ii) the predicted variable in the first equation has not to be used (here the predicted output).

[20] For instance, a farm in Mato Grosso which converts a savannah area into an agricultural area has the same impact on deforestation that a farm in Acre which converts a tropical forest area into an agricultural area.

[21] The coefficients estimated in the translog specification are not the input's elasticity and so the result cannot be easily interpreted as in the constant-elasticity Cobb–Douglas case. The elasticities of mean output with respect to the jth input variable is calculated at the means of the log of the input variable and their second order coefficients as follows:

$$\frac{\delta lnY}{\delta X_j} = \beta_j + 2.\beta_{jj}\overline{lnX_j} + \Sigma^4_{j\neq k}\beta_{jk}\overline{lnX_k}. \tag{6.9}$$

to purchased inputs and labor[22]. Moreover, the model seems to be correctly specified because the returns to scale are positive (in all specifications)[23] and the condition of monotonicity seems to be fulfilled[24]. Thereby, the production technology and inputs used are relevant to estimate technical efficiency.

Second, technical efficiency is significant in all regressions, suggesting that the translog stochastic production frontier seems to be relevant to estimate technical efficiency and so for use in the land use model. However, as a robustness check, two different distributions for efficiency are used which could generate heterogeneities in the estimation of technical efficiency. Indeed, the share of half-normally distributed efficiency in the random deviation is more important than the share of an exponentially distributed one and the average is lower for a half-normally distributed efficiency (0.56) than for an exponentially distributed one (0.66). Hence, the choice of the estimated efficiency could influence the results in the land use model. Thus, to deal with this heterogeneity and choose between a half-normally distributed efficiency and an exponentially distributed one, Spearman's rank correlation coefficients and measures for comparing maximum likelihood models are used. First, Spearman's coefficient between the two possibilities of the distribution of efficiency is 0.99 suggesting small differences between the two estimated technical efficiencies. Second, from both the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC), the exponential distribution is preferred to the half-normal one in all specifications[25].

6.4.2 Land use determinants

This subsection presents the results for the effect of economic efficiency, i.e., technical efficiency, on environmental efficiency, i.e., natural land conversion at the farm level. Before turning to the presentation of the main results, the potential endogeneity of technical efficiency due to the potential simultaneity between technical efficiency and the propensity of land clearing is discussed. Actually, the farmer's propensity for clearing land could be determined simultaneously with the farmer's choice of technologies and inputs. For instance, a farmer could be inefficient because he does not use all his available lands, or an efficient farmer produces efficiently due to his relatively better land uses. However, this situation is not obvious because technical efficiency does not imply a higher land use but a better combination of each input to produce more[26]. Despite this explanation, Spearman's rank correlation tests between the residues and technical efficiency are presented (see Table 6.2) for each regression. In all cases (except in the first column without non linearities), the two variables are uncorrelated. Hence, the problem of endogeneity should not change the results.

The first column shows the linear effect of technical efficiency that follows an exponential law. Technical efficiency has a positive and significant effect so that more efficient farms convert more natural areas into agricultural land.

[22] At the sample mean, the marginal productivity of livestock is 0.04 whereas at the mean sample, the marginal productivity of size is negative. This result does not validate the theoretical predictions but seems to be relevant in the Brazilian case. In fact, land is more a political or illegal attribute than an economic input suggesting that it does not contribute normally to agricultural production (Pereira, 2003).

[23] The returns to scale are respectively about 1.03 at sample mean, 0.92 at minimum sample and 1.52 at maximum sample (from the coefficients of column 6).

[24] The conditions of monotonicity on labor, cattle, purchased inputs, and size are fulfilled for, respectively, 82%, 63%, 79%, and 100% of farmers (from the coefficients of column 6).

[25] These results also hold in the Cobb–Douglas case. Details available upon request.

[26] This problem could occur because land is an input which is, in turn, used to estimate technical efficiency. However, technical efficiency is in the error term in the stochastic production frontier model so that it has to be uncorrelated with explanatory variables such as land.

The second column shows a non-linear effect of efficiency but without county fixed effects to test the hypothesis of the abundance of land. Efficiency squared has a positive and significant coefficient at the one percent level and the additive term of technical efficiency is negative, implying a **U**-shaped effect of technical efficiency on agricultural land use. Moreover, these results arise without county fixed effects suggesting that agricultural conversion is not driven by county fixed effects and so not by natural areas surrounding farms. Thus, the abundance of the stock of natural land does not seem to condition the effect of technical efficiency on agricultural expansion.

The third column is the preferred specification and considers a non-linear effect of efficiency with county fixed effects. The **U**-shaped effect of technical efficiency remains robust. A one percent increase in efficiency induces an increase of nearly 0.02% in the agricultural land ratio[27]. Moreover, an increase of 10% in the mean efficiency (from 0.66 to 0.73) implies an increase of nearly 0.86% in the agricultural ratio[28].

Further, the reversal point is obtained for an efficiency of 0.61 suggesting an optimal efficiency to reduce agricultural land ratio[29]. Moreover, only 25% of farms have an efficiency lower than 0.61. Thus, many farms are on the ascendant slope implying that technical efficiency induces more agricultural conversion of natural areas.

In column 4, a half-normally distributed technical efficiency is introduced. The **U**-shaped effect of efficiency remains significant.

Finally, in all regressions, farm size has a negative and significant effect suggesting that small farms convert more natural land into agricultural land than do large farms. In column 3, for instance, a one standard deviation average increase in farm size decreases the agricultural land ratio by 0.03. Small farms have actually more constraints than large ones, inciting them to use the relatively more abundant factor (land). More precisely, a small farmer could have a high discount rate pushing them to favor short term activities (Boserup, 1965; Angelsen & Kaimowitz, 2001). The uneven land distribution in the BLA could particularly well explain this result (Pereira, 2003; Andersen et al., 2002). Small farmers do not have not the right political connections for acquiring land, so that they must cultivate their plots in order to acquire them[30]. Another explanation relies on the problem of *de facto* openly accessed "unproductive" private land which could incite small farmers to convert their "unproductive" land, i.e., natural land, into agricultural plots in order to reinforce their rights.

Besides, renters, sharecroppers, and illegal occupants convert more natural land than owners. This result implies that property rights allow of reducing deforestation, i.e., an owner is more likely to implement more long term activities (Mendelsohn, 1994). It is also found that temporary crops (soybeans) and cattle activities are the two main types of production which increase agricultural land conversion (Caviglia-Harris, 2005). Lastly, the status of being a cooperative and the funds received by farmers are found to reduce agricultural pressure on natural land (Margulis, 2003).

[27] We have at the mean efficiency, $\frac{\delta.ratio}{\delta.efficiency} = \delta.efficiency + 2 \times \delta.efficiency^2 = -0.228 + 2 \times 0.186 \times eff.mean = 0.02$; where the coefficients are elasticities and $eff.mean$ is the mean of the technical efficiency.

[28] With the coefficients of column 3 of Table 6.2, p.184 and after transformation in order to have elasticities, we have: $\Delta ratio = [1.068 - 0.228 \times 0.73 + 0.186 \times 0.73 \times 2] - [1.068 - 0.228 \times 0.66 + 0.186 \times 0.66 \times 2] = 0.01$ or an increase of 0.86% in the agricultural ratio.

[29] Around this level of efficiency, a marginal increase of efficiency does not increase agricultural expansion.

[30] The Brazilian agrarian reform developed by President Fernando Henrique Cardoso (1995–2002) starting from 1995–1996 can not be analyzed with the results found in this chapter.

6.5 Summary and concluding remarks

The aim of this chapter is to study the trade-off between agricultural efficiency and environmental efficiency by assessing the effect of farm technical efficiency on deforestation using census-tract-level data from the Censo Agropecuario 1995–96. This census allows us to analyze the behavior of each farm present in the Legal Amazon between 1995–1996. A two step approach is implemented to assess this link. The first one is to estimate technical efficiency with a stochastic production frontier model and the second one is to use this estimated efficiency in a land use model in order to study the determinants of deforestation, defined as agricultural land ratio, at the farm level.

The results suggest that technical efficiency has a **U**-shaped effect on agricultural land conversion: less and more efficient farms both convert more natural areas into agricultural land. On the one hand, less efficient farms have relatively more labor and credit constraints due to the fact that land is more available in the BLA context in which forest land and "unproductive" plots are openly accessed, and so are more incited to use the more abundant factor (the land). For those farmers, land inputs are substitutes for the other relatively more constrained inputs to extend production. On the other hand, the more efficient farms have fewer constraints. They could use more optimally labor and capital, inciting them to use more land in a low valued environment. For efficient farmers, land is complementary to labor and capital. Moreover, the reversal point is found to be an efficiency ranging from 61% but less than 25% of Brazilian farmers in Legal Amazon had a technical efficiency lower than 61% in 1995–96. Thus, the majority of farms are on the ascendant slope implying that Brazilian farmers convert more natural land into agricultural plots when their efficiency increases. This result could be explained by the poor environmental valuation of Brazilian tropical forest land, resulting in a lack of internalization of the social value of forested land into farmers' production decisions, and the problem of de facto openly accessed "unproductive" private lands which pushes farmers to exploit their extensive margins before their intensive ones (Angelsen, 1999).

Overall, the poor environmental valuation, the uneven land distribution in the BLA, and the problem of *de facto* openly accessed forest land and "unproductive" private plots, mainly explain the **U**-shaped effect of technical efficiency on the conversion of natural land into agricultural plots.

In this sense, an important improvement would be to use the new census 2005–2006 of IBGE. It would be interesting to have information on agricultural activities after Avança Brasil to study if this development policy, conducted after the 1995 census, has allowed of improving the environmental valuation of Brazilian tropical forest as well as whether agrarian reforms, implemented after 1995 in the regional development policy, have contributed to reduce land concentration[31].

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[31]Recently, Brazil's climate change plan, adopted in 2008 and implemented in 2009 by President Lula, attempted to reduce global warming by stimulating high efficiency, maintaining a high proportion of renewable energy in electricity production, encouraging the use of biofuels in the transportation sector, and reducing deforestation. In this last issue, the goal is to drastically downsize illegal deforestation and then to eliminate the net forest loss in 2015 (a tree planted for a tree cut). This plan influences obviously on farmers' production decisions but neither the 2006 census or the 1995 census could be used to study this issue.

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6.6 Tables of results

Table 6.1: Estimation of technical efficiency (TE) with the translog specification

Dependent variable: aggregated output						
Distributional form (TE)	half-normal	half-normal	half-normal	exponential	exponential	exponential
	1	2	3	4	5	6
Cattle	0.1***	0.1***	0.127***	0.11***	0.11***	0.134***
	(0.014)	(0.021)	(0.017)	(0.014)	(0.023)	(0.019)
Labor	0.709***	0.709***	0.696***	0.683***	0.683***	0.672***
	(0.02)	(0.021)	(0.023)	(0.019)	(0.021)	(0.023)
Surface	0.18***	0.18***	0.165***	0.169***	0.169***	0.155***
	(0.015)	(0.019)	(0.02)	(0.014)	(0.023)	(0.02)
Purchas. inputs	-.004	-.004	-.010	-.004	-.004	-.009
	(0.01)	(0.013)	(0.013)	(0.009)	(0.011)	(0.011)
Cattle^2	0.06***	0.06***	0.057***	0.065***	0.065***	0.059***
	(0.004)	(0.006)	(0.006)	(0.004)	(0.007)	(0.006)
Labor^2	0.087***	0.087***	0.085***	0.101***	0.101***	0.097***
	(0.007)	(0.008)	(0.007)	(0.006)	(0.007)	(0.007)
Surface^2	-.019***	-.019***	-.018***	-.016***	-.016***	-.015***
	(0.004)	(0.006)	(0.006)	(0.004)	(0.006)	(0.006)
Purchas. inputs^2	0.082***	0.082***	0.085***	0.084***	0.084***	0.088***
	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)
Cattle*Labor	-.100***	-.100***	-.076***	-.112***	-.112***	-.082***
	(0.008)	(0.011)	(0.011)	(0.008)	(0.012)	(0.009)
Cattle*Surface	-.021***	-.021**	-.021**	-.025***	-.025**	-.023***
	(0.006)	(0.009)	(0.009)	(0.006)	(0.01)	(0.009)
Cattle*Purchas. inputs	-.024***	-.024***	-.030***	-.024***	-.024***	-.031***
	(0.004)	(0.006)	(0.006)	(0.004)	(0.006)	(0.005)
Labor*Surface	0.047***	0.047***	0.036***	0.051***	0.051***	0.038***
	(0.007)	(0.009)	(0.009)	(0.007)	(0.01)	(0.009)
Labor*Purchas. inputs	-.098***	-.098***	-.108***	-.103***	-.103***	-.115***
	(0.006)	(0.007)	(0.007)	(0.006)	(0.007)	(0.007)
Surface*Purchas. inputs	-.013***	-.013**	-.009	-.013***	-.013**	-.009
	(0.004)	(0.005)	(0.006)	(0.004)	(0.006)	(0.006)
Constant	6.161***	6.161***	6.034***	6.027***	6.027***	5.899***
	(0.045)	(0.061)	(0.06)	(0.042)	(0.048)	(0.056)
Observations	14201	14201	14201	14201	14201	14201
χ^2 statistic	86783.99	120499.8	123410.6	96915.27	143606.6	98098.48
Log-likelihood	-17583.57	-17583.57	-17246.06	-17158.9	-17158.9	-16768.81
Sig-u (TE.)	0.89	0.89	0.912	0.514	0.514	0.523
Sig-v (errors.)	0.647	0.647	0.612	0.638	0.638	0.606
$H_0 : sigma_u = 0$	470.201***	470.201***	599.259***	1319.54***	1319.54***	1553.772***
AIC criteria	35,140.6	35,140.6	34,542.1	34,297.3	34,297.3	33,532.9
BIC criteria	35,314.4	35,314.4	34,731.2	34,471.2	34,471.2	33,767.3
Bootstrap.	no	yes	yes	no	yes	yes
Dummy "State"	no	no	yes	no	no	yes

Estimation method: Maximum likelihood estimator with standard errors given in parentheses (clustered by county). Standard errors bootstrapped (200 rep.). $*$: Significant at 10% level; $**$: significant at 5% level; $***$: significant at 1% level. Eqs. (1)–(6) differ by the distributional form of TE, the use of state fixed effects, and the bootstrapping approach.

Table 6.2: Land use determinants

Dependent variable: Agricultural land ratio				
Distributional form of efficiency	exponential	exponential	exponential	half-normal
	1	2	3	4
Efficiency (TE)	0.054***	-.197**	-.231***	-.209***
	(0.018)	(0.09)	(0.071)	(0.074)
Efficiency squared (TE^2)		0.247***	0.272***	0.285***
		(0.086)	(0.067)	(0.074)
Size	-.046***	-.052***	-.047***	-.047***
	(0.001)	(0.001)	(0.001)	(0.001)
Land tenure (relative to owner)				
Renter	0.078***	0.114***	0.076***	0.076***
	(0.009)	(0.009)	(0.009)	(0.009)
Sharecropper	0.064***	0.09***	0.062***	0.062***
	(0.01)	(0.011)	(0.01)	(0.01)
Occupant	0.009	0.016**	0.009	0.009
	(0.006)	(0.007)	(0.006)	(0.006)
Type of production (relative to cattle)				
Temporary crop	0.049***	0.052***	0.047***	0.047***
	(0.016)	(0.019)	(0.016)	(0.016)
Permanent crop	0.0009	-.044**	-.004	-.004
	(0.019)	(0.022)	(0.019)	(0.019)
Plant	-.144***	-.284***	-.150***	-.151***
	(0.022)	(0.03)	(0.022)	(0.022)
Hog-chicken	-.068***	-.076***	-.075***	-.075***
	(0.022)	(0.027)	(0.022)	(0.022)
Other animals	-.071	-.310***	-.074	-.074
	(0.055)	(0.062)	(0.054)	(0.054)
Public goods				
Cooperative	-.008	-.015*	-.007	-.006
	(0.005)	(0.008)	(0.005)	(0.005)
Tech. assist.	0.01*	-.014*	0.01*	0.01*
	(0.005)	(0.007)	(0.005)	(0.005)
Electricity	0.035***	0.058***	0.035***	0.035***
	(0.006)	(0.007)	(0.006)	(0.006)
Financing	-.002***	-.002**	-.002***	-.002***
	(0.0006)	(0.0008)	(0.0006)	(0.0006)
Technology				
Fertilizer	0.012**	0.015*	0.013**	0.013**
	(0.006)	(0.008)	(0.006)	(0.006)
Pest control	0.022**	0.051***	0.021**	0.022**
	(0.009)	(0.01)	(0.009)	(0.009)
Soil conservation	0.032***	0.048***	0.032***	0.032***
	(0.006)	(0.007)	(0.006)	(0.006)
Artif. insemination	-.057***	-.044***	-.056***	-.056***
	(0.008)	(0.009)	(0.008)	(0.008)
Irrigation	-.017***	-.004	-.017***	-.017***
	(0.005)	(0.007)	(0.005)	(0.005)
Mechanical force	0.035***	0.059***	0.035***	0.035***
	(0.005)	(0.007)	(0.005)	(0.005)
Constant	0.997***	0.948***	1.070***	1.063***
	(0.019)	(0.033)	(0.027)	(0.026)
Observations	14201	14201	14201	14201
Log likelihood	3592.906	794.168	3609.739	3613.507
Spearman coefficient	0.025***	0.003	0.003	0.002
Dummy	County	No	County	County

Estimation method: Tobit estimator with robust standard errors given in parentheses (clustered by county). $*$: Significant at 10% level; $**$: significant at 5% level; $***$: significant at 1% level. Col. 1 tests for linearity effect of TE and Cols. 2–4 test for **U**-shaped effect of TE. Spearman coefficient displays the Spearman's rank correlation coefficients for residuals and TE, and the following test: Ho = residuals and TE are independent.

6.A Appendix

6.A.1 Presentation of the main variables

Output variable The output variable is defined as animal production, crop production, and plant production. Animal production is an aggregated value of the production of cattle, pigs, chickens, horses, sheep and goats, and other animals. However, the value of the purchase of animals (mainly cattle, pigs, and chickens) is deducted to reflect the fact that these animals can also be a source of inputs and not be recognized as a produced value. Crop production is divided between temporary production such as wheat and soybeans (85%) and permanent production such as coffee and bananas (15%). Plant production includes forestry (10%), plants (horticulture, 12%) and all productive plant extractions (78%). The output of each farm is represented in *reais* and transformed into logarithm.

Labor variable This variable includes all the persons who worked in the farm during the census. There were both family and hired labor and all were measured in full-time equivalent units. We recorded a child under 14 years as half of an adult and a person in temporary employment as three quarters of a permanent worker. Permanent employees over 14 years were recorded as an adult family member working full time in the farm. Finally, a child (under 14) working temporarily in the farm received a double weight (38% (0.75*0.5) of a permanent worker). This variable was then logarithmically transformed.

Livestock variable The livestock in cattle equivalents is used. We aggregated livestock from the relative prices of each type of animal, calculated from the database on the movements of purchases and sales of animals. For each type of animal, a weighting factor was computed as the ratio between the price of a head of that animal and the price of a head of cattle (as reference). For example, given that the price of a horse and the price of a cattle head were respectively 248.4 *reais* and 190.88 *reais*, the weighting factor was 0.77 for a horse (5.18: pigs, 209.76: chickens, 9.21: sheep and goats). Then, the stock of each animal was multiplied by its weighting factor and then each stock was added in order to have the livestock variable in cattle equivalents (and then its logarithm was taken).

6.A.2 Descriptive statistics

Table 6.3: Size variable

Total area (hectare, ha)	Code	Total area (hectare, ha)	Code	Total area (hectare, ha)	Code
Less than 1 ha	1	Between 1 and 2	2	Between 2 and 5	3
Between 5 and 10	4	Between 10 and 20	5	Between 20 and 50	6
Between 50 and 100	7	Between 100 and 200	8	Between 200 and 500	9
Between 500 and 1,000	10	Between 1,000 and 2,000	11	Between 2,000 and 5000	12
Between 5000 and 10,000	13	Between 10000 and 100,000	14	More than 100,000	15
Without notification	16				

Table 6.4: Descriptive statistics of land tenure

Land tenure	Ratio			Size (code)			Output (reais)		
	Mean	Median	Stand. dev.	Mean	Median	Stand. dev.	Mean	Median	Stand. dev.
Owner	0.73	0.81	0.25	7.26	7	3.65	126,912	525,935	1,706,901
Renter	0.86	1	0.25	5.18	5	2.94	8,655	115,633	922,843
Sharecropper	0.82	1	0.27	4.78	4	2.86	4,547	37,970	120,615
Occupant	0.76	0.9	0.29	5.42	5	2.88	108,325	15,893	369,881

Table 6.5: Descriptive statistics

Variables	Mean	Standard deviation	Median	Min	Max
		Stochastic production frontier model			
Output (Reais)	321,856	1,318,644	42,847	1	61,815,322
Cattle (Nbr)	2,750	7,671	174	0	171,521
Labor (Nbr)	255	611	52	1	16,562
Surface (ha)	8,361	33,800	372	0.002	1,574,492
Purchased inputs (Reais)	62,436	500,142	2,518	0	27,417,804
		Technical efficiency			
Half-normal distribution	0.56	0.58	0.14	0.004	0.950
Exponential distribution	0.66	0.70	0.15	0.0001	0.956
		Land use model			
Ratio	0.67	0.29	0.70	0	1
Size (coded variable)	6.24	3.46	6	1	15
Owners (=1)	0.52	0.50	1	0	1
Renters (=1)	0.13	0.34	0	0	1
Sharecropper (=1)	0.09	0.29	0	0	1
Occupant (=1)	0.26	0.44	0	0	1
Peri-annual crop (Reais)	151,491	1,139,290	8,200	0	61,048,403
Permanent crop (Reais)	26,475	127,743	1,027	0	5,287,537
Plant (Reais)	32,711	333,378	1,204	0	31,489,928
Cattle (Reais)	114,310	357,221	4,435	0	8,867,316
Hog and chicken (Reais)	21,184	177,456	1,706	-365,042	9,705,833
Other animals (Reais)	3,013	19,485	0	0	789,220
Financing (Reais)	25,623	241,833	0	0	1,108,2574
Cooperative (=1)	0.25	0.43	0	0	1
Tech. assist. (=1)	0.49	0.5	0	0	1
Electricity (=1)	0.60	0.49	1	0	1
Fertilizer (=1)	0.49	0.50	0	0	1
Pest and disease control (=1)	0.83	0.38	1	0	1
Soil conserv. (=1)	0.27	0.42	0	0	1
Insemination (=1)	0.78	0.41	1	0	1
Irrigation (=1)	0.17	0.38	0	0	1
Meca. force (=1)	0.46	0.50	0	0	1

Chapter 7

Ecological fiscal incentives and spatial strategic interactions*

7.1 Introduction

Development Policies implemented in Brazil from the late 60's to the mid 80's were considered as "very aggressive with little regard to the environment." However, the growing interest of the international community for environmental problems and the worsening of the economic situation in Brazil led to a change in this in the late 80's (Andersen et al., 2002). Indeed, several programs sprang up with the purpose of promoting sustainable development (see Feres & da Motta (2004) on water management). This change was of the utmost importance since Brazil is recognized as a major reserve of forests and biodiversity. Myers et al. (2000) point out that Brazil is estimated to host one-sixth of the endemic plant species of the Earth, to cite but just one example.

Among the programs developed to promote sustainable development, the ICMS-Ecologico or ICMS-E ("*Imposto sobre Circulacão de Mercadorias e Servicos - ecológico*" or "*Ecological value added tax*") is of particular interest. It is a fiscal transfer mechanism implemented in order to promote land conservation at the local level. It is not only designed for Amazonian states[1] but also aims at protecting Atlantic forests, threatened by fragmentation (see Brooks & Balmford (1996), Brooks et al. (1999) or Pütz et al. (2011) for example).

The ICMS-E is an intergovernmental fiscal transfer from state to municipalities, used today in about half of the Brazilian states. It rewards municipalities for the creation of protected areas (namely conservation units, CUs) and watershed reserves. One reason for its implementation was the demand from municipalities hosting federal or state managed protected areas to be compensated for the opportunity cost of providing this public good. Yet it also aims to act as an incentive to create new protected areas.

Since its implementation in the early 90's, the ICMS-E is a real success in terms of CUs creation. In 2000, the areas under protection had already increased by 62.4% in the State of

*This chapter is an adapted version of an article co-authored with José Feres and Alexandre Sauquet.

[1]Such as *Avanca Brasil* for example (Andersen et al., 2002).

Minas Gerais and by 165% in the State of Paraná (May et al., 2002). Moreover, the mechanism has two interesting features. It is implemented (1) without external source of financing (the funds redistributed are collected from goods and services tax in the concerned State), and (2) at very low transaction costs. This way, it has been claimed that the ICMS-E could be an alternative to other instruments such as pollution permits or pigovian taxes, notably for the implementation of commitments in international environmental agreements (see Farley et al. (2010)).

Despite attractiveness, very few studies have been carried out on the ICMS-E. Grieg-Gran (2000) analyzes which municipalities are better off with the ICMS-E reform. She finds mixed evidence. She points out that until 2000, only 60% of the municipalities of Rondonia and Minas Gerais with protected areas benefited from the introduction of the ICMS-Ecologico. Furthermore, May et al. (2002) provide some interesting State level statistics for the Paraná and Minas Gerais states as well as several inspiring case studies[2]. Finally, Ring (2008) highlights the appeal of the ICMS-E by providing a clear description of the mechanism along with trend and macro level statistics on the creation of CUs in the three states mentioned above.

However, although these three studies are informative and highlight the strengths of the ICMS-E, no one questioned the efficiency of the mechanism. Yet, the ICMS-E is a decentralized policy, and as stated by Oates & Portney (2003), the efficiency of a decentralized policy implies the absence of interactions between agents. However, as we will see in our theoretical part, there are several reasons for expecting municipalities to influence each other when deciding to create CUs or not and that there is a risk of a race to the bottom, i.e., competition between counties[3] to attract economic agents which leads to the setting-up of lax environmental standards.

Therefore, the aim of this chapter is to investigate whether or not there are interactions between municipalities when they set the propensity of their lands under protection. We collected data on the ICMS-E for 399 municipalities of the state of Paraná from 2000 to 2010. This state constitutes therefore a case of primary interest because it was the first to adopt the considered mechanism in 1991 and a pioneer by introducing a quality-weighting factor for the redistribution of the ICMS-E.

The contributions of this chapter are diverse. We build a new database thanks to the reports released by the IAP (Instituto Ambiental do Paraná). We adapt a land-use model from Chomitz & Gray (1996) to the problematic of setting aside lands for protection and assess its validity through the bayesian spatial tobit estimator proposed by LeSage (1999) and LeSage & Pace (2009). The spatial Bayesian tobit model allows us to test the presence of interactions between municipalities in their conservation decisions. Negative spatial interactions between municipalities are found, suggesting that the profitability hypothesis applies and that conservation behavior are strategic substitutes.

The chapter is organized as follows. Section 2 provides a review of literature and places this

[2]They interviewed several mayors, asking them why they used the ICMS-E mechanism.
[3]The terms county and municipalities will be used indistinctively in the rest of the chapter.

chapter at the frontier of the literature on i) the provision of public goods, ii) the environmental federalism and iii) the land use motivations. Section 2 also explains how this chapter differs from previous works on the ICMS-E. Section 3 discusses the context in which the ICMS-E was implemented in the Brazilian state of Paraná. Section 4 presents the theoretical land use model and estimation strategy while Section 5 gives the results. Section 6 concludes with possible policy implications.

7.2 Literature review

The aim of this chapter is to analyse the efficiency of ICMS-E on the land allocation decision rule at county level through the presence of spatial strategic interactions. The aim (promote the production of local public good), the nature (fiscal transfer scheme) and the functioning (based on a fixed pool of money) of the ICMS-E allows this chapter to be placed in the three strands of the literature: the provision of public good, the fiscal federalism and the land use competition model.

First, the main goal of the ICMS-E is to provide a public good, here the conservation of biodiversity. Thereby, the ICMS-E is an incentive tool used to incite local actors, here the counties, to take into account the positive externalities of preserving biodiversity by paying them to do so. The literature on the provision of public goods is substantial but here we focus only on studies concerning the incentives at local level through payments in the case of biodiversity. The loss of biodiversity as well as the lessening of the environmental services provided by ecosystems for human well-being have been recognized as one of the main global problems. Biodiversity calls for centralised policies and standard setting such as numerous international conventions like the Convention on Biological Diversity (WRI, 2005). However, the state of the biodiversity is mainly influenced by decentralised activities, despite global centralised standards. Also, it is widely recognized that the improvement of the value of ecological services through market prices is even more difficult since there are fundamental conflicts between the rules by which markets allocate resources and the rules which govern ecosystems (Gowdy, 1997). For instance, this is especially the case for benefits related to non-use values which are difficult to assess trough market prices, such as existence and option values. This way, some papers address the problem to conciliate the local and global level. For instance, Horton et al. (2003) use a contingent valuation to elicit individuals' preferences for non-market environmental resources such as the payment for the implementation of a proposed programme of protected areas in Brazilian Amazonia. Their study shows large-scale positive spillovers of the preservation of the Brazilian forest since the majority of households in Italy and the UK were willing to pay to support large-scale tropical forest preservation efforts. List et al. (2002) analyze the "beggar thy neighbour" effect in the case of U.S. environmental policy making at state-level concerning endangered species expenditure patterns. They show that states free ride in the sense that they spend less relative to federal government in the protection of endangered species. Relating to

this, some authors have tried to conciliate the global and local level by designing an optimal pattern of biodiversity protection which reflects both the local and global benefit of biodiversity protection (Perrings & Gadgil, 2003). One such patterns creates incentives to reward or pay local communities for their conservation efforts as does the ICMS-E (Ring, 2008). This solution calls for a fiscal federalism which is the second strand of literature to which this chapter belongs.

Second, the ICMS-E is a fiscal redistribution from the state to municipalities based on environmental federalism which studies the role of spatial externalities in the choice of the level of government in the provision of the public good. The mechanisms underlying the ICMS-E allow for the analysis of the interrelationships between municipalities and the efficiency of decentralisation. The literature on fiscal federalism is also substantial but we focus mainly on papers concerning environmental federalism with important spatial externalities such as the ICMS-E. Basically, environmental fiscal federalism is a sub-field of fiscal federalism literature which is linked to public economics[4]. Fiscal federalism typically occurs in the context of a system with several levels of government and uses a general normative framework for the estimation of functions to different levels of government and the appropriate fiscal instruments for carrying out these functions (Oates, 1999). In the case of environmental fiscal federalism, this implies the substantial "issue of the appropriate role of the various governments in the setting of environmental standards, the design of regulatory measures to attain the standards, and the monitoring and enforcement of these measures" (Oates, 2001, p.3). Regarding this setting, the principle of fiscal decentralisation has been first advanced by (Oates, 1972). The main idea is that most public goods and services could be provided more efficiently at the lowest governmental level if production and consumption are limited[5]. Moreover, this rule of decentralisation for allocating public goods and services should apply only in the case of none economies of scale, otherwise the provision of the public goods should be moved to the cost-efficient centralised level. However, since local public good has the use property of non-rivalry and non-excludability, the presence of spatial externalities or spillovers can occur between jurisdictions (see Ring (2008) for a review of the literature on this point). In this case, third mechanisms have been advanced to internalise these spatial spillovers. One solution advanced is to internalise spillovers through fiscal transfers from more centralised levels to the local level to compensate for the external benefits of its expenditures to produce the local public good (Olson, 1969)[6]. Beyond this problem of the allocation of the local public good through decentralisation and the internalisation of spatial spillovers, the problem of the "race-to-the-bottom" has been widely studied in the literature (Oates & Portney, 2003). The basic idea is that "local" officials could set excessively lax environmental standards to hold down the costs associated with the preservation of the environment

[4]See Oates (1999) for a review of fiscal federalism.

[5]Decentralization is also viewed as a way for responding more appropriately to the regionally differing preferences of the population (see for instance Oates (2001)).

[6]The two other solutions are: the principle of fiscal equivalence and the regional cooperation. The first solution proposed by Olson (1969) consists in having a match between those who receive the benefits of a collective good and those who pay for it. The second solution relies on negotiations between the relevant parties to achieve an efficient Coasian type of resolution of jurisdictional spillovers (Oates, 2001).

for existing and prospective firms with the aim of encouraging new business investment and economic growth. In the literature, many papers focus on these strategic interactions between jurisdictions in the provision of public good such as biodiversity conservation. There is both an extensive theoretical literature (see Wilson (1996) for a global review of this literature and Oates & Portney (2003) for a review in the case of environmental public goods) and empirical studies on biodiversity (see for instance Levinson (1999); List & Gerking (2000); Fredriksson & Millimet (2002) for the case of United States, Murdoch et al. (1997) for the European Union, and Akin et al. (2005); Arze et al. (2008); Rota-Graziosi et al. (2010) for developing countries in the case of public spending, since no paper studies the issue of "the race-to-the-bottom" for biodiversity conservation in developing countries).

Thirdly, the ICMS-E implies that counties have to choose between the preservation of the natural areas and their conversion into other economic uses such as agriculture. In turn, the ICMS-E influences the allocation of land, i.e., land uses, at the county level (see Kaimowitz & Angelsen (1998) for a review of models used to study deforestation and Nelson & Geoghegan (2002) for a review of the literature concerning the land use based deforestation model). The literature on land use is also substantial but we focus only on studies concerning deforestation at local level. This literature studies the role of economic factors inducing deforestation and thereby threatening biodiversity, giving particular attention to the exploitation pattern of forest resources. Chomitz & Gray (1996) are the first to use this type of spatially explicit model to study the effect of road development on deforestation in Belize. Then, many papers apply this model to a pixel or household levels (for instance Chomitz & Thomas (2003); Marchand (2010) for Brazil; Deininger & Minten (2002); Alix-Garcia et al. (2005); Alix-Garcia (2007) for Mexico; Godoy & Contreras (2001) for Bolivia; Godoy et al. (1997) for Honduras; and Cropper et al. (2001) for Thailand) or to an entire municipality (for instance Pfaff (1999); Araujo et al. (2009) for Brazil, Deininger & Minten (1999) for Mexico).

Finally, this chapter, being in this three strands of the literature, differs from the other (few) papers which have studied the ICMS-E. The existing empirical studies are based on the States of Paraná, Minas Gerais and Rondonia, which were among the first States to introduce the ICMS-E, and focus more on the effects of the ICMS-E in terms of total areas protected. For instance, Grieg-Gran (2000) examines the effects of the ICMS-E in the states of Minas Gerais and Rondonia and finds that both the compensation and incentive objectives have been achieved in the two States. She also studies the distributional impact of the ICMS-E and finds that in the state of Rondonia this effect is difficult to observe whereas in Minas Gerais, the ICMS-E has more adversely affected the wealthiest counties. May et al. (2002) provide a presentation of how the ICMS-E functions. They actually tries to understand how and under what conditions the ICMS-E works. They find that the ICMS-E has promoted the conservation of natural resources by increasing both the size and the number of protected areas. For instance, the area of municipal protected parks has increased respectively by 192 and 236 percent between 1991 and 2000 in the state of Paraná and Minas Gerais. Ring (2008) analyses the effectiveness of

the ICMS-E through the creation of new protected areas. She also finds that municipalities in the state of Paraná and Minas Gerais developed a strong interest in designating new public protected areas at the local level. Finally, all of these papers conclude that the Brazilian experience illustrates that the ICMS-E is efficient both to compensate for land-use restrictions and incite to engage in more conservation activities at the local level.

In turn, this chapter is linked to the previously cited literature but differs by studying the efficiency of the ICMS-E through the presence of interactions between counties in their land allocation.

7.3 ICMS-E and conservation units in Paraná

7.3.1 Presentation of the ICMS-E

Brazil is a federal country with 27 states which capture most of their revenue from tax on the circulation of goods and services, i.e., a value-added tax (VAT), named the ICMS tax (*Imposto sobre Circulacão de Mercadorias e Servicos*). They have to return 25% of their revenue collected from sales taxes to municipalities following certain criteria. Three quarters of this redistribution is defined by the federal constitution (the main criterion is the added value created by each municipality), but the Article 158 of the Federal Constitution states that the remaining 25% (i.e., 6.75% of the total) is allocated according to each state's legislation (for instance based on population, geographical area and primary production).

In 1992, the state of Paraná (see the geographical map 7.1, page 214, on Brazilian states) was the first to reward municipalities for protected areas (biodiversity) and watershed reserves (water quality) within their boundaries by redistributing the ICMS-E according to environmental criteria (see May et al. (2002, P.175) for a more complete presentation of the law making process in Paraná.)[7]. It is worthy noticing that municipalities have no obligation to create and improve protected areas, but are simply rewarded depending on the extent to which they meet the criteria in comparison with other municipalities. Also, since only a fixed pool of money is available in any given year, the municipalities compete with each other to receive the money.

This new fiscal incentive tool was called ICMS-E or "ecological ICMS". In Paraná, the law implemented awarded 5% of ICMS revenue to municipalities in proportion to their protection of watersheds and conservation areas (also called "conservation units" (CUs)). Half of this (2.5%) is used to reward municipalities for the creation of CUs. The Biodiversity Conservation Coefficient, used for the redistribution of the ICMS-E between counties, is derived from the ratio of CUs on total area. These CUs can be publicly managed (federal, state or municipal level), privately owned or managed by public-private partnerships (such as *reserva particular*

[7] 14 other Brazilian states have already introduced the ICMS-E, including São Paulo (1996), Minas Gerais (1996), Rondonia (1996), Amapá (1996), Rio Grande do Sul (1998), Mato Grosso (2001), Mato Grosso do Sul (2001), Pernambuco (2001), Tocantins (2002) (see the official website of the ICMS-E, http://www.icmsecologico.org.br/, and Veríssimo et al. (2002); Ring (2008)).

do patrimônio natural, RPPN). Payments to municipalities are also provided for federal and private protected areas. Also, the protected areas may be used directly (for instance sustainably managed forest and indigenous areas) or indirectly (for instance parks, biological reserves or ecological stations). The other half is for those municipalities that have watershed protection areas which partly or completely provide services for public drinking water systems in neighboring municipalities[8]. The main motivation of this fiscal redistribution policy was initially to compensate municipalities for the opportunity costs of conservation areas (often decided by the central level, i.e., the state) and for protecting watersheds. But this policy created significant incentives for the creation of new protected areas which, in turn, allow to increase the number and area of both state and municipal protected areas.

Moreover beyond the quantitative aim of this policy, Paraná was the first to insert qualitative criteria into the ICMS-E (Farley et al., 2010; May et al., 2002). This reflects improvements over time in qualitative features of CUs and also their relationship with the surrounding community[9]. The more these objectives are fulfilled by municipalities, the more the revenue of ICMS-E received are substantial. Basically, the state of Paraná use two components to calculate the Biodiversity Conservation Coefficient: a quantitative component and a qualitative one. The former is the percentage of municipal land area under conservation units corrected by a value describing the level of restriction on use such as biological reserve. The latter is a qualitative criteria that evaluates the quality of the conservation unit on the basis of variables such as the biological and physical quality, the quality of water resources in and around the CUs, how important the CU is in the regional ecosystem, the quality of planning, implementation, maintenance and the legitimacy of the unit in the community. The quality of each CU is assessed by regional officers of the state Environmental Institute of Paraná (Instituto Ambiental do Paraná, IAP). Their evaluation is then expressed as a score called quality factor used in the calculation of revenue distribution. Each score differs in accordance with the type of CU as well as the objectives of state environmental policy, giving greater weight to the state's environmental management capacity over that of municipal or federal agencies[10].

To determine the additional funds allocated to each municipality, the biodiversity conservation coefficient or ecological index EI_i of the municipality i is calculated as follows (this part is adapted from Loureiro et al. (2008, p.22-23) and Ring (2008)).

First is the calculation of the conservation coefficient (BCC_{ji}) of each CU j in the munici-

[8]See for instance the case of the municipality of Piraquara which have 10% of its territory covered by protected areas for biodiversity conservation and the remaining 90% used for conserving a major watershed to supply the Curitiba metropolitan region (1.5 million inhabitants) with drinking water (May et al., 2002; Ring, 2008).

[9]For instance, the quality criteria of a CUs will increase if the county creates buffer zones around this area.

[10]The quality index is also assessed by exceeding compliance with extant agreements with municipalities; development of facilities; supplementary analysis of municipal actions regarding housing and urban planning, agriculture, health, and sanitation; support to producers and local communities; and the number and amount of environmental penalties applied, within the municipality, by public authorities (May et al., 2002).

pality i as follows:

$$BCC_{ij} = \left(\frac{Area\ CU_j}{Area\ municipality_i} \right) * FC_n, \tag{7.1}$$

where $Area\ CU_j$ and $Area\ municipality_i$ are respectively the area of the conservation unit j and the area of the municipality i. Each BCC_{ij} is multiplied by a conservation factor FC_n which is variable and assigned to protected areas according to management category n (see the table 7.3 page 215 in appendix for more information of the weighting factor of each protected areas).

Then each BCC_{ij} is assigned an ESC criterion to take into account the variation of the quality as follows:

$$BCCQ_{ij} = [BCC_{ij} + (BCC_{ij} * ESC)], \tag{7.2}$$

where ESC is the variation of the quality of the CU weighted by the management strategy and the nature of the protected areas, i.e., municipal, state, federal.

Then the municipal conservation factor (MCF_i) is based on the sum of each $BCCQ_{ij}$ in the municipality i as follows:

$$MCF_i = \sum_{j=1}^{J} BCCQ_{ij}. \tag{7.3}$$

where J is the number of CU in the municipality i[11]. Finally the biodiversity conservation coefficient or ecological index EC_i of the municipality i is

$$EI_i = \frac{MCF_i}{SCF}, \tag{7.4}$$

where the state conservation factor SCF is given by the sum of all municipal conservation factors (MCF) in the state:

$$SCF = \sum_{i=1}^{Z} MCF_i, \tag{7.5}$$

where the Z the number of municipalities in the state which receives funds from the ICMS-E.

A brief overview of the evolution of the number of counties in the ICMS-E for municipal CUs between 2000 and 2010 is given by the figure 7.3 (in appendix, page 217). The number of municipalities which have received funds from the ICMS-E has increased by 9 counties between 2000 and 2010 (57 in 2000 compared to 66 in 2010) over the 399 counties in the dataset. In consequence, respectively 342 and 329 counties did not receive fiscal transfers from the ICMS-

[11] For instance, Curitiba had 15 conservation units in 2000.

E for the creation of municipal CUs in 2000 and 2010. Moreover, it is worth noting that 4 counties no longer received funds from the ICMS-E, i.e., they converted municipal CUs, during the last decade while 13 new counties received funds from ICMS-E for the creation of their first municipal CUs.

In a broader view, there were 174 counties in the ICMS-E in 2000 compared to 192 in 2010, i.e., receiving funds to compensate for the presence of CUs in their territory (see figure 7.4, page 217 in appendix). The number of counties in the fiscal mechanism has thus increased while 4 counties have decided to leave the mechanism. In contrast, 22 new counties have earned money from the ICMS-E.

7.3.2 Evolution of conservation units in Paraná

The ICMS-E mechanism was first implemented in 1992. From this date up to 2010, the evolution of the CUs created in the state of Paraná is a way of testing the success of the ICMS-E.

From data on CUs created between 1991 and 2000, collected in (May et al., 2002), and our data between 2000 and 2010, the figure 7.2 gives the evolution of the area of all CUs in hectare between 1991 and the last year of available data in 2010. It is found that the evolution of CUs can be divided into two periods. In the first decade, the creation of CUs increased sharply that the ICMS-E has not only compensated counties for the creation of CUs but also encouraged them to create CUs. However, in the last decade (from 2000), the creation of CUs is found to hold steady with a very low increase of 5 percent. From this, it can be assumed that the level of created CUs in the state of Paraná through the ICMS-E mechanism has reached its equilibrium.

However, these figures concern all CUs, i.e., federal, state and municipal CUs. The evolution of municipal CUs created is relevant in our study which concerns the implication of the ICMS-E in terms of spatial strategic interactions on the creation of municipal CUs. From our data between 2000-2010, it is found that the evolution of the number of municipal CUs follows the same trend as all CUs. In consequence, our data seems to confirm that from 2000, the dynamics created by the ICMS-E have reached their equilibrium. This overview suggests that ICMS-E is no longer sufficient to incite counties to create CUs after several years of implementation.

7.4 Conceptual framework

In order to analyse the influence of neighboring counties on the propensity of a county to create parks , an economic land use model is used (Chomitz & Gray, 1996; Pfaff, 1999; Chomitz & Thomas, 2001; Arcand et al., 2008). The starting point is the dual nature of the model implying simple assumption that each land is allocated between alternative uses to maximise returns. In this model, the profitability of each use is compared to implement the decision concerning the land allocation. From this model, a county-level, land-allocation decision rule is derived which

provides an econometric deforestation equation to be estimated.

7.4.1 Basic land-use model

Following Chomitz & Gray (1996) and Pfaff (1999), we assume that a county can choose their land allocation from a binary framework. It is assumed that the county can be defined as an economic agent which could decide the land use allocation of each of its plots. This way, this model differs from an aggregated plot-level decision rule model into a county-level model (Pfaff, 1999). We can make this assumption since we observe only the creation of municipal conservation units (CUs), i.e., a county-level decision.

At any point in time, a county will decide to allocate a plot of land between different land uses to maximize profit:

$$\max \pi_{ij}^{l} = P_{ij}^{l} Q_{ij}^{l}(I_{ij}^{l}) - R_{ij}^{l} I_{ij}^{l}, \tag{7.6}$$

where π_{ij}^{l} is the profit of the parcel i in the county j of a given land use l, P_{ij}^{l} are plot-level prices for the vector of feasible outputs from the given land use l, Q_{ij}^{l} is the vector of all outputs produced from the land use l, I_{ij}^{l} is the vector of inputs used in all types of production from the land use l, and R_{ij}^{l} are plot-level prices for the vector of inputs used.

Given the dual nature of the model, there are two possible land uses (protected, i.e., the creation of a municipal CUs, or unprotected, i.e., the conversion of a forested land). Optimal input choice yields to maximise π_{ij}^{l} and the county level decision rule regarding land use allocation is

$$\max_{l} V_{ij}^{l}, \tag{7.7}$$

where

$$\max_{l} V_{ij}^{l} = \max_{l|I} \pi_{ijt}^{l}. \tag{7.8}$$

Thus, the county decision concerns the choice of the land use to have the maximum profit from its land use. Put differently, the clearing decision will be in a static view: $Choose_{ij}^{l} = protected \quad \text{if: } V_{ij}^{protected} > V_{ij}^{unprotected}$.

The municipality j will decide to preserve its plot i, i.e., create a CUs, only if the maximum profit generated from the conservation is higher than the maximum profit resulting from the conversion option.

This decision-rule based on the comparison of the maximum profit of each land use depends obviously on the prices of both inputs and outputs used in each land use. For instance, a decreasing price of the input used in the land use option *unprotected* leads to an increase of the profit associated with this land use. In this case, the county will be relatively better off if it decides to convert its natural land. Thereby, prices by influencing the magnitude of each

profit have an impact on the decision rule which can be modelled as follows:

$$Choose_{ij}^{l} = protected \qquad \text{if } D_{ij}^{protected}(P_{ij}^{l}, R_{ij}^{l}) > 0,$$

where

$$D_{ij}^{protected}(P_{ij}^{l}, R_{ij}^{l}) = V_{ij}^{protected}(.) - V_{ij}^{unprotected}(.).$$

This representation of the land allocation decision-rule allows economic factors to be integrated into the explanation of land use through their links with both input and output prices.

7.4.2 Observed variables and spatial interactions

Observed economic factors

The land use decision-rule is thus determined by $P_{i,j}^{l}$ and $R_{i,j}^{l}$ which are plot-level output and input prices. Put differently, this is the differential between the prices of each land use option which will determine the land allocation. However, we cannot observe them directly so we use closed county-level variables. Thus, the solution will be to use proximate variables which affect the differential prices and so in turn the land allocation decision. In the case of P_{ij}, the best way to approximate output prices at plot-level will be to have them at county-level P_j. Unfortunately, we have none of these variables so local output demand variables are used such as the county population pop_j (as a scale measure of the potential local market for cleared economic activities), the share of industry in the total county's activities ind_j (as a measure of development projects), the share of agricultural activities in the total county's activities agr_j (as a measure of local agricultural food demand) and the income level in a county inc_j as a measure of the economic development. All of these variables are assumed to have an impact on the differential output prices in favor of an increase of the *unprotected* option. Moreover, the effect of the variable *income* (per capita) could be more ambiguous since richer counties could be better off preserving their forests for ornamental purposes. To test this idea, the quadratic term of *income* will be used. Thus, (1) poorer counties are assumed to be more inclined to do parks since their comparative advantages to proceed in *unprotected* activities are lower than richer counties, and (2) richer counties are also assumed to create more parks. The quadratic term $incsq_j$ is thus assumed to be negative, i.e., the income effect on the creation of parks is concave.

In the case, of $R_{i,j}$, local input supply variables are used such as the rural density (per km^2) rur_j (as a measure of the rural wage) and the urban density (per km^2) urb_j (as a measure of the urban wage). These two variables are found to be proxies variables impacting the differential input prices in favor of *unprotected* activities. Put differently, these variables have a negative effect on the propensity to create parks by strengthening the opportunity cost of the *protected* option.

Lastly, we assume that the area of other CUS (federal and state), named FED_j could have an impact on the land allocation decision-rule through the differential prices. Given that the area of a county is by definition fixed, more non-municipal CUs increases the scarcity of the land. In this context, the effect of the land allocation decision is ambiguous. Assume that the land scarcity increases the land price. This pushes the economic agent to not invest in this county since the cost for *unprotected* option goes up. The municipality knowing that can decide to protect the land and create a CUs to earn money from the ICMS-E. Alternatively, an increase in the land price could attract only the more efficient agents into the county pushing this latter to convert their forested land into potential productive land for agriculture and industry.

Spatial interactions

The aim of this work is to test for the presence of neighboring effects in the decision to create municipal CUs in a county. This issue is particularly relevant since the ICMS-E is a decentralized system, and as Oates & Portney (2003) state, one condition for decentralization to be optimal is the absence of interactions between agents. Testing the presence of interaction is therefore crucial to assess the efficiency of the mechanism.

The interactions between a county and its neighbors can evolve in two directions. On the one hand, the level of CUs in a county and one of its neighbors could be strategic complements. Indeed by decreasing its conservation index, the municipality offers firms and peasants an easier climate to make profits and to extend their activities. Moreover, a new firm could vote with its feet (Tiebout, 1956) and choose the municipality where the environmental standards are lower to settle down. This way, a race to the bottom could be observed[12].

On the other hand, if we think in terms of the profitability of the two options, conservation and exploitation, we could expect conservation decisions to be strategic substitutes. The creation of new CUs by a county could have two effects. Firstly, since municipalities compete for a fixed pool of money, when a given municipality creates new CUs, it decreases the amount transferred by the state for each CUs, thus decreasing the profitability of the conservation option. Secondly, the creation of new CUs decreases the stock of lands available for economic production in a particular area. Then, it increases the value of plots available for economic production and then the profitability of the exploitation option. A municipality could therefore decide to increase its supply of land for economic agents (by decreasing its number of CUs), in order to attract peasants and firms when its neighbor is decreasing its supply. We could therefore expect protection decisions to be strategic substitutes.

From our theoretical framework, the land-allocation decision-rule for the plot i in the county

[12]In practice, there is no means to distinguish between a race to the top and a race to the bottom, but only to find strategic complementarity between decisions. However, our theoretical analysis leads us to think that if decisions are effectively strategic complements, they will lead to a race to the bottom.

j becomes

$$D_{ij}^{uncleared}(Q_k^{protected}, FED_j, pop_j, ind_j, agr_j, inc_j, incsq_j, urb_j, rur_j). \tag{7.9}$$

where $Q_k^{protected}$ is the level of CUs in the neighboring county k which is assumed to influence negatively (positively) $D_{ij}^{protected}$ by decreasing (increasing) the profitability of the *protected* option and increasing (decreasing) the profitability of the *unprotected* option.

A land use decision-rule such as equation 7.9 leads to the equation which will be estimated and presented in the following subsection 7.4.3.

7.4.3 Econometric model and data used

To estimate the presence of interactions between municipalities in their conservation decisions, we borrow the methodology used in the tax-competition and public spending literature (see for example Case et al. (1993), Brueckner (2003), Lockwood & Migali (2009) or Rota-Graziosi et al. (2010)). We estimate a Spatial AutoRegressive (SAR) model, where the spatially lagged endogenous variable is a weighted sum of neighbors' decisions, such as:

$$P^* = \rho W P^* + \beta X + \varepsilon \tag{7.10}$$

where P^* is a $N \times 1$ vector of the propensity to create a municipal CUs by a county. N is the number of municipalities in the sample, here 399. X is a $M \times N$ matrix of our M explanatory variables influencing the differential potential profit between land use conversion and land conservation previously defined (pop, ind, agr, inc, $incsq$, rur, urb and FED) and the β a vector of their corresponding coefficients. ε is a $N \times 1$ vector of residuals. WP^* is a spatially lagged endogenous variable, where W is a $N \times N$ contiguity matrix of which each element w_{jk} takes the value of 1 if two counties share a common border, 0 otherwise (where j identifies a municipality different from municipality k). Hence, ρ capture the presence of interactions between municipalities.

The dependent variable is latent, i.e., cannot be observed for $p^* < 0$. Indeed, there is a large number of zero observations in our sample. In 2010, 342 municipalities over 399 do not create municipal CUs. It is hard to think that each municipality is in exactly the same situation. We can therefore argue that censoring is at stake and that their are negative profits for the action measured by our dependent variable. Therefore, we have:

$$p_{j,t} = 0 \quad if \quad p^*_{j,t} \leq 0$$
$$p_{j,t} = p^*_{j,t} \quad otherwise,$$

where $p_{j,t}$ is the observed dependent variable. Following Chomitz & Gray (1996), we account

for this censoring using a tobit model, where the conditional distribution of $p_{j,t}$ given all other parameters is a truncated normal distribution, constructed by truncating distribution from the left at 0.

Finally, the following expanded form of the spatial autoregressive tobit models is:

$$\begin{aligned} p^*_{j,t_{2010}} &= \rho \sum_{j \neq k}^{J} w_{jk} p^*_{k,t} + \beta p_{j,t_{2000}} + \delta FED_{j,t_{2010}} + \alpha_1 pop_j + \alpha_2 ind_j + \alpha_3 agr_j + \alpha_4 inc_j \\ &+ \alpha_5 incsq_j + \alpha_6 urb_j + \alpha_7 rur_j + \alpha_8 Curitiba + \mu_r + \vartheta_{i,t_{2010}}, \end{aligned} \tag{7.11}$$

where the observed dependent variable, $p_{j,t_{2010}}$, is alternatively (1) the ratio of municipal parks of county j in 2010 defined as the ratio between total CUs areas and total county area, and the coefficient of quality measuring the quality of the created municipal CUs (see subsection 7.3.1). This latter measure can be viewed as the propensity to create CUs since more effort put into the maintenance or the development of the quality of CUs implies more money for the county from the ICMS-E, and thus less money from the ICMS which rewards counties on the basis of their created added value.

$p_{j,t_{2000}}$ represent the initial ratio or coefficient of quality in 2000. $FED_{j,t_{2010}}$ is the ratio of other CUs (federal and state CUs) in the county i in 2010. pop_j, urb_j and rur_j are respectively the average annual population growth, urban density and rural density between 2000-2010. ind_j (agr_j) is the average ratio between the GDP of industrial (agricultural) activities and the total municipal GDP between 2000 and 2008. inc_j is the annual average GDP per capita between 2000 and 2008 and $incsq_j$, its squared equivalent. $Curitiba$ is a dummy variable which takes a value of 1 for the capital of Paraná namely Curitiba and 0 otherwise to control for the strong differences of this county compared to the others. μ_r is a micro-region dummy representing a legally defined administrative area consisting of groups of municipalities bordering urban areas. This dummy allows to ckeck for unobserved fixed effects shared by same neighboring counties. In the state of Paraná, 40 micro-regions are censused for 399 counties.

Data concerning CUs ($p_{j,t_{2010}}$, $p_{j,t_{2000}}$ and $FED_{j,t_{2010}}$) are taken from the ICMS-E official website[13]. All other variables come from the IPEA DATABASE[14] (see table 7.4 page 218 in appendix for more information on descriptive statistics).

7.4.4 Spatial estimation

Estimator

The estimation of parameters from spatial autoregressive tobit model represent a computational challenge and cannot be done via analytic methods, such as maximum likelihood. Therefore we rely on the bayesian approach developed by LeSage (1999), LeSage & Pace (2009) and applied

[13]Data downloadable on this website http://www.icmsecologico.org.br/.
[14]Data downloadable on this website http://www.ipeadata.gov.br/.

by Autant-Bernard & LeSage (2011).

In this approach, the unobserved negative profits associated with the censored 0 observations are considered as parameters to estimate. The model is estimated via MCMC (Monte Carlo Markov Chain) estimation procedure. The procedure uses the Geweke m-steps Gibbs sampler to produce draws from a multivariate truncated normal distribution in order to generate the unobserved negative utilities associated with the censored 0 observations[15] [16].

Interpretation of the coefficients estimated

Coefficients from a SAR model cannot be interpreted directly. Indeed there is an implicit form behind the model presented in equation 7.10. It can be rewritten as:

$$P^* - \rho W P^* = \beta X + \varepsilon \tag{7.12}$$

$$P^*(I_N - \rho W) = \beta X + \varepsilon \tag{7.13}$$

$$P^* = (I_N - \rho W)^{-1}\beta X + (I_N - \rho W)^{-1}\varepsilon \tag{7.14}$$

As we can see from equation 7.14, $\frac{\partial p^*}{\partial x'} \neq \beta$, but $\frac{\partial p^*}{\partial x'} = (I_N - \rho W)^{-1}\beta$. This occurs because of the spillovers generated by the decisions of neighboring counties. To interpret the coefficients of a spatial model, the researcher has to calculate the direct impact of a variable, its indirect impact and the total impact (equal to the direct impact plus the indirect one). Indeed, a change on an explanatory variable in a particular region will affect the p^* value of this region (direct impact), but also the other regions because of the spatial spillovers (the indirect impact). Computation details of these impacts are clearly described in (LeSage & Pace, 2009, p.33-39).

7.5 Results

7.5.1 Neighboring effects and created CUs

Results concerning the neighboring effects and other economic factors on the propensity to create CUs for a county are presented in tables 7.1 (page 212) and 7.2 (page 213). Results

[15] The m-steps correspond to the number of draws. Following LeSage & Pace (2009), considering our sample size(N=399), we choose m=10 even if could be relatively computationally challenging.

[16] In addition, to produce estimates that will be robust in the presence of non-constant variance of disturbances (heteroscedasticity) and outliers, it is assumed that, in the development of the Gibbs sampler, the hyperparameter r that determines the extent to which the disturbances take on a leptokurtic character is stated at 4 as suggested by LeSage (1999)In a Bayesian regression model, the relative variance terms are assumed fixed but unknown parameters that need to be estimated. Bayesian methods rely on an informative prior for the these parameters. This prior distribution will take the form of an independent $\frac{\chi^2(r)}{r}$ distribution. This allows us to estimate the additional parameters related to the variance terms by adding the single parameter r to the estimation procedure. See LeSage (1999, p.99-100) for more information.

with the ratio between the total area of municapal CUs and the total area of the county as dependent variable are first presented. The second table provides results with the coefficient quality as an alternative variable of the propensity to create CUs. In both regressions, the contiguity spatial weight matrix is used to represent the prior strength between two counties. Also, the gibbs sampler approach with 10 steps, for the computation of the vector of parameters which replaces the unobserved latent utility (here for $p^*_{j,t} < 0$), and 1,000 draws is used for the estimation of the spatial autoregressive tobit model. Moreover, in each table, the total impact of each control variable as well as its direct and indirect impacts are presented.

In table 7.1 where CUs ratio is used as dependent variable, negative spatial interactions between counties are found suggesting that a county is more inclined to create municipal CUs if their neighboring counties decrease the number of their CUs. This way, this result points out that the hypothesis of profitability, predicted by the theoretical model, seems to be at stake in the choice of creating municipal CUs in the state of Paraná between 2000 and 2010. This way, in this period, it is more profitable for a county to earn money from the ICMS (awarded according to the created value added) and thus to convert its natural land for agricultural or industrial plants to attract peasants or firms of neighboring counties which have preferred to create CUs and be awarded by the ICMS-E. The functioning of the ICMS-E is an explanation of these behaviors since the pool of money is fixed in the ICMS-E leading a county to not be incited to enter into the mechanism and so be more inclined to convert its natural land. In such a county with neighbors having created CUs, the ICMS-E increases the opportunity cost to create CUs and the profit to convert land by attracting economic agents of neighbors who could be more inclined to migrate toward a county promoting economic plants. This result is linked to the descriptive statistics proposed above and could explain the stable trend in the creation of municipal CUs in the last decade after a strong upward trend in the first years of the implementation of the ICMS-E.

Concerning the other economic factors assumed to have an effect on the land allocation rule-decision of a county (through their effects on the differential profit between land uses option), the population variables have the expected negative coefficient but only the urban density has a significant effect. This result could suggest that urban counties are less inclined to promote municipal CUs due to the presence of a strong urban demand for foods or industrial products.

Moreover, the structure of the county's economy is found to be important to explain the propensity to create municipal CUs. In fact, the more the share of agriculture or industry is important in the municipal activities, the less the propensity to create municipal CUs. This result points out the role of economic activities in the propensity to create CUs. More developed counties in terms of agricultural or industrial activities can be more encouraged to continue developing their activities to earn money from the ICMS which awards counties on the basis of their created value added.

Moreover, the income effect is concave (the additive term is positive and the quadratic one

negative) but not significant[17]. Also, the other CUs in the county are found to not be significant to explain the propensity to create CUs[18] (while Curitiba is found to be positive and significant since the capital is one of the most advanced counties in terms of created CUs[19].

Besides, the Table 7.1 provides the estimated direct, indirect and total effects of each explanatory variable. Recall that direct impact can be interpreted as a marginal impact, the indirect one as a spatial spillover effect and total one as a summary measure of the total impact associated with changes in each explanatory variable. All significant effects previously presented (for population growth and the weight of agriculture and industry) are found to be mainly direct effects since their indirect counter parts are non significant. Concerning these latter effects, it is found that no explanatory variables have a significant indirect effect. Despite that, some variables have the expected signs as the urban density or the industrial or agricultural ratio. the greater the urban population in the neighboring counties, the greater the propensity for a county to create CUs since the neighbors are expected to create less CUs due to their sizeable urban density. The same result applies for the weight of the agricultural or industrial sector. Also, concerning the indirect effect, it is found that the previous level of created CUs (in 2000) of neighbors decreases the probability for a county to create CUs in 2010. This result is significant at 10 percent and confirms the negative spatial interaction which occurs between counties.

Table 7.2 presents results for the coefficient of quality as dependent variable. Negative spatial interactions between counties are also found. This result has a double interest. First it confirms the negative effects of neighboring counties on the propensity to create CUs for a county. Second it states that the underlying mechanism of ICMS-E is certainly an explanation of these negative spatial interactions. In fact, a county will be incited to increase its coefficient of quality in the attempt to strengthen its share in the ICMS-E and earn more money. Thus, if this county decides to reduce its quality because its neighbors have increased theirs, this could be a strategic decision to promote economic activities over CUs in an attempt to attract peasants or firms from neighboring counties who are focusing on increasing their CUs quality. This result thus confirms the profitability hypothesis and the efficiency problem of the ICMS-E which reduces the incentives to increase the quality of CUs due to the functioning of this mechanism.

Concerning the other economic factors, the negative effects of agricultural and industrial

[17]Results do not change without the quadratic term. The income effect remains positive but non significant, the effects of other control variables do not change nor do the significant negative spatial interactions between counties.

[18]In all regressions, the variable $OtherCUsratio2010$ ($Othercoeff.quality2010$) refers to the federal and state managed CUs (coefficient quality) within a county, i.e., the variable $FED_{j,t_{2010}}$ in the conceptual framework.

[19]This result validates the necessity to control for the specific case of Curitiba for which the behavior is not explained by the current specification. In fact, though Curitiba has a strong urban density as well as important industrial activity, the level of created CUs is important. Other underlying mechanisms occur to explain these results. For instance, the proximity with the state government or the development of an important middle class more sensitive to environmental purposes can explain the specificity of Curitiba. Above all, these elements can be explained by our model by increasing the profitability of the *preserved* option.

activities are still found suggesting that more developed counties are less sensitive to increasing the quality of their CUs. This may be because these counties prefer to spend money on developing their activities rather than maintaining and promoting their CUs. Finally, neither the population variables nor the income variables have a significant effect. Concerning the indirect effects (spatial externalities), two variables have a significant effect. First is the negative initial level of quality (in 2000) suggesting that the more was the initial level of neighbors, the less the propensity for the county to increase the quality of its CUs. The second significant indirect impact is the positive effect of agriculture. Thus, the greater the weight of agriculture in the neighbors of a municipality, the greater the propensity to create CUs in this county.

7.5.2 Robustness checks

The previous regressions are run with different number of m-steps ($m = 1$ or $m = 20$) of the Gibbs sampler process and different number of draws (n=10,000). Robustness tests are made on the estimation procedure since the main computational challenge using a Bayesian framework is the state of some parameters such as the number of draws or the number of m-step in the computation of estimated negative utility for the censored observations of the dependant variable (LeSage & Pace, 2009).

The first robustness test on the number of steps in the Gibbs sampler process is to test the convergence in the computed vector of parameters which replaces the unobserved latent utility (here for $p^*_{j,t} < 0$) (LeSage & Pace, 2009, p.287). The basic idea is to build up an adequate sample from the truncated multivariate normal distribution. Using a value of $m = 10$ is fairly standard in applied code used in Bayesian framework but for robustness a value of $m = 1$ and $m = 20$ is used.

The second test consists in increasing the number of draws and comparing the inferences based on a smaller set of draws (here n=1,000) to those resulting from a larger set of draws (here n=10,000) in order to evaluate the accuracy of the convergence. The basic assumption is that if the inferences are identical, then formal diagnostics on convergence tests may have been misleading (see (LeSage, 1999, p124-125) for more details) and the convergence can be assumed to be good.

Tables 7.5 (page 219) and 7.7 (page 221) provide results with the CUs ratio as dependent variable for respectively 1 and 20 steps of the Gibbs sampler process with 1,000 draws. The spatial interactions are still found to be negative and significant as are the urban density, the agricultural ratio and the industrial one. The level of created CUs in 2000 is now found to have a significant and negative indirect effect suggesting the presence of negative neighboring effects on the propensity to create CUs. Also, urban density is now found to have a significant positive indirect effect. This reinforces the role of urban density in the decision to create CUs. If the neighbor of a county has a strong urban density, the propensity to create CUs in this county will be stronger since this county could expect that its neighbor is not inclined to create CUs.

All other results do not change.

Tables 7.6 (page 220) and 7.8 (page 222) provide results with the coefficient of quality as dependent variable for respectively 1 and 20 steps of the Gibbs sampler process with 1,000 draws. The spatial interactions are still negative and significant as is the agricultural ratio (the industrial ratio is no longer significant). The level of the coefficient of quality in 2000 is still found to have a significant and negative indirect effect validating the presence of negative neighboring effects on the propensity to create CUs. Also, the positive indirect impact of agriculture on the coefficient of quality remains significant. As in the regression with $m = 10$, no other variables have a significant indirect effect.

Finally, the number of draws are increased to n=10,000. Tables 7.9 (page 223), 7.11 (page 225) and 7.13 (page 227) present results with the CUs ratio as dependent variable for respectively 1, 10 and 20 steps of the Gibbs sampler process with 10,000 draws while Tables 7.10 (page 224), 7.12 (page 226) and 7.14 (page 228) concern the same regression with the coefficient quality as dependent variable. In all regressions, the spatial interactions are still found to be significantly negative. In the case of the CUs ratio, the urban density and the weight of agriculture and industry are still significant negative effects while for the quality, only the weight of agriculture is still significantly negative. Concerning indirect effects, the initial level of either the ratio of CUs or the coefficient of quality is still found to be negative and significant. Also, two indirect effects appear robust: the positive indirect impact of urban density on the CUs ratio and the positive indirect impact of agriculture on the coefficient of quality.

Finally, in all regressions, Curitiba is found to have a positive propensity to create municipal CUs. To sum up, six results seem to be robust: (1) the negative spatial interactions, (2) the spatial externalities of the initial level of both the CUs ratio and the coefficient of quality, (3) the negative direct and positive indirect effect of agriculture on the coefficient of quality, (4) the negative direct and positive indirect effect of urban density on the CUs ratio, (5) the negative direct effect of agriculture and industry on the CUs ratio, and (6) Curitiba has a positive propensity to create municipal CUs and to increase the quality of its municipal CUs.

7.6 Conclusion

The aim of this chapter was to assess the efficiency and the functioning of the ICMS-E by testing the presence of spatial interactions between Brazilian counties in the state of Paraná. The ICMS-E is a fiscal tool developed in Brazilian states to promote the conservation of natural land by the creation of conservation units (CUs) in Brazilian counties. The ICMS-E is a fiscal transfer from the state to municipalities on the basis of the performance of each county in the creation and management of CUs. This way, ICMS-E can be viewed as a payment for environmental services based on internal financing.

This fiscal scheme is important since it is a way to finance PES but also it is a fiscal transfer in a federalism context. This nature gives strong hypothesis to test the efficiency of this fiscal

scheme at the local level, i.e., in the horizontal relationships (between local government here counties). In fact, the question of the efficiency of fiscal transfer mechanisms has been widely studied in literature and this analysis is an attempt to propose a new investigation through the role of spatial interactions between Brazilian counties, which can be created by ICMS-E, in the allocation of their land.

Indeed, the ICMS-E directly influences the land allocation rule-decision of counties. The ICMS-E is part of a broader fiscal transfer mechanism named the ICMS. This latter rewards counties in function of the value added created by each county. Thus, municipalities have the choice between (1) set aside their land for protection and be awarded by the ICMS-E, and (2) convert their natural land to attract agricultural and industrial plants and be awarded by the ICMS.

Therefore, this study tries to investigate if the behavior of neighboring counties in terms of created municipal CUs has an effect on the propensity for a county to create municipal CUs between 2000 and 2010 in the state of Paraná. The choice of the time-span analysis is motivated by the availability of data but is interesting due to the fact that, in this period, the level of municipal created CUs remained very stable after a strong upward trend in the first decade of the implementation of the ICMS-E (1992-2000) suggesting a structural break. This way, the mechanism of ICMS-E seems to have reached its equilibrium in terms of created CUs questioning its efficiency.

From a land use model and a spatial autoregressive Bayesian tobit model, the results suggest the presence of negative spatial interactions between counties. These negative spatial externalities can be explained by the hypothesis of profitability which states that the county will prefer to develop economic activities to attract peasants and firms from its neighbors who have preferred to create CUs. The functioning of the ICMS-E is an explanation of this result. Since the pool of money shared between counties is fixed, it is preferable for a county to earn money from the ICMS by increasing its economic activities in the case where its neighbors have decided to create CUs and earn money from the ICMS-E.

The results do not highlight a race to the bottom between counties which would have finally questioned the efficiency of the ICMS-E. However, the strategic substitutability nature of conservation behavior seems to lead the mechanism to reach an equilibrium. This is due to the fact that counties compete for a fixed pool of money. However, there is no reason that this fixed pool of money leads to the optimal level of land set aside for protection. This way, the efficiency of the ICMS-E can be questioned. Policy makers should take into account these potential evolutions of such a mechanism to avoid these negative externalities. Policy recommendations would be to increase the attractiveness of the mechanism by increasing the "piece of the pie".

Lastly, the ICMS-E has had great success and has allowed to increase the number of CUs in Paraná. This experience should be viewed as a new and interesting tool to finance local public good from internal financing but by taking into account the potential negative spatial

interactions.

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7.7 Tables of results

7.7.1 Main results

Table 7.1: Spatial interactions and CUs ratio with 10 m-steps and 1,000 draws

Variable	Coefficient	Direct	Indirect	Total
Spatial lag	-0.007011			
	0.039946			
CUs ratio 2000	2.450483	2.470317	-0.020291	2.450026
	0.000000	0.000000	0.102321	0.000000
Other CUs ratio 2010	-0.000710	0.001981	0.000026	-0.001753
	0.976757	0.946970	0.922559	0.947293
Pop. growth	-0.000322	-0.000327	0.000003	-0.000325
	0.259430	0.288006	0.415655	0.288136
Agricultural ratio	-0.169450	-0.174327	0.001459	-0.172868
	0.000001	0.000006	0.163014	0.000006
Industrial ratio	-0.068504	-0.069506	0.000575	-0.068932
	0.029937	0.034596	0.266131	0.034340
Log GDP	-0.010680	-0.010857	0.000101	-0.010756
	0.706258	0.716632	0.758276	0.716680
Log GDP squared	0.003089	0.003079	-0.000028	0.003051
	0.647294	0.664999	0.713979	0.665038
Rural density	-0.000337	-0.000341	0.000003	-0.000339
	0.448038	0.447035	0.549503	0.446850
Urban density	-0.000142	-0.000144	0.000001	-0.000142
	0.000000	0.000001	0.151160	0.000001
Curitiba	0.246863	0.251381	-0.002116	0.249265
	0.000776	0.001720	0.199942	0.001651
Intercept	0.043000			
	0.197629			

Note: Dependent variable is the CUs ratio. P-value is below the estimated coefficient. Estimated with the spatial Bayesian tobit estimator with 1,000 draws and 10 m-steps for 399 observations with 333 censored at 0. Column 2 displays the coefficient estimated, Column 3 the direct effect, Column 4 the indirect effect and Column 5 the total effect. 40 micro-regions dummies are used but results are not presented to save space.

Table 7.2: Spatial interactions and coefficient of quality with 10 m-steps and 1,000 draws

Variable	Coefficient	Direct	Indirect	Total
Spatial lag	-0.009271			
	0.018412			
Coeff. quality 2010	2.006170	2.044481	-0.019894	2.024587
	0.000000	2.024587	0.052545	0.000000
Other coeff. quality 2010	0.047598	0.046818	-0.000457	0.046361
	0.298762	0.046361	0.432839	0.357414
Pop. Growth	-0.000046	-0.000052	0.000000	-0.000051
	0.827393	-0.000051	0.851236	0.821913
Agricultural ratio	-0.097775	-0.101095	0.001000	-0.100095
	0.000010	-0.100095	0.117243	0.000214
Industrial ratio	-0.040390	-0.041674	0.000418	-0.041256
	0.105803	-0.041256	0.287865	0.110357
Log GDP	0.006718	0.006271	-0.000065	0.006206
	0.776353	0.006206	0.806217	0.794730
Log GDP squared	-0.002303	-0.002186	0.000022	-0.002164
	0.674712	-0.002164	0.730517	0.703189
Rural density	-0.000532	-0.000562	0.000006	-0.000556
	0.210439	-0.000556	0.352319	0.200035
Urban density	-0.000005	-0.000005	0.000000	-0.000005
	0.686180	-0.000005	0.756034	0.706445
Curitiba	-0.200547	-0.207605	0.002026	-0.205579
	0.001138	-0.205579	0.102197	0.002151
Intercept	-0.025808			
	0.372629			

Note: Dependent variable is the coefficient of quality. P-value are below the estimated coefficient. Estimated with the spatial Bayesian tobit estimator with 1,000 draws and 10 m-steps for 399 observations with 333 censored at 0. Column 2 displays the coefficient estimated, Column 3 the direct effect, Column 4 the indirect effect and Column 5 the total effect. 40 micro-regions dummies are used but results are not presented to save space.

7.A Appendix

7.A.1 Paraná in Brazil

Figure 7.1: Paraná in Brazil

Source: Encyclopaedia Britannica

7.A.2 Calculation of the ICMS-E: the conservation factor

Table 7.3: Conservation factor FC_n for different management categories n of protected areas in Paraná

Management category	Federal	State	Municipal
Ecological research station	0.8	0.8	1
Biological reserve	0.8	0.8	1
Parks	0.7	0.7	0.9
Private natural heritage reserve (RPPN)	0.68	0.68	.
Area of relevant ecological interest	0.66	0.66	0.66
Forest	0.64	0.64	0.64
Indigenous area	0.45	.	.
Buffer zones (*Faxinais*)	.	0.45	.
Environmental protection area	0.08	0.08	0.08
Special, local areas of tourist interest	0.08	0.08	0.08

Source: Adapted from (Loureiro et al., 2008, p.73). A point (.) mentions that there is none CU of this nature. For instance, there is none municipal or state indigenous area.

7.A.3 Creation of CUs over time

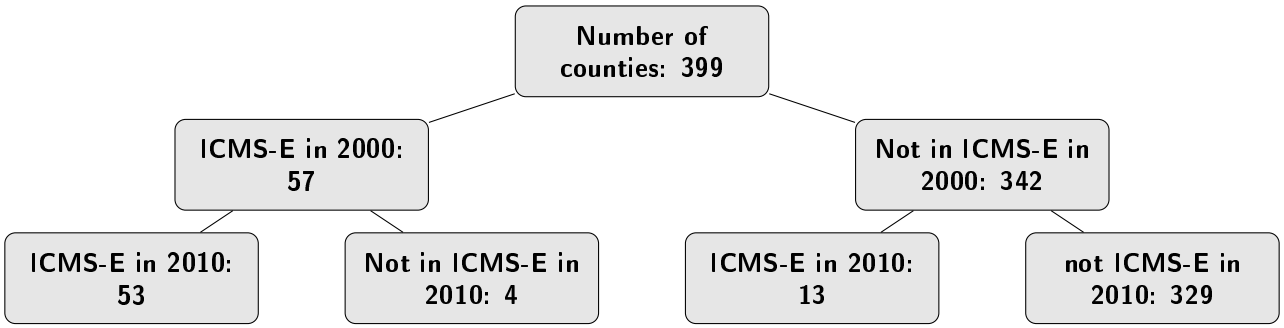
Figure 7.2: Evolution of the creation of all CUs in Paraná between 1991 and 2010

Note: Evolution of the areas (in hectare) of all conservation units (federal, state and municipal) between 2000 and 2010.

Source: Authors' calculation from May et al. (2002) and Grieg-Gran (2000), and authors' collected data.

7.A.4 Descriptive statistics

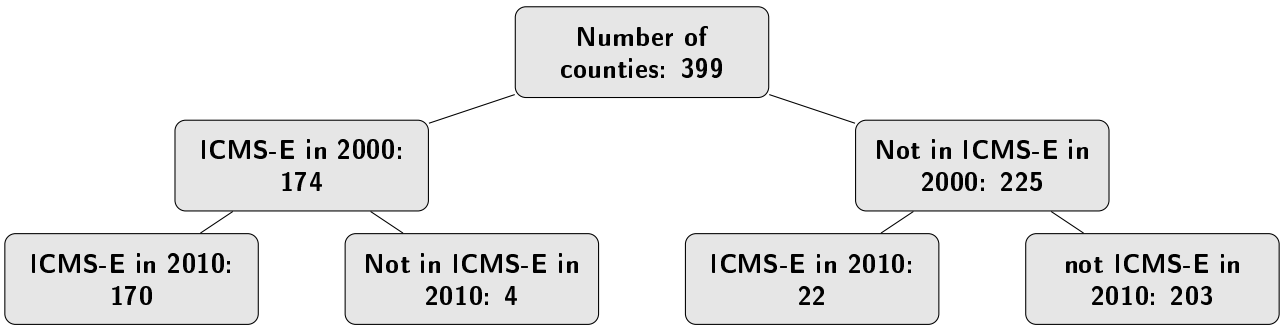
Figure 7.3: Evolution of the number of counties in the ICMS-E for municipal CUs



Note: Evolutions between 2000 and 2010 of the number of counties concerning by the ICMS-E for the creation of municipal CUs.

Source: drafted by the authors

Figure 7.4: Evolution of the number of counties in the ICMS-E



Note: Evolutions between 2000 and 2010 of the number of counties concerning by the ICMS-E, whatever the CUs.

Source: drafted by the authors

Table 7.4: Summary statistics

Variable	**Mean**	**(Std. Dev.)**	**Min.**	**Max.**	**N**
CUs ratio (2010)	0.0034	(0.0238)	0	0.2175	399
Coefficient quality (2010)	0.0018	(0.009)	0	0.1272	399
CUs ratio (2000)	0.0018	(0.0156)	0	0.1993	399
Coefficient quality (2000)	0.0013	(0.0093)	0	0.1695	399
CUs ratio (Federal, State) 2010	0.0444	(0.1322)	0	0.9876	399
Coefficient quality (Federal, State) 2010	0.0135	(0.0386)	0	0.3254	399
Population growth	2.2483	(11.7301)	-38.4769	73.3038	399
Ratio agriculture	0.3051	(0.1484)	0.0004	0.6235	399
Ratio industry	0.1439	(0.1148)	0.0288	0.8336	399
Log GDP	1.6361	(0.3994)	0.8232	3.7569	399
Log GDP squared	2.836	(1.5153)	0.6777	14.1145	399
Rural population density	9.4345	(10.9149)	0	192.9066	399
Urban population density	51.1113	(233.5605)	0.8544	3918.803	399

Source: Authors' calculation.

7.A.5 Tests of robustness

Table 7.5: Spatial interactions and CUs ratio with 1 m-step and 1,000 draws

Variable	Coefficient	Direct	Indirect	Total
Spatial lag	-0.015591			
	0.048943			
CUs ratio 2000	2.496689	2.503930	-0.042608	2.461322
	0.000000	0.000000	0.054628	0.000000
Other CUs ratio 2010	0.002393	0.001981	-0.000046	0.001935
	0.916636	0.930292	0.920119	0.930683
Pop. growth	-0.000238	-0.000225	0.000004	-0.000221
	0.424124	0.447735	0.532125	0.447435
Agricultural ratio	-0.158445	-0.157292	0.002696	-0.154596
	0.000000	0.000000	0.080066	0.000000
Industrial ratio	-0.061420	-0.059479	0.001014	-0.058464
	0.038589	0.048624	0.204452	0.048505
Log GDP	-0.007360	-0.009311	0.000168	-0.009144
	0.781168	0.730343	0.743329	0.730660
Log GDP squared	0.002291	0.002695	-0.000050	0.002646
	0.720088	0.676374	0.686222	0.676887
Rural density	-0.000265	-0.000301	0.000004	-0.000296
	0.447976	0.417102	0.509725	0.417162
Urban density	-0.000150	-0.000150	0.000003	-0.000148
	0.000000	0.000000	0.065177	0.000000
Curitiba	0.269058	0.269791	-0.004644	0.265147
	0.000112	0.000093	0.088660	0.000089
Intercept	0.033778			
	0.309710			

Note: Dependent variable is the CUs ratio. P-value are below the estimated coefficient. Estimated with the spatial Bayesian tobit estimator with 1,000 draws and 1 m-step for 399 observations with 333 censored at 0. Column 2 displays the coefficient estimated, Column 3 the direct effect, Column 4 the indirect effect and Column 5 the total effect. 40 micro-regions dummies are used but results are not presented to save space.

Table 7.6: Spatial interactions and coefficient of quality with 1 m-step and 1,000 draws

Variable	Coefficient	Direct	Indirect	Total
Spatial Lag	-0.007961			
	0.014861			
Coeff. quality 2000	2.147355	2.159819	-0.017943	2.141876
	0.000000	0.000000	0.036036	0.000000
Other coeff. quality 2010	0.046348	0.046710	-0.000395	0.046315
	0.408003	0.417072	0.502236	0.416754
Pop. growth	-0.000087	-0.000099	0.000001	-0.000098
	0.731515	0.717683	0.724148	0.717865
Agricultural ratio	-0.120156	-0.121699	0.001038	-0.120661
	0.000029	0.000048	0.071360	0.000045
Industrial ratio	-0.045715	-0.046228	0.000400	-0.045827
	0.130484	0.129116	0.272974	0.128712
Log GDP	0.007792	0.007482	-0.000067	0.007415
	0.762524	0.772693	0.789936	0.772713
Log GDP squared	-0.002343	-0.002240	0.000020	-0.002220
	0.698956	0.713641	0.744413	0.713582
Rural density	-0.000506	-0.000507	0.000004	-0.000503
	0.192836	0.212209	0.317450	0.212040
Urban density	-0.000005	-0.000005	0.000000	-0.000005
	0.738243	0.725055	0.739453	0.725143
Curitiba	-0.222670	-0.223891	0.001851	-0.222040
	0.003560	0.003754	0.079546	0.003770
Intercept	-0.033999			
	0.277112			

Note: Dependent variable is the coefficient of quality. P-value are below the estimated coefficient. Estimated with the spatial Bayesian tobit estimator with 1,000 draws and 1 m-step for 399 observations with 333 censored at 0. Column 2 displays the coefficient estimated, Column 3 the direct effect, Column 4 the indirect effect and Column 5 the total effect. 40 micro-regions dummies are used but results are not presented to save space.

Table 7.7: Spatial interactions and CUs ratio with 20 m-steps and 1,000 draws

Variable	Coefficient	Direct	Indirect	Total
Spatial lag	-0.011955			
	0.054346			
CUs ratio 2000	2.472687	2.470931	-0.034086	2.436845
	0.000000	0.000000	0.076657	0.000000
Other CUs ratio 2010	0.001294	0.001089	-0.000015	0.001073
	0.958121	0.964834	0.968624	0.964852
Pop. growth	-0.000202	-0.000219	0.000003	-0.000216
	0.460280	0.451633	0.536278	0.451457
Agricultural ratio	-0.159695	-0.161560	0.002267	-0.159293
	0.000000	0.000001	0.122555	0.000001
Industrial ratio	-0.063010	-0.063393	0.000877	-0.062516
	0.055935	0.056882	0.232081	0.056611
Log GDP	-0.010399	-0.011258	0.000177	-0.011081
	0.736135	0.717775	0.721503	0.718445
Log GDP squared	0.003060	0.003214	-0.000050	0.003164
	0.668355	0.657203	0.668395	0.657908
Rural density	-0.000365	-0.000352	0.000004	-0.000348
	0.407417	0.412746	0.473736	0.413702
Urban density	-0.000146	-0.000145	0.000002	-0.000143
	0.000000	0.000000	0.090621	0.000000
Curitiba	0.257999	0.255121	-0.003521	0.251600
	0.000338	0.000518	0.117675	0.000510
Intercept	0.035427			
	0.333635			

Note: Dependent variable is the CUs ratio. P-value are below the estimated coefficient. Estimated with the spatial Bayesian tobit estimator with 1,000 draws and 20 m-steps for 399 observations with 333 censored at 0. Column 2 displays the coefficient estimated, Column 3 the direct effect, Column 4 the indirect effect and Column 5 the total effect. 40 micro-regions dummies are used but results are not presented to save space.

Table 7.8: Spatial interactions and coefficient of quality with 20 m-steps and 1,000 draws

Variable	Coefficient	Direct	Indirect	Total
Spatial lag	-0.009105			
	0.001292			
Coeff. quality 2000	2.035416	2.076427	-0.021004	2.055423
	0.000000	0.000000	0.018837	0.000000
Other coeff. quality 2010	0.040812	0.040646	-0.000400	0.040246
	0.408140	0.417392	0.472173	0.417175
Pop. growth	0.000000	-0.000006	0.000000	-0.000006
	0.998694	0.980572	0.962839	0.980778
Agricultural ratio	-0.103823	-0.108229	0.001113	-0.107117
	0.000141	0.000444	0.053866	0.000422
Industrial ratio	-0.047554	-0.049881	0.000515	-0.049366
	0.068153	0.066962	0.164687	0.066619
Log GDP	0.012694	0.013010	-0.000132	0.012879
	0.593051	0.601068	0.641245	0.600876
Log GDP squared	-0.003612	-0.003715	0.000038	-0.003677
	0.516659	0.517007	0.563700	0.516828
Rural density	-0.000469	-0.000471	0.000005	-0.000466
	0.174240	0.195699	0.269246	0.195671
Urban density	-0.000006	-0.000007	0.000000	-0.000007
	0.626042	0.612264	0.640851	0.612186
Curitiba	-0.200199	-0.205167	0.002085	-0.203082
	0.001990	0.003042	0.059805	0.002994
Intercept	-0.029702			
	0.359977			

Note: Dependent variable is the coefficient of quality. P-value are below the estimated coefficient. Estimated with the spatial Bayesian tobit estimator with 1,000 draws and 20 m-steps for 399 observations with 333 censored at 0. Column 2 displays the coefficient estimated, Column 3 the direct effect, Column 4 the indirect effect and Column 5 the total effect. 40 micro-regions dummies are used but results are not presented to save space.

Table 7.9: Spatial interactions and CUs ratio with 1 m-step and 10,000 draws

Variable	Coefficient	Direct	Indirect	Total
Spatial lag	-0.005140			
	0.056389			
CUs ratio 2000	2.482924	2.484895	-0.014194	2.470701
	0.000000	0.000000	0.095831	0.000000
Other CUs ratio 2010	-0.003825	-0.003323	0.000013	-0.003310
	0.900281	0.912417	0.947854	0.912257
Pop. growth	-0.000389	-0.000387	0.000002	-0.000385
	0.249177	0.248091	0.371734	0.248147
Agricultural ratio	-0.198933	-0.197727	0.001141	-0.196586
	0.000003	0.000004	0.121557	0.000003
Industrial ratio	-0.082875	-0.081705	0.000469	-0.081237
	0.035391	0.036242	0.205557	0.036217
Log GDP	-0.002954	-0.003300	0.000025	-0.003275
	0.933269	0.924846	0.915268	0.924984
Log GDP squared	0.001617	0.001675	-0.000011	0.001664
	0.844032	0.837278	0.839422	0.837426
Rural density	-0.000413	-0.000404	0.000002	-0.000402
	0.408927	0.413295	0.510039	0.413380
Urban density	-0.000147	-0.000147	0.000001	-0.000146
	0.000002	0.000002	0.117095	0.000002
Curitiba	0.253359	0.254765	-0.001453	0.253312
	0.003102	0.002947	0.160360	0.002948
Intercept	0.031586			
	0.455131			

Note: Dependent variable is the CUs ratio. P-value are below the estimated coefficient. Estimated with the spatial Bayesian tobit estimator with 10,000 draws and 1 m-steps for 399 observations with 333 censored at 0. Column 2 displays the coefficient estimated, Column 3 the direct effect, Column 4 the indirect effect and Column 5 the total effect. 40 micro-regions dummies are used but results are not presented to save space.

Table 7.10: Spatial interactions and coefficient of quality with 1 m-step and 10,000 draws

Variable	Coefficient	Direct	Indirect	Total
Spatial lag	-0.005395			
	0.014428			
Coeff. quality 2000	2.083261	2.074935	-0.011564	2.063371
	0.000000	0.000001	0.041013	0.000001
Other coeff. quality 2010	0.048372	0.048150	-0.000270	0.047880
	0.361493	0.362783	0.434970	0.362756
Pop. growth	-0.000195	-0.000193	0.000001	-0.000192
	0.435325	0.434361	0.484684	0.434388
Agricultural ratio	-0.120498	-0.120197	0.000681	-0.119516
	0.000026	0.000029	0.065659	0.000027
Industrial ratio	-0.047154	-0.047487	0.000268	-0.047219
	0.101485	0.097240	0.216053	0.097171
Log GDP	0.009978	0.010066	-0.000057	0.010009
	0.710938	0.708264	0.742678	0.708208
Log GDP squared	-0.002560	-0.002584	0.000014	-0.002569
	0.681432	0.678730	0.721658	0.678643
Rural density	-0.000330	-0.000323	0.000002	-0.000321
	0.310357	0.316166	0.399120	0.316184
Urban density	-0.000005	-0.000005	0.000000	-0.000005
	0.697017	0.687786	0.729164	0.687705
Curitiba	-0.208601	-0.206840	0.001156	-0.205683
	0.004653	0.005035	0.091795	0.005023
Intercept	-0.028195			
	0.424255			

Note: Dependent variable is the coefficient of quality. P-value are below the estimated coefficient. Estimated with the spatial Bayesian tobit estimator with 10,000 draws and 1 m-step for 399 observations with 333 censored at 0. Column 2 displays the coefficient estimated, Column 3 the direct effect, Column 4 the indirect effect and Column 5 the total effect. 40 micro-regions dummies are used but results are not presented to save space.

Table 7.11: Spatial interactions and CUs ratio with 10 m-steps and 10,000 draws

Variable	Coefficient	Direct	Indirect	Total
Spatial lag	-0.007539			
	0.069369			
CUs ratio 2000	2.495967	2.506382	-0.020690	2.485693
	0.000000	0.000000	0.080566	0.000000
Other CUs ratio 2010	-0.005525	-0.006300	0.000060	-0.006240
	0.853061	0.831965	0.834697	0.832145
Pop. Growth	-0.000334	-0.000321	0.000002	-0.000318
	0.318289	0.338173	0.442593	0.338137
Agricultural ratio	-0.195091	-0.194324	0.001616	-0.192707
	0.000001	0.000001	0.105033	0.000001
Industrial ratio	-0.083564	-0.082709	0.000683	-0.082026
	0.025659	0.028276	0.182906	0.028239
Log GDP	-0.003673	-0.004373	0.000051	-0.004322
	0.915589	0.900116	0.880971	0.900429
Log GDP squared	0.001730	0.001888	-0.000019	0.001869
	0.830145	0.815637	0.812098	0.815906
Rural density	-0.000446	-0.000439	0.000004	-0.000436
	0.370995	0.372566	0.476569	0.372608
Urban density	-0.000149	-0.000150	0.000001	-0.000149
	0.000001	0.000001	0.106328	0.000001
Curitiba	0.257427	0.260770	-0.002175	0.258595
	0.002245	0.002220	0.149811	0.002189
Intercept	0.029565			
	0.478434			

Note: Dependent variable is the CUs ratio. P-value are below the estimated coefficient. Estimated with the spatial Bayesian tobit estimator with 10,000 draws and 10 m-steps for 399 observations with 333 censored at 0. Column 2 displays the coefficient estimated, Column 3 the direct effect, Column 4 the indirect effect and Column 5 the total effect. 40 micro-regions dummies are used but results are not presented to save space.

Table 7.12: Spatial interactions and coefficient of quality with 10 m-steps and 10,000 draws

Variable	Coefficient	Direct	Indirect	Total
Spatial lag	-0.007860			
	0.029336			
Coeff. quality 2010	2.032120	2.023016	-0.017006	2.006010
	0.000000	0.000000	0.054477	0.000000
Other coeff. quality 2010	0.049377	0.048734	-0.000415	0.048319
	0.331595	0.330935	0.419984	0.330930
Pop. Growth	-0.000111	-0.000106	0.000001	-0.000105
	0.651782	0.661953	0.684167	0.662091
Agricultural ratio	-0.110865	-0.109444	0.000936	-0.108508
	0.000062	0.000076	0.088593	0.000073
Industrial ratio	-0.044297	-0.044561	0.000383	-0.044178
	0.106283	0.100042	0.246642	0.099914
Log GDP	0.009938	0.010105	-0.000085	0.010019
	0.697339	0.689017	0.724200	0.689013
Log GDP squared	-0.002748	-0.002781	0.000023	-0.002758
	0.646194	0.638565	0.680507	0.638569
Rural density	-0.000368	-0.000370	0.000003	-0.000367
	0.279075	0.274648	0.369824	0.274771
Urban density	-0.000005	-0.000005	0.000000	-0.000005
	0.713923	0.701541	0.750868	0.701395
Curitiba	-0.202580	-0.200935	0.001693	-0.199242
	0.003004	0.003034	0.101583	0.003045
Intercept	-0.036568			
	0.265536			

Note: Dependent variable is the coefficient of quality. P-value are below the estimated coefficient. Estimated with the spatial Bayesian tobit estimator with 10,000 draws and 10 m-steps for 399 observations with 333 censored at 0. Column 2 displays the coefficient estimated, Column 3 the direct effect, Column 4 the indirect effect and Column 5 the total effect. 40 micro-regions dummies are used but results are not presented to save space.

Table 7.13: Spatial interactions and CUs ratio with 20 m-steps and 10,000 draws

Variable	Coefficient	Direct	Indirect	Total
Spatial lag	-0.008327			
	0.010486			
CUs ratio 2000	2.495267	2.494873	-0.022160	2.472713
	0.000000	0.000000	0.025873	0.000000
Other CUs ratio 2010	-0.004671	-0.004121	0.000042	-0.004079
	0.867565	0.883087	0.880357	0.883221
Pop. Growth	-0.000360	-0.000350	0.000003	-0.000347
	0.289930	0.308498	0.389802	0.308398
Agricultural ratio	-0.194244	-0.193731	0.001746	-0.191985
	0.000002	0.000003	0.057662	0.000002
Industrial ratio	-0.081738	-0.081420	0.000738	-0.080682
	0.030961	0.032545	0.150980	0.032383
Log GDP	-0.005865	-0.005877	0.000057	-0.005819
	0.866068	0.865847	0.869622	0.865921
Log GDP squared	0.002521	0.002465	-0.000024	0.002441
	0.757650	0.762807	0.773068	0.762907
Rural density	-0.000380	-0.000396	0.000003	-0.000393
	0.429516	0.423205	0.492801	0.423140
Urban density	-0.000148	-0.000148	0.000001	-0.000146
	0.000001	0.000001	0.040652	0.000001
Curitiba	0.256395	0.256319	-0.002273	0.254046
	0.001806	0.001864	0.071690	0.001863
Intercept	0.033295			
	0.419546			

Note: Dependent variable is the CUs ratio. P-value are below the estimated coefficient. Estimated with the spatial Bayesian tobit estimator with 10,000 draws and 20 m-steps for 399 observations with 333 censored at 0. Column 2 displays the coefficient estimated, Column 3 the direct effect, Column 4 the indirect effect and Column 5 the total effect. 40 micro-regions dummies are used but results are not presented to save space.

Table 7.14: Spatial interactions and coefficient of quality with 20 m-steps and 10,000 draws

Variable	Coefficient	Direct	Indirect	Total
Spatial lag	-0.028634			
	0.395237			
Coeff. quality 2010	2.095744	2.081309	-0.010148	2.071161
	0.000000	0.000000	0.126884	0.000000
Other coeff. quality 2010	0.042334	0.042886	-0.000205	0.042681
	0.417894	0.407404	0.531560	0.407304
Pop. Growth	-0.000122	-0.000115	0.000001	-0.000115
	0.622875	0.637291	0.663719	0.637450
Agricultural ratio	-0.112345	-0.110796	0.000547	-0.110249
	0.000081	0.000097	0.155555	0.000096
Industrial ratio	-0.043165	-0.042758	0.000204	-0.042553
	0.127466	0.128396	0.305998	0.128478
Log GDP	0.009026	0.008900	-0.000039	0.008862
	0.722778	0.723182	0.790352	0.723044
Log GDP squared	-0.002489	-0.002484	0.000011	-0.002473
	0.679850	0.676647	0.757503	0.676481
Rural density	-0.000372	-0.000369	0.000002	-0.000367
	0.304807	0.299605	0.447697	0.299588
Urban density	-0.000005	-0.000005	0.000000	-0.000005
	0.708593	0.704741	0.781924	0.704572
Curitiba	-0.211293	-0.208959	0.001024	-0.207935
	0.003677	0.003984	0.182370	0.003970
Intercept	-0.004810			
	0.075243			

Note: Dependent variable is the coefficient of quality. P-value are below the estimated coefficient. Estimated with the spatial Bayesian tobit estimator with 10,000 draws and 20 m-steps for 399 observations with 333 censored at 0. Column 2 displays the coefficient estimated, Column 3 the direct effect, Column 4 the indirect effect and Column 5 the total effect. 40 micro-regions dummies are used but results are not presented to save space.

Part V

General conclusion

Main results

Institutions are the rule of the human game allowing for the reduction of uncertainty and transaction costs and thereby increasing the allocation of resources. Institutions are particularly important in a complex modern human society to shape and regulate economic, social and political human interactions. The effects of institutions on economic development but also on sustainable development such as deforestation have thus been widely investigated.

This thesis investigates the effects of institutions on deforestation given that the combat against deforestation is coming to the top of the global policy agenda. The preservation of forested areas is a condition of balanced development in developing and emerging countries. The example of Brazil is relevant. This country is trying to reconcile its strong economic growth and the preservation of its huge tropical Amazonian forest in order to protect the unbelievable biodiversity hotpot and ensure a carbon sink.

Therefore, the effects of institutions, as important elements of the human incentives structure, on deforestation have been studied in this thesis around three new issues. First was the role of history throughout the legacies of each countries in terms of legal origin (of law and regulation) and colonial origin. The basic idea was that institutional legacies can affect deforestation but also conditioned the effect of institutions on deforestation. Second was the understanding of the role of the demand for good governance, defined as the compliance with the law and the degree of public officials accountability, on deforestation. The starting point was that the demand side of the governance system is important to explain and actually understand the effects on deforestation of the supply side (for instance the effects of the rule of law) and so, in turn, the sustainability of these reforms in terms of forest preservation. Third was the role of institutions and governance system as the underlying framework conditioning the effect of proximate causes on deforestation through two micro applications studies in Brazil. The main motivation of this last part was to propose another way to understand the importance of the institutional background as a catalytic element.

The first part relied on the theory of the persistence of institutions using the framework of the historical and comparative institutional analysis (HCIA). This framework states that the current institutional framework is a reflection of a historical process. In consequence, the first part has analysed whether inherited legacies such as legal origin and colonial origin can help to understand how institutions shape deforestation. The first part of the thesis was thus based on the literature which studies the existence of institutional persistence through legal origin on law and regulation as well as colonial origin.

This thesis begins with an historical and comparative analysis of the evolutions of the forest law in France and Great Britain from the 11th to the 20th century. Given that the analyse of institutional persistence in the three following chapters relies on the differences between legal origin (the French civil law and the British common law), as well as colonial origins (particularly the French and British heritage), the first chapter gives (1) an analysis of the main historical differences between the French and English forest law in order to (2) better understand the role of legal and colonial legacies on deforestation. The main result was that from the 18th century, the French forest law became more severe and promoted a huge durable forestry management compared to the English Forest Law. This analysis proposes in turn a historical explanation for the differing impact of French and English colonial and legal origins on deforestation.

The thesis goes on to test the presence both of legacies on deforestation (chapter 2) and of legacies on the effects of institutions on deforestation (chapters 3 and 4) using three econometric analysis. The second chapter deals with the role of legacies on deforestation and investigated if inherited legacies such as legal origin and colonial origins can explain deforestation in 110 developed and developing countries. The starting point of this chapter was that differences in deforestation among countries could be attributed to their legal systems. This assumption was based on recent empirical works which have shown that countries whose legal systems are based on French civil law differ systematically in terms of economic performance from those whose legal systems are based on English common law. The consequences of these differing legal traditions on current economic performances have been thus broadly studied in the literature and this chapter has contributed to this literature by investigating the impact of legal origin on deforestation. What is found in the literature is that legal origin is correlated with a wide range of institutions and policies which could be expected to produce higher rates of deforestation such as corruption, miss-defined property rights, or a weak rule of law in French civil law countries as opposed to common law ones. For this reason, differences in legal origin could explain differences in deforestation. Moreover, this chapter makes an attempt to test the main result of the first chapter in terms of the superiority of the French forest law compared to the English ones. Finally, the proposal of investigate the influences of both the legal and colonial origins on deforestation is a way to evaluate the role of forest law origins. The starting point was that behind French (English) legal or colonial origins could be analysed the French (English) forest law.

The main result of the second chapter was that civil law countries deforest significantly less than common law countries. Nevertheless, the implementation of each legal system was exogenous only for previously colonized countries in which the legal system was transplanted by the colonizer. In these countries, the differential impact of the French civil law was found to remain significant. Moreover, a close relationship between colonial history and legal origin is obvious. This fact makes it difficult to attribute the differences in environmental performance to legal origin as opposed to other aspects of colonial policy. In this sense, the differential impact of the French civil law could be attributed to French colonial legacies. Fortunately, the test of a specific French difference has been feasible since not all previously colonized countries with a French civil law inheritance were colonized by France. It was found that former French colonies tend to deforest less than former British, Spanish, or other colonies. This difference can be attributed to forest law legacies inherited from the 1827 French Forestry Code (chapter 1).

The third and fourth chapters of this thesis study if (1) inherited colonial legacies (chapter 3) and (2) legal origin (chapter 4) can explain deforestation by shaping the current impact of the institutional background on deforestation, i.e., to study the presence of institutional persistence.

The third chapter investigates the role on deforestation of colonial origin. The starting point was to study whether moving from French to British colonial legacies may influence the level of deforestation and whether the quality of institution may affect this relationship. The effects of institutional persistence on deforestation through colonial legacies were estimated on a core dataset of 61 non European and former colonized countries. The main results were that (1) an improvement of the quality of institutions was found to better dampen deforestation in countries previously colonized by Spain or Great Britain (compared to those colonized by France), and (2) that former French colonies were inclined to deforest less than former Spanish and British colonies in a context of bad governance. This last result actually suggested that in

a context of poor governance (such as poor property rights, corruption, autocracy, low level of government functioning), the presence of some French colonial legacies were helping to preserve the forest such as French forest law legacies (chapter 1).

The fourth chapter analyses the role of legal origin on law and regulations on deforestation through institutions. The effects of institutional persistence on deforestation through legal origin were estimated on a core dataset of 82 countries having a French civil law origin, a common law origin, or a German civil law origin from 1990 to 2005. Moreover, a core dataset of 60 non European and previously colonized countries was used to investigate the exogeneous role of legal origin in more depth. The main results were that (1) an improvement of the corruption control was found to dampen deforestation in French civil law countries whereas (2) better democratic rules and less ownership risk were more prone to reduce deforestation in common law countries. By contrast, some institutions such as the quality of the legal structure and the rule of law have no differential effect dependant on the legal origin, i.e., whatever the legal origin, an enhancement of each of these two indicators was found to be significantly associated with less deforestation. In addition to these conditioned institutional effects, French civil law countries are found to deforest less than common law countries in a context of bad governance suggesting, in turn, the presence of some French legacies helping to preserve the forest. This result highlights the importance of puzzling out the role of the origin of the legal system for fighting against deforestation.

The second part of this thesis investigates an important dimension of the institutional framework affecting deforestation in developing countries: the demand for good governance. The current global policy agenda has made governance systems one of the main elements for responding to deforestation issues in developing countries, as they are an available way of shaping human actions towards common goals such as sustainable development. In this context, good governance practises have to be reached to promote sustainable development. These practices also obviously depend on the rule of law proposed by the suppliers of good governance to enhance governance in the line of rule of law theory which is an attempt to discover and promote proper legal structures for sustainable development. However, in most studies of governance, emphasis is put only on the supply side of reforms without taking into account the demand side for good governance reforms. Therefore, the second part was an attempt to show that the demand side for good governance matters in the comprehension of the failures of the supply side for good governance and in the promotion of sustainable development (chapter 5).

In this second part, the demand side for good governance was defined more broadly as the degree of accountability of public officials. Moreover, the concept of demand for good governance used in the fifth chapter in terms of environmental compliance with the law, related to the respect and the enforcement of the legal system was derived from that definition. As a result, the relations between the demand and the supply side are found to be complex because compliance (demand side) may be treated as an indivisible part of the rule of law (supply side). Understanding the interactions between the demand side and the supply side for good governance thus become important and relevant (chapter 5). Using a principal–agent model, environmental compliance and judicial efficiency were found to be complementary or substitutable in strengthening the forest stock. More precisely, the main proposition of the model stated that environmental compliance could be viewed as a substitute of low judicial efficiency or a complement of high judicial efficiency in strengthening the forest stock. Moreover, empirical estimates, using cross sectional data for 60 developing countries, have supported the main

theoretical prediction. The demand for good governance was found to insure the sustainability of good governance reforms, i.e., to preserve the forest stock. However, the results have showed that an improvement of the efficiency of governance infrastructure reduced the level of forest stock only in the case of a lack of environmental compliance. Hence, the non-sustainability of good governance reforms in developing countries can be explained by a lack of demand for good governance. This chapter has given, in turn, an explanation for the sustainability of governance reforms and has called for more consideration of the role of demand for good governance.

The last part of the thesis gives two micro-economics applications into the Brazilian context of the role of institutions and governance system as underlying causes shaping the effect of proximate causes on deforestation. This last part attempts to understand the effects of agricultural productivity in the Brazilian Legal Amazon (chapter 6) and the ICMS-ecologico (ICMS-E), a fiscal tool in the state of Paraná (chapter 7), on deforestation.

Agricultural expansion is one of the main causes of deforestation in the Brazilian Amazon. Because of this, the seventh chapter has investigated the impact of agricultural technical efficiency on the propensity of farmers to convert natural land into agricultural plots, i.e., deforestation. This analysis was performed in the Brazilian Legal Amazon (BLA) characterized by a poor institutional background with a weak environmental valuation of the Brazilian forest, an uneven land distribution, and a problem of the *de facto* openly accessed forested and "unproductive" lands.

This chapter has thus given a new explanation of the economic drivers of deforestation at the farm level. The starting point was to investigate whether there exists a clear and unambiguous link between agricultural efficiency, as a proximate cause, and deforestation in the specific institutional context of the BLA, as an underlying cause. In this context, a potential increase of productivity could create incentives to convert more natural land when an efficient farmer is (i) in a context of relatively poor environmental valuation implying that this kind of farmer does not internalize the social cost of forest into their production decisions, and (ii) in a *de facto* openly accessed "unproductive" private land which pushes farmers to exploit their extensive margins before their intensive ones. A two step econometric approach was thus adopted. A bootstrapped translog stochastic frontier that was a posteriori checked for functional consistency was used in order to estimate technical efficiency, estimates of which were put into a land use model to assess the impact of productivity on deforestation. Regressions were estimated on census-tract-level data from the Censo Agropecuario 1995–1996 in the BLA (Acre, Amazonas, Amapa, Para, Rondõnia, Roraima and Tocantins (North region), Mato Grosso (Center-West region), and Maranhão (North-East region)).

Econometric results have suggested that technical efficiency was found to have a **U**-shaped effect: less and more efficient farms were more inclined to use land for agricultural activities increasing deforestation. However, it was found that the majority of farms were on the ascendant slope, i.e., agricultural technical efficiency increased deforestation in the BLA. This result has been explained by the poor environmental valuation of Brazilian tropical forest land, resulting in a lack of internalization of the social value of forested land into farmers' production decisions, and *de facto* openly accessed "unproductive" private land which has pushed farmers to exploit their extensive margins before their intensive ones.

The last chapter of the thesis has dealt with an important challenge in the sustainable development agenda which is to find financial resources to incite local actors to produce local public good, having strong global benefits, such as environmental parks. In this sense, Brazilian states have implemented a new payment scheme, the ICMS-E, to incite municipalities to

preserve and promote conservation units. As a consequence, the eighth chapter aims to analyse the consequence of this tool, which implies a choice in land uses, between the development of economic activities and the creation of conservation units, in terms of spatial strategic interactions between neighboring municipalities for the creation of parks. Moreover, the municipalities of the state of Paraná were used since the mechanism is the most advanced.

The starting point of this chapter was that given the nature of the ICMS-E, there could be spatial interactions between counties (positive (complement) or negative (substitute)) in their land allocation. In the case of positive interactions, a municipality could decide to preserve its forests if its neighbors have done so, to maintain its share of the money allocated in the ICMS-E or to be as green as its bordering municipalities. By contrast, the negative spatial interactions were assumed to be more inclined to occur due to the role of the ICMS-E. In fact, the aim of the ICMS-E was to compensate municipalities for the opportunity costs of parks created. Also, this compensation is negatively correlated with the number of municipalities in the program implying that counties could decide to not accept the ICMS-E if their neighboring counties do it so, as a strategic move.

From a land use based deforestation model at county-level and a spatial tobit model, estimated from a bayesian framework with Lesage's matlab code, the main result found was that there were negative spatial interactions between counties between 2000 and 2010 in the State of Paraná. This result has suggested that the ICMS-E has created spatial strategic interactions between counties. The aim of the incentive has thus weakened as the creation of parks in the State of Paraná has not increase since 2000 after 8 years (since 1992) of important growth. The main result of this chapter has questioned in turn the efficiency of this tool in the promotion of forest preservation by creating spatial strategic interactions in land use between municipalities.

To sum up, the last part of the thesis gives an illustration of the role of the institutions and governance system as underlying causes shaping the effect of proximate causes of deforestation. It founds that institutional failures (chapter 6), and political economy (chapter 7) are strongly associated with environmental economy.

Policy implications

The main global result of this thesis is that institutions are really important to understand the deforestation process in developing countries. Moreover this thesis brings three new important policy recommendations allowing for preserving woodland.

The first part, on the role of legacies and institutional persistence on deforestation, suggests that the History of each country is important in understanding its deforestation. Legal origin and colonial origin are substantial determinants of deforestation. The main results is that both French civil law and previously French colonized countries tend to deforest less than common law countries and other previously colonized countries. The comparative analysis of the first chapter can help to understand these results. The divergence between France and Great Britain during the 19th century towards more protection of woodland in France and less preservation of forest in Great Britain could explain why countries influenced by both the colonial and legal policy of France deforest less than those influenced by Great Britain.

In addition, both the third and fourth chapters stress the importance that institutions are significant factors in the process of deforestation but, overall, suggests that these influences should be understood in the light of the past experiences of each country including colonial and

legal legacies. These results question, in turn, the validity of policy recommendations in terms of institutions without taking into account legacies, and underlie the importance of relativism in understanding the effect of institutions on deforestation. The policy recommendation concerning the promotion or the enhancement of an institution has to take into account the past influences of each country.

The second part highlights the role of the demand for good governance in the promotion of sustainable development. The main policy recommendation relies on the strong interactions between the supply side and demand side for good governance. Thus, this thesis calls for more attention on the demand side to understand the failure of good governance reforms implemented in developing countries throughout the enhancement of the supply side without taking into account the demand side. Though the demand side is becoming more important with the initiatives of the World Bank to promote the degree of public officials' accountability as the first step toward the recognition of the demand side, more efforts have to be done to better understand the role of the demand side. Therefore, this thesis proposes a more extended definition of the demand for good governance through the concept of accountability and compliance. This thesis thus gives a new interpretation of the role of compliance including the environmental compliance as a strong factor of sustainable development. Policy recommendations have to promote both the public officials' accountability and the private agents' compliance to enhance the demand for good governance.

Finally, the thesis proposes micro-applications studies of the role of institutions as underlying causes shaping the effect of proximate causes. Institutions can affect deforestation because institutions are the rule of the game shaping economic incentives of private or public agents such as peasants or municipalities. Thus, the quality of the rule of the game conditions the behavior of agents toward more conservative activities or more conversion ones. The effect of institutions has thus to be understood as a catalytic role precipitating the role of proximate causes on deforestation such as agricultural productivity. Institutions should be understood as causes of deforestation which influence the effect of proximate causes and so, in turn, they should be viewed as elements helping bring about a change toward more sustainable development. Finally, the last chapter also illustrates this role of institutions but calls for more consideration of fiscal tools based on internal resources as payment for environmental services. The solution implemented in Brazil in several states such as Paraná has allowed to compensate municipalities which chose to protect their natural land through fiscal transfers from the federal state. This thesis calls for i) a development of this practise to promote the development of environmental services but also ii) a consideration of the heterogeneous context in which municipalities find themselves and the potential strategic interactions between municipalities which a mechanism of this type can create.

This thesis has thus highlighted that institutions are crucial to understand deforestation in developing countries and stresses the importance of taking into account colonial and legal legacies, the behavior of private agents in terms of demand side for good governance and the catalytic role of institutions in the design of policies to enhance institutions and preserve forest.

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RÉSUMÉ

Cette thèse étudie le rôle des institutions dans la compréhension du processus de déforestation dans les pays en développement. L'approche retenue est celle de la nouvelle économie institutionnelle qui définit les institutions comme le cadre incitatif d'une économie, qui structure les interactions économiques des individus. Le cadre institutionnel est donc un élément à part entière du système économique, qui agit sur l'environnement humain à travers la modulation des incitations des agents. A ce titre, les institutions jouent donc un rôle majeur dans le processus de conservation ou de conversion des forêts. L'analyse de ce rôle est la problématique centrale de cette thèse et s'articule autour de trois grandes parties: (1) le rôle de la persistance des institutions ou rôle de l'histoire dans la compréhension de celui des institutions, (2) le rôle de la demande de bonne gouvernance, et (3) le rôle des institutions comme élément catalytique conditionnant l'effet de causes plus directes de la déforestation. La première partie conclut sur le rôle majeur de la prise en compte des legs légaux et coloniaux pour expliquer l'effet des institutions sur la déforestation. La seconde partie explique le rôle majeur de la demande de bonne gouvernance pour préserver la forêt, en étant un substitut (complément) d'une mauvaise (bonne) offre de bonne gouvernance. Enfin, la troisième partie de la thèse suggère de comprendre les institutions comme un facteur catalytique de la déforestation qui permet de comprendre l'effet des causes directes de celle-ci telles que la productivité agricole des fermes de l'Amazonie Légale, ou les comportements stratégiques entre communes du Paraná dans la création de parcs municipaux.

Mots-clés : déforestation, institutions, gouvernance, droit forestier, origines légales, productivité agricole, intéractions spatiales, Brésil.

ABSTRACT

This thesis investigates the role of institutions on deforestation within the framework of the New Institutional Economics. This theory states that institutions can be defined such as the incentive system which shape economic interactions throughout the modulation of the incentives of agents. This way, institutions are at stake in the process of deforestation and the analysis of this role is the core of this thesis, articulated around three parts: the role of institutional persistence (part 1), the importance of the demand for good governance (part 2), and the implications of institutions and governance system as an underlying framework shaping proximate causes of deforestation (part 3). The first part stresses the importance of taking into account colonial and legal legacies to understand the role of institutions on deforestation. The second part explains the leading role of the demand for good governance to preserve forests throughout its interactions with the supply for good governance. The third part proposes two micro-economics applications in Brazil. The role of institutions and governance system on forest cover is defined as a catalytic role precipitating the effect of proximate causes on deforestation such as agricultural productivity in the Legal Amazon, or strategic behaviors between counties in the creation of municipal conservation units in the state of Paraná.

Keywords: deforestation, institutions, governance, forest law, legal origins, agricultural productivity, spatial interactions, Brazil.