Conflicts over Property Rights and Natural-Resource Exploitation at the Frontier

(Forthcoming *Journal of Development Economics*)

Louis Hotte*

first draft: October, 1998
this version: December 2000

Abstract

Competition for land at the frontier is analyzed by considering a game between a first settler and a contestant. Although the first settler is the legitimate owner of a plot of land, its remoteness from the government's administrative center makes it difficult to prove it. This creates incentives for a contestant to dispute his claims. Both contenders will expend resources in order to secure ownership. Due to transport costs, the more remote is a plot of land, the lower its output value; this tends to discourage appropriative activities. Land degradation is sometimes used as a substitute to appropriative activities. A lower discount rate may encourage land degradation.

Keywords: property rights; natural resources; frontier; conflicts; land degradation
JEL classification: D23, D74, O13, Q20

Acknowledgements: An earlier version of this work forms a part of my Ph.D. thesis at the University of Montréal. I am most grateful to my thesis supervisor Gérard Gaudet. I have also benefited from comments by Stéphan Ambec, Leonard Dudley, Henry van Egteren, Karine Gobert, Gloria E. Helfand, Paul Johnson, Jean-Philippe Platteau, Carmine Nappi, Stephen Salant, Yves Sprumont, Tood Smith, Klaas van 't Veld and other seminar participants at the Universities of Michigan, Namur, Alberta, Ottawa, McGill University, Université du Québec à Montréal and Université des Sciences Sociales in Toulouse. Remaining errors are mine.

*Department of Economics and Centre de Recherche en Économie du Développement (C.R.E.D.), University of Namur, Rempart de la Vierge, 8, 5000 Namur, Belgium. Telephone: +32(0)81-72 48 48, Fax: +32(0)81-72 48 40, Email: louis.hotte@fundp.ac.be

1 Introduction

It is a well documented fact that many tropical forest areas are being subject to unsustainable land-use practices which result in severe land degradation and the permanent loss of forest cover. (Repetto, 1988, 1990; Barbier et al., 1991) A crucial feature common to most tropical forest areas consists in the fact that they are located far from the markets and the governments' administrative centers; for this reason, they are often referred to as "frontier regions". The purpose of this study is to try to understand how this particular feature of frontier regions can foster the adoption of unsustainable land-use practices.

There are many factors suspected to contribute to the state of affairs at the frontiers, as there is often a plethora of agents with various and conflicting interests operating in these regions. In the Brazilian Amazon for instance, Schmink and Wood (1992) list the presence of such diverse types of agents as large ranch and sawmill owners, directors of large mining companies, peasants, wage workers, independent miners, rubber tapers, fishers, Brazil nut collectors, Indians, as well as the many levels of government agencies (federal, state, and local), the military and the police. The authors note the presence of "fundamental contradictions within and between [government] agencies (federal, state, and local)" (p. 15), which testifies that the situation can be a complex one to grasp. There remains, nonetheless, one particularity of frontier settlements which is suspected to have a major impact: it is the presence of tenure insecurity.[1] Indeed, one obvious effect of tenure insecurity is to lower the expected value of long-term gains since the settler may have been evicted from the land before these gains have materialized; hence the reduced incentives to invest in sustainable land-use practices.[2]

The mechanics through which ill-defined property rights may encourage an inefficient exploitation of natural resources have been quite extensively investigated, especially in the case of free-access exploitation.[3] What has not deserved as much attention in the literature, however, is the fact that

[1] See, for instance, Schneider (1995), Cruz et al. (1992) and Dorner and Thiesenhuesen (1992).

[2] Another effect of insecure ownership is to limit the availability of credit for investments in productivity-enhancing technologies (Besley, 1995; Feder and Feeny, 1991); this effect will not be considered here.

[3] Classic references are Gordon (1954), Dasgupta and Heal (1979, ch. 3) and Hardin (1968).

incompletely defined property rights may result from a deliberate choice by the exploiter of a resource, who must weigh the benefits of better delineated property rights with its costs.[4] Indeed, when the owner of a natural-resource site decides to exploit his site, be it a crop-producing plot of land, a pasture, a fishery, a forest, a hunting ground, or else, he must decide not only on the intensity of exploitation of the resource, but also on the level of expenditures necessary to define and enforce his ownership rights. In the case of natural-resource exploitation, the protection of property rights may take different forms: for example, one requires the exclusion of encroachers who may try to appropriate some of the output from the site, while another involves an outright contest over who actually owns the site.

When encroachers are costly to exclude, Hotte (1997) has shown that in order to reduce exclusion expenditures, the exploiter may resort to increasing the intensity of exploitation of his resource. The reason is that a more intensive use of the resource lowers the returns from encroachment.

When there is the potential for a contest over a site's ownership, the incumbent may decide to protect his property rights in order to benefit from a long-term, sustained use of the resource. Alternatively, he may decide to deplete the resource, in which case tenure-securing expenditures are reduced since the long-term productive potential of the site has been destroyed, in return for the short-term gains of a quick depletion of the resource's stock. It is the choice between those two alternatives that will be considered in this paper.

As mentioned previously, insecure land ownership is particularly prevalent in frontier areas. This situation is explained by the fact that the more remotely located is the plot of land from the government's administrative centers, the less support the settler will receive in the recognition of his land claims, regardless of their legitimacy.[5] This opens up the possibility of conflicts, as late comers may try to contest the claims of the first settlers in order to evict them and appropriate the land.

The present paper develops a model which is intended to capture the

[4] Alston, Libecap and Mueller (1998) have proposed to endogenize the recourse to violence in a model of rural conflict using a game theoretic approach. Their model seeks to create a link between violence and land reform policy in Brazil in order to perform empirical tests. Their model does not, however, explicitly consider the choice of land use and the effect of distance to center.

[5] Many of the studies referenced in this paper report on this situation. Two good ones are Libecap (1989) and Alston, Libecap and Schneider (1995).

fact that the possibility of an eviction may lead the first settler to adopt an unsustainable use of the land. In doing so, the settler's level of expenditures devoted to the protection of his property rights are endogenized, as well as the level of the contestant's efforts at evicting the settler. In this respect, competition for land is set up as a game between a first settler and a contestant. The analysis proceeds by determining which regime of exploitation and land competition is likely to prevail as the distance from the center varies, taking into account the facts that the government's support in the definition of property rights wears off with distance, while the value of the output decreases due to higher transport costs.

The proposed model suggests that the introduction of a positive probability of eviction affects the value of the land in quite the same way as an increase in the discount rate. In one possible scenario, the results indicate that near the center, a settler is most likely to decide to protect his rights of ownership and choose a sustainable use of the land; this is because even though low transport costs confer a high value to the land's output and encourage competition for land, the proximity of government agencies which support the protection of property rights makes it easy for the settler to discourage contestants. As the distance increases, however, he may initially be induced to devote more efforts in protecting his rights of ownership because of the decline in government support. This creates opportunities for conflicts over land and discourages resource conservation. Finally, in more remote areas, competition for land becomes less severe as the output from the land has less value, thus encouraging resource conservation. As will be seen, other scenarios are also possible. The results also indicate that in some cases, a lower discount rate makes it more costly for the settler to protect his rights of ownership. This effect occurs because the lower discount rate contributes to increasing the present value of a sustainable use of the resource. Circumstances under which a lower discount rate, or a higher resource price, may foster the adoption of non-sustainable land-use practices are discussed.

The paper is organized as follows: Section 2 presents a survey of competition for land as it occurs in various parts of the world. In section 3, the distance from the center is fixed in order to derive a settler's value function for the land, which takes into account the possibility of an eviction. The value function of the contestant's activities are similarly derived. In section 4, a game of appropriation between a settler and a contestant is proposed in which the arrival rate of an eviction is endogenized. The reaction functions of both contenders are derived, as well as the precommitment equilibrium for

different values of the parameters. One of these parameters being the distance from the center, it is shown how these choices may be affected as the distance from the center varies. In section 5, the choice of a non-sustainable use of the resource is introduced. It is shown how a change in the distance from the center may foster the adoption of non-sustainable land-use practices. A conclusion summarizes the results.

2 The nature of land competition

In order to devise a model of competition for land, it is first necessary to get acquainted with the manner in which it takes place. Since an extensive survey would go beyond the scope of this paper, a collection of selected cases with be presented in turn. Some of the common features between these cases will be summarized thereafter; they will provide a basis for the construction of the model of land competition presented in the following section. Owing to the diversity of the cases considered, it is hoped that the proposed model will be of reasonably general relevance.

The case of the Brazilian Amazon frontier provides a good starting point. The following quote from Bunker (1985) summarizes the situation:

> [...] The enormous distances to administrative centers, the lack of commercial value of the land itself, and the frequent absence of the appropriate authorities made the costs of registration far greater than any benefits it might bring. Informal institutions of land tenure based on occupation, use, or sometimes superior force superseded the juridical forms of possession that functioned in the capitalist Brazilian center.
>
> The ranching and lumbering entrepreneurs, attracted by new roads and fiscal incentives, were able to exploit the discrepancies in land tenure institutions. In addition to the presumptive preeminence of national legal forms and titles over locally established use rights in land, these entrepreneurs had greater access to and influence over courts, police, and army detachments. They were further protected by distance from administrative centers to which local occupants might appeal against their violent expulsion. These factors impeded effective state action to control the violence and conflict. [...] (108-9)

In response to a situation that had become chaotic, the Brazilian government created in 1970 the National Institute of Colonization and Agrarian Reform (INCRA) which "was given control over the newly acquired federal lands with the responsibility of classifying land tenure, surveying, selling or colonizing, and titling them. INCRA's assigned goal was to impose an order which would control conflict between various segments of the rural population and regularize the possession and use of land in ways conducive to economic growth..." (109)

As it turned out, opportunities for conflicts over land ownership were not removed by the creation of INCRA, but they did adopt a different form: private interest groups began to devote resources in order to influence INCRA's land allocation policies (110-11).

In their study of the evolution of property rights in the Brazilian Amazon, Alston, Libecap and Schneider (1995) similarly observe that the degree of success of claimants in securing land titles will depend partly on their understanding of the workings of bureaucracies as well as their ability to influence politicians through votes and campaign funds. They add, however, that the farther is a site from the government's administrative center, the lower will be its provision of titling services. Government policy is also important as it will determine "... who receives title (through the allocation formula), when it is assigned (through marking and survey policies, pricing, and other settlement requirements), whether it is secure (through enforcement practices), and whether conflicts are adjudicated (through the police and courts)" (93). As for the settlers, land claiming activities usually took the form of clearing the land's boundaries or building markers around it, notarizing sales receipts, hiring a topographer, and traveling to INCRA offices in attempts to obtain official titles (110). The authors note that these activities can be regarded as investments by the settlers which call for considerable efforts and resources.

As instances of conflicts, Alston, Libecap and Schneider (1995) also report that in the state of Pará, squatters could claim ownership by invading land that was not being used productively, provided that they have improved it and occupied it for long enough. The initial owner's options were then to accept the invasion, or attempt to evict them or negotiate either a voluntary exodus or a transfer to them.

The above two reports about the nature of land competition on the Brazilian Amazon frontier appear to be quite representative of the manner in which it occurs in many other areas of the world, where property rights to land are

not firmly established. The cases presented below attest to this.

In a survey of environmental issues in Mozambique, Dejene and Olivares (1991) suggest that "the land law should recognize the rights of vast numbers of smallholders to the land they cultivate otherwise it will inevitably lead to encroachment by those with economic and political influence" (6). They report that conflicts between subsistence and commercial farmers occur because of the government's lack of knowledge about who actually owns the land. According to them, the government is unable to guarantee tenure security because of insufficient resources devoted to the implementation of a Land Law passed in 1987.

Durham (1979) relates an event that took place during a cotton and cattle boom in the 1950's in Honduras. The owner of a large hacienda built a fence around an area within which small farmers had been establishing homes for years, claiming that it was his. Unable to prove otherwise at the time, the settlers were forcibly removed, those who resisted were jailed, and a government agency sided with the hacienda owner by ordering the eviction of some 50 families. As it was later discovered that the land from which the settlers had been evicted was national, one can see a case where a large landowner devoted resources to influencing government officials, a situation fueled by deficiencies in the land titling records.

In their study of the interactions between land tenure and deforestation, Dorner and Thiesenhusen (1992) are mostly concerned about the fact that in many parts of the world, excessive deforestation in frontier areas often results from tenure insecurity suffered by landowners and settlers. They note that in the 1980's, the threat of a land reform in Paraguay has led to massive deforestation by landowners for fear that their forested areas be declared unproductive. The authors also present the case of the Brazilian Amazon frontier, where small farmers have been driven off their land, often through violent means, by large cattle growers and speculators from the cities. The lack of clear land titles at the frontier, combined with the political influence of large landowners and speculators, has contributed to perpetuating this situation. A similar situation is reported to have taken place in Zaire where, during a process of individualization and titling of land, an élite manipulated the titling mechanism in order to appropriate the land.

Lundahl (1979) reports that around 1950 in Haiti, outsiders began evicting peasants in the lower Artibonite valley after the completion of irrigation works. It was later reported that:

> It was of the opinion that the promise of prosperity created by the important works realized in the Artibonite had aroused an immediate desire to become owners of the lands close to the river among many citizens...
>
> Among the latter there are not only enlightened peasants, but also, and above all, townsmen who have discovered a sudden vocation to become agricultors, and even friends, favorites and members of the previous government acting directly or via intermediaries. (Duvigneaud and Figaro, 1958, p. 1, quoted in Lundahl, 1979, p. 604.)

Lundahl concludes that a peasant's tenure security may be jeopardized by "anything that increases the value of peasant land (604)."

Although this survey of competition is quite limited in scope, it is, in many respects, representative of a large number of cases encountered in the literature.[6] A common thread that binds together all of these cases is the difficulty for the occupier of the land in proving his rights of ownership. Unless the presence of an extensive "legal infrastructure" allows for the uncontestable registration of land claims at a reasonable cost relative to the value of the land, the claims may not be perfectly secure. As many of the cases presented have reported, frontiers are just such regions characterized by a limited legal infrastructure, a situation which opens up the door for land competition and short-termism in resource use.

3 The value of appropriative activities

In this section, it is proposed that both the settler's and the contestant's appropriative activities be formulated as investment decisions. The settler invests in enforcing his property rights, thereby lowering the probability of being evicted. The contestant invests in challenging the settler's claim, thereby increasing the probability of an eviction. As a result, the contenders' investment levels interact to determine the degree of success, hence the value, of their respective projects. But before we consider the strategic implications of the model, let us fix the levels of these appropriative activities; this allows us to derive the values of the contenders' projects for any given pair of

[6] Platteau (1995) offers an excellent concise survey of issues related to land rights in Sub-Saharan Africa. Its report of the nature of conflicts is quite consistent with the cases reported here (see, esp., pp. 17-18).

investment levels. Strategic equilibria will be computed in the next section. Note also that the analysis applies to a parcel of land which is located at a given distance from the market/administrative center; the effects of varying this distance is relegated to section 4.

The model considers the situation of a settler who sets foot on a previously untouched parcel of land in a frontier area. It is assumed that according to the law of the country, being first to arrive provides him with a legitimate right of ownership for the parcel of land, given that he respects some conditions regarding the maximum size of the parcel, the minimum length of stay, the type of use, and so on.[7] The analysis is simplified by assuming that the settler can choose between only two types of resource exploitation: either he opts for an indefinitely sustainable land use with constant output flow rate y, or he chooses to mine the resource, in which case the productive capital of the land is instantaneously depleted in return for an immediately marketable output stock of size S.[8] Land mining is thus irreversible.

Let $p(d)$ denote the unit output price, net of transport costs, for a plot of land located at distance d from the market/administrative center. Then, in an ideal situation of perfectly- and costlessly-defined property rights, the present value of a sustainable land use, given a private discount rate r, would be $p(d)y/r$. The payoff from land mining is $p(d)S$. Note that the price $p(d)$ is net of the opportunity cost of exploitation and that it is assumed to be the same for both types of land use. The settler would prefer a sustainable use of the land if the following were to hold:

$$\frac{p(d)y}{r} > p(d)S. \tag{1}$$

Given that the private and social discount rates are the same,[9] the choice of a sustainable use is socially optimal whenever (1) obtains. This will be assumed to be the case throughout the analysis.

[7] This is the rule of first possession on which the Homestead Act of 1862 in the United States was based. Similar rules typically apply to tropical frontier regions.

[8] A similar choice between two types of land use also appears in Schneider (1995) and Mendelsohn (1994), with the difference that in the case of land mining, they assume that the output flow rate decays at a fixed rate. In practice, of course, the settler may have other options which constitute intermediates from the ones considered here. These two extremes have been chosen here in order to simplify the analysis and bring out the effects of tenure insecurity on the choice of the settler.

[9] These two discount rates may differ due to the presence of credit constraints for frontier settlers (see Schneider 1995). This additional constraint will not be considered here.

When property rights are not perfectly defined, the probability of an eviction will affect the value of the land. Let us see how. For ease of exposition, the first settler is referred to as individual 1 and the contestant as individual 2. Their corresponding levels of investment in appropriative activities are denoted by x_1 and x_2. As mentioned above, these investments affect the probability of the occurrence of an eviction. In order to express this probability in continuous time, an exponential distribution is assumed. Hence, the probability of an eviction having occurred by date t is $Pr\{\tau(x_1, x_2) \leq t\} = 1 - exp\{-f(x_1, x_2)t\}$, where $\tau(x_1, x_2)$ is the date of eviction and $f(x_1, x_2)$ is twice differentiable and is assumed to have the following properties:[10]

$$f = f(x_1, x_2) \geq 0,\ f_1 \leq 0,\ f_2 \geq 0,\ f_{11} \geq 0,\ f_{22} \leq 0, \tag{2}$$

$$f(x_1, 0)|_{x_1 \geq 0} = 0. \tag{3}$$

The properties in (2) imply that higher levels of the settler's investments in tenure security reduce the probability that an eviction will have occurred by date t, while increases in the contestant's investments raise that same probability; both effects occur at a decreasing rate; and the probability of an eviction cannot be negative. Property (3) confers an initial advantage to the first settler by assuming that in the absence of any appropriative expenditures on the part of both contenders, the first settler's property rights are perfectly secure. This may be interpreted as saying that (at least some of) the state's expenditures directed to support legitimate claims to property are substitutes to the owners' efforts.[11]

Since the settler receives a flow of income py before being evicted and zero thereafter, his expected payoff from the land can be expressed as a function

[10] Subscripts refer to partial derivatives with respect to the corresponding arguments of the function.

[11] As far as the contestant is concerned, assumption (3) is consistent with a property of the ratio form of a *contest success function* proposed by Hirshleifer (1988, 1991), which holds that an eviction will not occur if the contestant does not engage in appropriative activity and the first settler's efforts are positive. Hirshleifer's contest success function is, however, undefined when $x_1 = x_2 = 0$, whereas here it is assumed that no eviction will occur in this case too. Section 4.2 discusses the effects of adding this last assumption.

of his own investment level and that of the contestant as[12] [13]

$$V^1(x_1, x_2) = \int_0^\infty pye^{-rt}e^{-f(x_1,x_2)t}dt - x_1 \quad (4)$$

$$= \frac{py}{r + f(x_1, x_2)} - x_1. \quad (5)$$

The effect of introducing a probability of eviction which follows an exponential distribution amounts to increasing the *effective discount rate* of the settler by the value of the exponent.[14]

We now turn to the contestant. In order to evaluate the expected value of his appropriative activities, it is first necessary to determine what will be his tenure situation in the case of a successful eviction, that is, what is the value of the "prize" to be won by the contestant. It will be assumed that once the contestant is successful at evicting the settler, property rights over the appropriated plot of land will thereafter be well established. As can be attested by the cases presented in the previous section, such an assumption may be justified by the fact that the activities devoted to challenging the claims of the settler often comprise efforts at influencing public officials or legislation. If a successful eviction is thus backed by an official recognition of the state, one may assume that it becomes significantly more difficult to challenge afterward.[15] As a result, once an eviction occurs, the contestant gains a secured access to an income stream py of infinite duration. He does not, however, enjoy any income flow from the contested parcel of land before an eviction occurs. The expected payoff for the contestant's activities can be expressed as a function of both his own investment level and that of the

[12] d has been removed as an argument of p in order to clarify the exposition. It will be reintroduced later.

[13] Note that in order to concentrate on the issue of tenure insecurity, both contenders are assumed to be neutral towards risk and will thus seek to maximize the present value of their respective "projects".

[14] Mendelsohn (1994) arrives at the same conclusion. The situation is in many respects similar to that of a race for a patent as described in Reinganum (1989, pp. 855-56). Some important differences are that for each contender, the stochastic processes here are not independent, and the players' positions are not symmetrical.

[15] Another plausible assumption would be for the contestant to be in the same situation as the settler once he successfully obtains an eviction. In this case, the prize to be won by the contestant would carry the same value as that of the settler's before the eviction. This alternative possibility would surely affect the results, but it remains to be seen how. It is the object of ongoing research by the author.

settler as

$$V^2(x_1, x_2) = \int_0^\infty pye^{-rt}(1 - e^{-f(x_1,x_2)t})dt \; - \; x_2 \tag{6}$$

$$= \frac{py}{r} - \frac{py}{r + f(x_1, x_2)} \; - \; x_2 \tag{7}$$

$$= \frac{py}{r} - [V^1(x_1, x_2) + x_1] \; - \; x_2. \tag{8}$$

A comparison with expression (5) reveals that gross of appropriative activities, the contestant's project may have more value than the settler's if $f(x_1, x_2) > r$; this is so, even though both contenders are assumed to share equal access to credit and intend to make a similar use of the land. Moreover, summing the value of both contender's projects yields

$$V^1 + V^2 = \frac{py}{r} - x_1 - x_2, \tag{9}$$

which represents the value of the plot of land when property rights are perfectly and costlessly defined and enforced, minus the expenditures in appropriative activities. Since both contenders will not invest more than the value of their respective projects, the aggregate amount of resources devoted to appropriative activities will not exceed py/r, the value of the coveted land in the case of perfectly- and costlessly-defined property rights.

Now that we have determined the values of the settler's and the contestant's projects for fixed investment levels x_1 and x_2, it becomes necessary to determine what effort levels will be chosen by these agents. We turn to this by specifying a game between the settler and the contestant.

4 A game of appropriation

The problem of a first settler on the frontier is that even though the law may be on his side with respect to the legitimacy of his land claim, the remoteness of the frontier makes it difficult for him to prove it. This is due to the limited presence of a "legal infrastructure" which can assist the settler in proving his claims and creates an opportunity for other individuals to contest the settler's claim and attempt to evict him. The settler, however, can anticipate the arrival of a contestant and engage in tenure-securing expenditures which can take different forms: he may start exploiting the land at a very early date,[16]

[16]See Southey (1978) on rent dissipation due to early arrival of settlers.

join a local squatters' association, mark or fence the land, hire the services of a surveyor, plant permanent crops, pay taxes, obtain a notarized title from the nearest town, prepare to defend himself using violent means, etc. Assuming that those tenure-securing expenditures are sunk costs that can be observed by a contestant, the latter responds by choosing a corresponding level of contesting activities. Note that the model does not distinguish between the different types of appropriative activities; they are simply summarized by investment levels x_1 and x_2. Therefore, it is implicitly assumed that the choice of action is conditioned by the nature of the institutional setting. All of these activities, in the end, aim to increase the chances of appropriating the land.

The timing of the game between the settler and the contestant is as follows:[17] the settler moves first by choosing the type of land use, i.e. whether to mine or sustainably use the land, and, if he opts for a sustainable use, he must decide on a level of tenure-securing expenditures, x_1; he is then followed by the contestant who must choose the level of his expenditures, x_2, devoted to challenge the settler's land claim. The contestant is assumed to be a second mover in the sense that he will be able to observe the settler's choices before he makes his decision. Although this implies a sequence of some sort between each contender's move, the analysis is simplified by assuming that each player's decision is taken at the outset.[18]

In the case of land mining, no conflict occurs since it was assumed that its productive capital was depleted immediately; its payoff is thus pS. In the case of a sustainable use of the land, the settler must decide on how much to invest in tenure security, taking into account the reaction of the contestant.

[17]The order of the moves in exogenously specified in the proposed game. This can be justified by the fact that the first settler has a relative advantage in appropriating the land as a first settler, while the contestant's relative advantage lies in contesting a first settler's claims. These relative advantages may be the result, for instance, of each contender's differing opportunity cost of time, their abilities at gaining access to different levels of government officials, etc. The distinction is necessary because a first settler may otherwise prefer to act as a contestant and vice versa, in which case the order of moves would become endogenous. (I am grateful to Henry van Egteren and Todd Smith for bringing this point to my attention.) See Baik and Shogren (1992) for a comment on the endogenous order of moves in contests.

[18]In their analysis of conflict over property, Grossman and Kim (1995) similarly retain the assumption of a two-stage game in which the resources allocated to offensive weapons are chosen after having observed the resources devoted to defensive fortifications. And so does Grossman (1999) in an analysis of revolutions.

We will therefore begin by deriving the equilibrium value of a sustainable use of the land for the settler. This equilibrium value will subsequently be compared to the value of land mining, in order to determine the conditions under which land mining is preferred by the settler.

The contestant being a Stackelberg follower, he will choose x_2 along his reaction function. This function is obtained through the necessary conditions for the maximization of $V^2(x_1, x_2)$ in (8), for any given x_1, which are

$$\frac{\partial V^2(x_1, x_2)}{\partial x_2} \leq 0, \quad x_2^* \geq 0, \quad \left[\frac{\partial V^2(x_1, x_2)}{\partial x_2}\right] x_2^* = 0. \tag{10}$$

The settler's problem can be conveniently expressed as choosing x_1 and x_2 in order to maximize $V^1(x_1, x_2)$ in (5), with the condition that the contestant remains on his reaction function given in (10), that is

$$\max_{x_1, x_2} V^1(x_1, x_2) \tag{11}$$

$$\text{s.t.} \quad \frac{\partial V^2}{\partial x_2} \leq 0, \tag{12}$$

$$\frac{\partial V^2}{\partial x_2} x_2 = 0, \tag{13}$$

$$x_2 \geq 0, \tag{14}$$

$$x_1 \geq 0. \tag{15}$$

This problem is solved in the appendix, where x_1^L and x_2^F refer to the Stackelberg leader's an follower's respective equilibrium choices. In order to keep the problem tractable, the ensuing analysis makes use of the following functional form for the contest success function, which satisfies the conditions in (2) and (3):

$$f(x_1, x_2) = \frac{b(d)x_2}{c + x_1}, \quad \text{with} \quad b(d), c \geq 0 \quad \text{and} \, b'(d) > 0, \tag{16}$$

where d represents the distance from the center, b is the parameter that determines the marginal effectiveness of the contestant's activities at increasing the probability of an eviction, and c is the parameter that gives an initial advantage to the settler.

Due to the non-negativity constraints on x_1 and x_2, it is useful to classify the equilibria into four separate regimes. Regime I is defined as the one in

which $x_1^L = x_2^F = 0$; regime II as the one in which $x_1^L > 0$ and $x_2^F = 0$; regime III includes the cases with $x_1^L = 0$ and $x_2^F > 0$; and the equilibria with $x_1^L > 0$ and $x_2^F > 0$ define regime IV. Note that regimes I and II include all the equilibria for which no conflict takes place, such that no eviction ever occurs. Regime III also denotes a situation without conflict, but an eviction will eventually occur. As for regime IV, it includes all the cases with conflict and eventual eviction.

4.1 The effect of distance to center

In the present analysis, we are mostly interested in knowing how the situation evolves as the distance from the center varies. For this reason, Figure 1 shows which of the four regimes will hold for any combination of the price $p(d)$ and parameter $b(d)$, since it is these two parameters that are assumed to vary with the distance from the center. If the option of a non-sustainable use of the land is left aside for the moment, the graph of Figure 1 offers various possible scenarios as the distance from the center increases. Which one will hold in practice will depend on how $p(d)$ and $b(d)$ vary with the distance.

figure 1 here

In order to illustrate one possibility, let us consider four plots of land located at distances d_1, d_2, d_3 and d_4, with $d_1 < d_2 < d_3 < d_4$. As explained previously, for $d_i < d_j$, we have $p(d_i) > p(d_j)$ due to transport costs, and $b(d_i) < b(d_j)$ due to the declining effect of the legal infrastructure in support of the settler's property rights. At distance d_1, Figure 1 depicts the case where a low b, combined with a high price, makes it worthwhile for the settler to invest at completely discouraging a potential contestant from entering into a conflict. As the distance increases to $d_2 > d_1$, the price decreases while b increases in such a way as to fall into regime IV: even though the price has decreased, the increase in b was so important that it is no more worthwhile for the settler to invest at entirely containing the contestant's efforts. Then, moving farther to d_3, b is now so high in relation to the output price that it becomes too costly for the settler to invest in reducing the contestant's efforts. Finally, at distance d_4, transport costs become so important that the land's output has little value: even though the efforts of the contestant may be quite effective at obtaining an eviction, the advantage that the law confers to the first settler does not make them worthwhile.

The previous illustration represents but one plausible scenario. It is quite possible, for instance, that starting from point d_1, the price decreases so fast as b increases, i.e. $-\Delta p/\Delta d$ is large relative to $\Delta b/\Delta d$, that regimes IV and III are never encountered; in such a case, competition over land never takes place. Moreover, if there exists a plot of land located far enough, say at distance $\overline{d}$, that $p(\overline{d}) = 0$, then, assuming continuity in $p(d)$ and $b(d)$, there will be some plots of land located far enough that warrant no conflict, even though they have positive values. And finally, again assuming continuity in $p(d)$ and $b(d)$, an inspection of Figure 1 reveals that if regime IV does occur, it is necessarily preceded by regime II and followed by regime III as one moves away from the center.

4.2 Relation with other models of appropriation

Readers familiar with models of appropriation (or predation) may ask what are the assumptions in the present model which allow for the existence of each of the four regimes encountered. In this respect, two assumptions are important: one is that the first settler is a Stackelberg leader, another is the presence of parameter c in the contest success function (16). Indeed, with c equals to zero, Hirshleifer (1995) has found that in a Cournot-Nash setting, only equilibria that fall in regime IV are possible, while Grossman and Kim (1995) have found that regime II is also possible when one contestant is a Stackelberg leader. Hence, equilibria with $x_2 = 0$ must be attributed to the fact that the settler is a Stackelberg leader.

As for regimes I and III, in which $x_1 = 0$, their existence hinges on the assignation of a positive value to parameter c. In regime I for instance, the equilibria are such that the probability of an eviction is zero even though both contenders do not undertake appropriative activities. This possibility contrasts with Hirshleifer's (1995) analysis of anarchy, in which there is always conflict. The difference is not really surprising since in the present analysis, the presence of (partial) state enforcement of property rights is assumed.[19]

We have now determined the regimes that prevail for any combination of $p(d)$ and $b(d)$ in the case of a sustainable use of the land. As far as the settler is concerned, it is now necessary to compare the implied equilibrium

[19] I am grateful to an anonymous referee for pointing out the importance of distinguishing the role played by both assumptions.

value of a sustainable use of the land with that of its alternative use, resource mining.

5 Resource Mining

In order for the settler to prefer a sustainable use over land mining, the value of the former must, of course, be larger. For each of the four regimes, it is thus necessary to compute the equilibrium value of a sustainable use of the land in order to compare it with that of land mining. Since the value of land mining is equal to pS, the following condition must be satisfied in order for the settler to prefer a sustainable use:

$$V(x_1^L, x_2^F) = \frac{py}{r + f(x_1^L, x_2^F)} - x_1^L \quad \geq \quad pS. \tag{17}$$

In regime I, we have $x_1 = 0$ and $f(x_1^L, x_2^F) = 0$. In this case, condition (17) is always satisfied (see assumption (1)) and the settler prefers a sustainable use of the land. In regime II, we have $f(x_1^L, x_2^F) = 0$ and $x_1^L = pyb/r^2 - c$, as derived in Appendix A. Inserting into (17), we obtain the following condition for a sustainable use of the land:

$$\frac{py}{r} - \left(\frac{pyb}{r^2} - c\right) \quad \geq \quad pS. \tag{18}$$

As for regime III, we have $x_1^L = 0$ and $r + f(x_1^L, x_2^F) = \sqrt{pyb/c}$, such that condition (17) can be expressed as follows:

$$\frac{yc}{pb} \quad \geq \quad S^2. \tag{19}$$

And finally, in regime IV, we have $x_1^L = py/4b - c$ and $r + f(x_1^L, x_2^F) = 2b$, which implies the following condition for a sustainable use:

$$\frac{y}{4b} + \frac{c}{p} \quad \geq \quad S. \tag{20}$$

In Figure 2, conditions (18), (19) and (20) have been introduced into the graph of Figure 1 in the case where $y/r < 2S$. Note that if $y/r \geq 2S$, there is never any mining in regime II of Figure 2.

Figure 2 reveals, again, that various scenarios are possible as $p(d)$ decreases and $b(d)$ increases with the distance from the market/administrative

center. It can be seen that if $b(d)$ does not increase too sharply as $p(d)$ decreases, resource mining may not take place at all, and the previously considered scenarios may still occur in a similar fashion, as depicted by points d_1 to d_4. If, however, $b(d)$ does increase fast enough, the pair $(p(d_2), b(d_2))$ may fall at point d_2' in Figure 2, in which case land mining does take place. One may note that starting from point d_1 in regime II, situations of conflict may be altogether bypassed if, as the distance increases, $b(d)$ increases so fast as to avoid the conditions of region IV, thus making land mining a preferable option for the settler. Such a situation would occur, for instance, when land mining proves to be a relatively attractive option for the settler, such as with a large value of S, the immediately marketable stock of the resource. Whether S is large will depend on the characteristics of the resource.

figure 2 here

The role played by the discount rate r deserves a comment. From the results presented in Appendix A, it can be deduced that as py/r tends toward pS, the upper frontier of regime I merges with the lower frontier of the land mining region. This is not surprising since with $py/r = pS$, any positive tenure-securing expenditure, as well as any positive probability of eviction, would immediately drive the value of a sustainable use below that of land mining. In this case, therefore, one would never observe any confrontation nor investment in tenure-securing expenditures. But as py/r gets larger than pS, as would be the case with a decrease in the discount rate, confrontation equilibria become more likely.

It is often suggested that a reduction in the discount rate tends to encourage the adoption of sustainable land-use practices in tropical forest areas. The present model suggests that this is not necessarily the case. With a proper choice of parameter values, one may devise cases where a drop in the rate of interest induces a shift of equilibrium from regime I (with a sustainable use of the resource) to a regime of land mining. This perverse effect is due to the fact that even though a lower discount rate, taken in isolation, increases the value of a sustainable use of the resource for the first settler, it also does so for the contestant. Hence, it fosters incentives to contest its ownership. In equilibrium, the incentives for the contestant may be such that the first settler chooses to mine the resource instead of engaging into a conflict. One may similarly find cases where the drop in the rate of interest causes a shift from regime II (free of confrontation) to regime IV (with con-

frontation).[20] These results suggest that in a world where property rights are costly to protect, a reduction in the discount rate may induce more land degradation or conflict over resources, unless it is accompanied by a stronger presence of the state in support of the settler's tenure-securing efforts.

An inspection of figure 2 also reveals that an exogenous increase in the resource price may lead the first settler to adopt land mining. This effect would result, for instance, after the construction of a logging road which improves access to some remote region, thereby lowering transport costs. The imposition of a tax on the resource would have the opposite effect of encouraging resource conservation.[21]

6 Conclusion

This study has proposed a model of competition for land in frontier regions. These regions were characterized by the fact that due to their remote location, land owners cannot enjoy the strong presence of a legal infrastructure in support of their claims to ownership. As a result, contestants may be tempted to dispute those claims. The owner of the land, however, may respond by devoting resources toward a better delineation of his property rights. On the other hand, as the distance to the centers increases, appropriative activities may be discouraged by the fact that transport costs reduce the value of the land's output.

It was seen that as the distance from the center increases, many different scenarios are possible, which depend on how fast the price of the resource decreases with distance in relation to the decreasing presence of a legal infrastructure. In one scenario, land owners located near the center protect their rights in such a way as to completely discourage any potential contestant, and the land is used in a sustainable manner. This is due to the strong support of government agencies which are located nearby. A similar equilibrium results at large distances from the center. But in this case, a contestant is not interested in entering into a conflict because transport costs make the value of the output too low to justify appropriative activities. It is at intermediate distances that problems may arise. In one scenario, the land is used in a sustainable way but conflicts take place in which both contenders engage in

[20] This corroborates the finding by Alston, Libecap and Mueller (1998) that subsidized rural credit seems to increase the incidence of rural violence.

[21] I am grateful to Jean-Philippe Platteau for bringing this last point to my attention.

appropriative activities. In another scenario, no conflict takes place but the land is degraded; in this case, land owners have chosen to deplete the stock of the resource as a substitute to the protection of property rights.

Comparative statics suggest that a decrease in the discount rate may in some cases encourage land degradation. This is because even though a lower discount rate makes a long term use of the resource more valuable to land owners, it also encourages more competition over land. The second effect may induce some owners to resort to a depletion of the land's productive potential in order to avoid conflict. More generally, this suggests that any policy aimed at increasing the value of land's output in order to promote conservation shoud be combined with a better government support for the protection of property rights.

APPENDIX

A The settler's problem with precommitment

The Lagrangian function for the problem described in (11) through (15) is [22]

$$L(x_1, x_2) = V^1(x_1, x_2) - \lambda_1 \frac{\partial V^2}{\partial x_2} + \lambda_2 x_2 + \lambda_3 x_1 + \mu \frac{\partial V^2}{\partial x_2} x_2,$$

The Kuhn-Tucker conditions are

$$L_1 = \frac{\partial V^1}{\partial x_1} + (\mu x_2 - \lambda_1) \frac{\partial^2 V^2}{\partial x_2 \partial x_1} + \lambda_3 = 0, \tag{21}$$

$$L_2 = \frac{\partial V^1}{\partial x_2} + (\mu x_2 - \lambda_1) \frac{\partial^2 V^2}{\partial x_2^2} + \mu \frac{\partial V^2}{\partial x_2} + \lambda_2 = 0, \tag{22}$$

$$\lambda_1 \geq 0, \quad \lambda_1 \frac{\partial V^2}{\partial x_2} = 0, \tag{23}$$

$$\lambda_2 \geq 0, \quad \lambda_2 x_2 = 0, \tag{24}$$

$$\lambda_3 \geq 0, \quad \lambda_3 x_1 = 0, \tag{25}$$

plus constraints (12) to (15). Note that it will be useful to make use of the fact that from equation (8), we have:

$$\frac{\partial V^1}{\partial x_2} = -\frac{\partial V^2}{\partial x_2} - 1. \tag{26}$$

In order for regime I to prevail, the Kuhn-Tucker conditions must be satisfied at $x_1 = x_2 = 0$. Since $f_1(0, 0) = 0$, we have $\partial V^1 / \partial x_1 = -1$. The Kuhn-Tucker conditions for regime I become

$$-1 - \lambda_1 \frac{\partial^2 V^2}{\partial x_2 \partial x_1} + \lambda_3 = 0,$$

$$\frac{\partial V^1}{\partial x_2} - \lambda_1 \frac{\partial^2 V^2}{\partial x_2^2} + \mu \frac{\partial V^2}{\partial x_2} + \lambda_2 = 0,$$

$$\lambda_1 \geq 0, \quad \lambda_1 \frac{\partial V^2}{\partial x_2} = 0,$$

$$\lambda_2 \geq 0 \text{ and } \lambda_3 \geq 0.$$

[22] Superscripts ^{L} and ^{F} for the equilibrium values of x_1 and x_2 are removed for clarity of exposition.

If $\lambda_1 = 0$, we have $\partial V^2(0,0)/\partial x_2 \leq 0$, such that $\lambda_3 = 1$ and $\lambda_2 = -\mu\partial V^2/\partial x_2 - \partial V^1/\partial x_2 > 0$. If $\lambda_1 > 0$, then $\partial V^2(0,0)/\partial x_2 = 0$. Both cases are consistent with the necessary conditions for regime I. As a result, regime I is defined by the region

$$\left.\frac{\partial V^2}{\partial x_2}\right|_{(0,0)} = \frac{pyb}{r^2 c} - 1 \leq 0. \tag{27}$$

In order for regime IV to prevail, the Kuhn-Tucker conditions must be satisfied with $x_1 > 0$ and $x_2 > 0$. This implies that $\lambda_3 = \lambda_2 = \partial V^2/\partial x_2 = 0$ and the following

$$\frac{\partial V^1}{\partial x_1} + (\mu x_2 - \lambda_1)\frac{\partial^2 V^2}{\partial x_2 \partial x_1} = 0,$$
$$-1 + (\mu x_2 - \lambda_1)\frac{\partial^2 V^2}{\partial x_2^2} = 0.$$

Using the functional form for $f(x_1, x_2)$ in (16), it is straightforward to show that these two equalities reduce to

$$r + f(x_1^L, x_2^F) = 2b, \tag{28}$$

where $x_1^L = py/4b - c$ and $x_2^F = (2b - r)py/4b^2$. As a result, regime IV can only prevail if $py/4b > c$ and $b > r/2$.

As for regime II, we have $x_1 > 0$ and $x_2 = 0$. This implies that $\lambda_3 = 0$. If $\lambda_1 = 0$, we have, from (21), $\partial V^1/\partial x_1 = 0$. This creates a contradiction since at $x_2 = 0$, we have $\partial V^1/\partial x_1 = -1$. If $\lambda_1 > 0$, we have $\partial V^2/\partial x_2 = 0$. From (21), this implies $\lambda_1 = -1/(\partial^2 V^2/\partial x_1 \partial x_2) > 0$ and, from (22), $\lambda_2 = 1 - [\partial^2 V^2/\partial x_2^2]/[-\partial^2 V^2/\partial x_1 \partial x_2]$. Making use of functional form in (16), λ_2 will be positive iff $b < r/2$. Therefore, regime II prevails when $\partial V^2/\partial x_2|_{(x_1,0)} = 0$ and $b < r/2$. From $\partial V^2/\partial x_2|_{(x_1,0)} = 0$, we get $x_1 = pyb/r^2 - c$.

Finally, in regime III, we have $x_1 = 0$ and $x_2 > 0$. This implies that $\lambda_2 = 0$ and $\partial V^2/\partial x_2 = 0$. Inserting this into (21) and (22) and rearranging, we get $\lambda_3 = -\partial V^1/\partial x_1 - [\partial^2 V^2/\partial x_2^2]/[-\partial^2 V^2/\partial x_1 \partial x_2]$. Making use of functional form in (16), it can be shown that λ_3 will be positive iff $c > py/4b$. And from $\partial V^2/\partial x_2 = 0$, we get $x_2 = (c/b)(\sqrt{pyb/c} - r)$.

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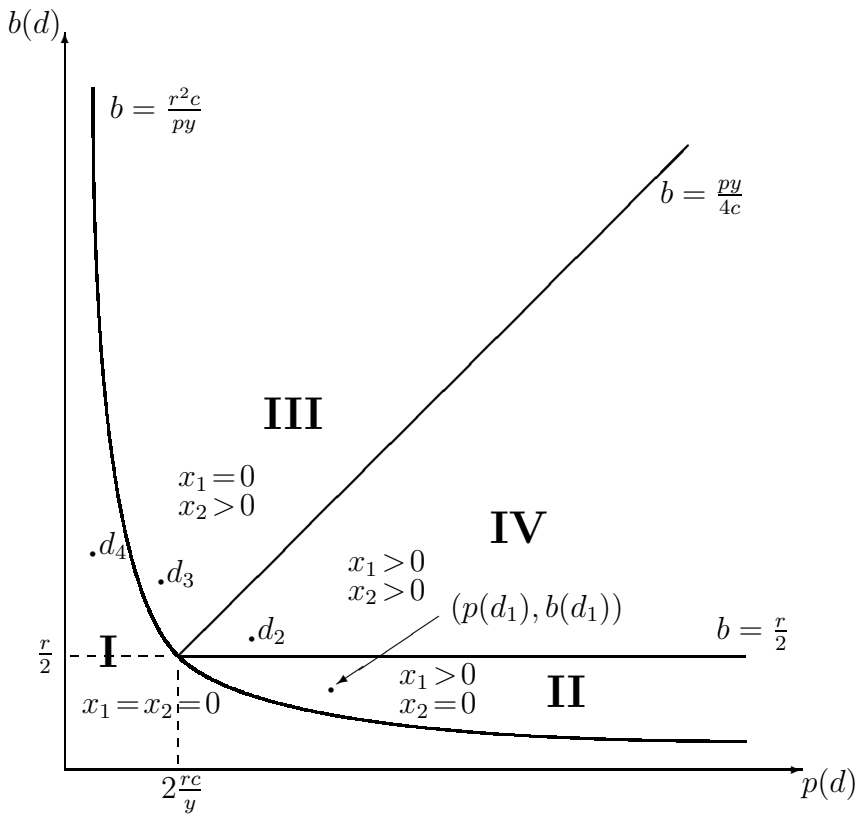

Figure 1: Regimes of appropriative activities with sustainable land use

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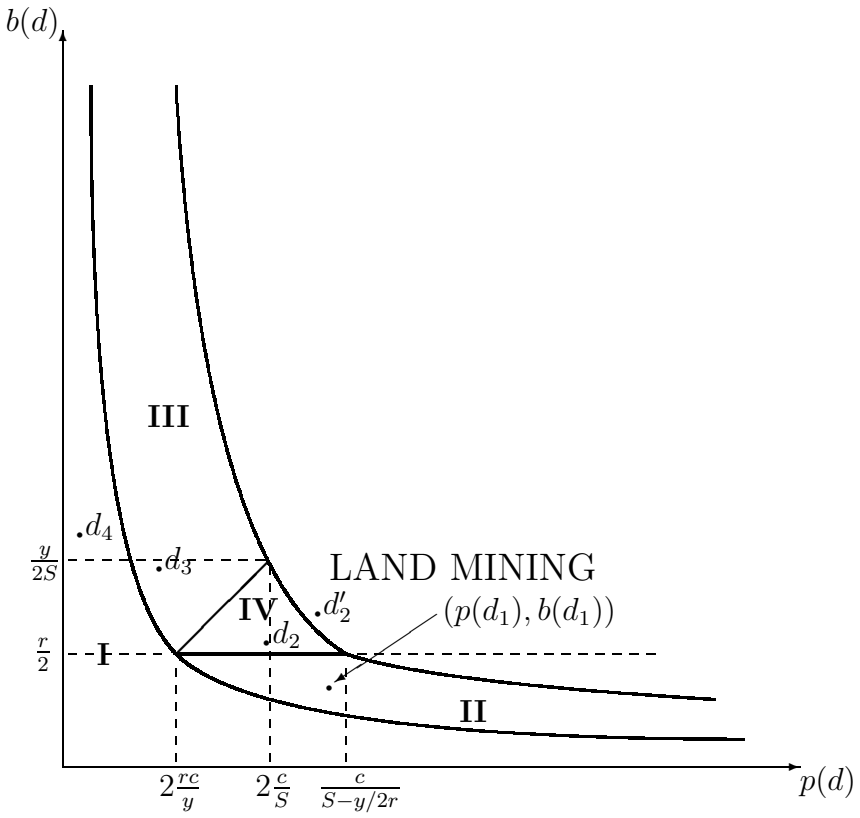

Figure 2: Land mining region