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Exploiting common resources with capital-intensive technologies: the role of external forces

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ABSTRACT. This paper focuses on the interactions between local communities having at least some degree of informal claims over natural resources and firms interested in commercially exploiting such resources, explicitly allowing for interventions by third parties interested in community welfare and environmental outcomes. Integrating conflict and bargaining theories, we develop a bargaining model with endogenous inside and outside options, in which the feasibility and outcomes of a potential bargaining game depend on the unraveling of a conflict stage and vice versa. The model implies that, contrary to the conventional bargaining model, distribution and efficiency cease to be separable. We show that certain third-party interventions in the bargaining process may have unexpected and counterproductive effects.

1. Introduction

Most natural resources of great economic significance – e.g., oil, natural gas, hydraulic resources for electricity generation, mines, and dense forests – require capital-intensive technologies for their commercial exploitation (Bohn and Deacon, 2000).[1] In many countries an important portion of these resources 'belongs' to local communities, although property rights are often diffuse and not necessarily fully enforced by the government. Frequently, these communities are poor, geographically isolated, and lack formal title to the resources. As a consequence, they have difficulties in meeting the collateral requirements to borrow the considerable funds needed to acquire

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[1] It is possible to exploit some of these resources via more traditional labor-intensive methods as well, albeit at a much reduced scale.

the technology and capital necessary to commercially exploit the resources by themselves (Bose, 1998). Thus, communities have to rely on specialized firms for resource exploitation.

This paper focuses on the interactions between local communities having at least some degree of informal claims over natural resources and firms interested in commercially exploiting such resources. The analysis allows for interventions by third parties (e.g., non-governmental agencies (NGOs), international donors, and others interested in the welfare of communities and in the environmental consequences of resource extraction) that often are made to support communities in their interactions with firms. These interactions may involve outright conflict over property rights where the community needs to first show that it is able to exercise nominal rights over the resource and thus prevent unilateral exploitation by the firms. If the community succeeds in this, bargaining over the distribution of the benefits of resource exploitation and over the intensity of resource extraction may ensue. For reasons to be explained below the intensity of resource extraction affects not only the size of the 'cake' but also its very distribution between the bargaining parties; distribution and efficiency are not separable. We show that in this context certain common interventions by third parties in favor of the communities can have some paradoxical and environmentally counterproductive effects.

Over the last decade, more than 60 countries worldwide have decentralized at least some aspects of natural resource management (Ribot, 2002; Kaimowitz, 2002a), which in many cases has led to some degree of control over natural resources by local communities, a process frequently referred to as 'devolution'. Indonesia, South Africa, and Mexico, among many other countries, now require that firms interested in exploiting natural resources negotiate with local communities.[2] Canada, Australia, and the United States have recognized partial rights of indigenous groups to participate in the management of forests, fisheries, and mines. This effectively allows communities to bargain with other agents interested in exploiting the resources (referred to hereafter as 'the firm'), but does not necessarily preempt other forms of interactions, including conflicts over *de facto* property rights.[3]

Three features characterize the devolution process in most countries. First, the transfer of authority to local communities is often incomplete; legal rights are diffused and little public enforcement of such rights is provided (Ribot, 2002; Palmer, 2004; Feder and Feeny, 1991). Second, there

[2] See, e.g., Palmer (2004), Barr *et al.* (2001), Bray *et al.* (2003), Mayers and Vermeulen (2002), Ribot (2002), and World Development Report (2000/2001, 2003).

[3] Examples: Barr *et al.* (2001) and Palmer (2004) describe conflicts over rights to logging in Indonesia. In Ecuador, Occidental Petroleum agreed to significant compensation of the Sehuaya community for the right to establish a test well on community land (http://forests.org/archive/samerica/secoocid.htm). In 1996, indigenous farmers in Chontal, Mexico blocked petroleum exploitation on their lands until firms compensated them (http://flag.blackened.net/revolt/mexico/reports/taboil.html). Native communities in the United States have renegotiated coal leases and made oil and gas agreements (http://encarta.msn.com/encyclopedia_761570777_30/Native_Americans_of_North_America.html).

is external participation by NGOs, international donors and others affecting the community–firm relationships.[4] Third, in most countries firms cannot purchase land or other communal resources either because communities do not have formal legal title or because government regulations explicitly impede it (Kaimowitz, 2002b). Firms thus have to rely on bargaining with communities, or, alternatively, on exploiting the resource unilaterally, but generally without being able to obtain formal property rights.

Despite the incompleteness of the transfer of authority to communities and shortcomings in their implementation, decentralization and devolution were expected to greatly reduce environmental degradation and to significantly improve management of natural resources. This expectation was based on the perception that these processes may contribute to ameliorating property right imperfections. While there are certainly cases of success, increasing empirical evidence indicates that these processes have not always reduced resource degradation and, in some cases, have even accelerated it.[5]

The model presented in this paper provides a consistent explanation for this important stylized fact by showing that devolution, in combination with certain generally accepted interventions, may lead to outcomes often inconsistent with expectations. This paper makes three contributions to the existing literature: first, unlike conventional analyses of the management of communal resources, which focus on *internal within-community* governance issues (e.g., Ostrom, 1990; Bardhan, 1993a,b; Baland and Platteau, 1996; Agrawal, 2001), we concentrate on how *external forces* affect the patterns of exploitation of natural resources. This is a vital issue in the context of capital-intensive resource exploitation, which has been mostly ignored by the literature (see also Bromley, this issue).

Second, we integrate conflict and bargaining theory in a way in which the feasibility and outcomes of a potential bargaining game depend on the unraveling of a conflict stage, and the conflict resolution is affected by the potential outcome of a possible bargaining stage that may ensue. Conflict analysis (e.g., Alston *et al.*, 1999a,b; Angelsen, 2001; Hotte, 2001; Burton, 2004) emphasizes conflicts over property rights. This literature focuses exclusively on the conflict without allowing for the possibility that actual or potential conflict may lead to negotiation or bargaining, and that potential bargaining outcomes may affect conflict resolution. Bargaining

[4] Another important third-party is the state. Governments intervene by setting the institutional framework in the processes of decentralization and devolution. Also, governments are responsible for not clearly delimiting property rights and especially for failing to enforce communal rights (Larson and Ribot, 2004).

[5] For example, Larson and Ribot (2004), summarizing a variety of studies on decentralization in the natural resource sector, conclude that decentralization has had mixed impacts on the environment. In Indonesia, decentralization has led to increased logging with little regard to environmental consequences (Resosudarmo, 2004; Casson and Obidzinski, 2002). See Walker (2000) and Lewis (1995) for descriptions of dramatic cases of environmental destruction in large part attributed to devolution and decentralization in South Africa and the USA, respectively.

models, on the other hand, do not explicitly consider the role of latent conflict in bargaining outcomes (Muthoo, 1999).

Third, we formally model the effects of participation by third parties in the bargaining process. An important implication of this is that inside options, defined as the parties' payoffs while in the process of bargaining (Bulow and Rogof, 1989), are endogenous. This in turn results in distribution and efficiency ceasing to be separable as implicitly assumed in the standard bargaining model.

We show that third-party intervention in the bargaining process may have unexpected and counterproductive effects. In particular, if at least some third-party agents increase their support to communities where the environmental threat is large (the 'hotspot' approach), bargaining may result in a more intense resource exploitation and greater environmental damage than without intervention. Paradoxically, the greater is the bargaining power of the community *vis-à-vis* the firm the more likely it is that the effect of the hotspot intervention will magnify the environmental damage. The hotspot effect is catalytic in nature: its existence does not require that all or even the majority of the third-party agents use the hotspot approach to intervene. Neither does it require that the external parties actually intervene in the particular community–firm bargaining considered. It suffices that a non-negligible subset of external agents uses it so that the community and the firm will form expectations about the probability that some third-party agent may intervene in such fashion. Once these probabilities are incorporated in the bargaining game its outcome will lead to the above results.

We show that explicitly modeling the linkages between conflict and bargaining outcomes leads to non-trivial changes in the comparative static results. Specifically, improvements in the community's bargaining power *vis-à-vis* those of the firm are likely to increase resource extraction and thereby to increase pressure on the environment. Moreover, an increase in the wage rate may have continuous or discontinuous effects on the environment, depending on initial conditions.[6] We show that the continuous effect generally corresponds to the standard comparative static intuition (that is, an increase in the wage rate reduces environmental degradation). The discontinuous effect, however, can be paradoxical.

The remainder of the paper is structured as follows. Section 2 presents the game-theoretic model. Section 3 examines the effect of alternative strategies of intervention by third-party actors on the environment. Section 4 draws conclusions on effective intervention strategies.

2. Modeling community–firm interactions

In what follows we use the terms 'forest' and 'logging' as metaphors but we remind the reader that the problem can be equally expressed more generally in terms of 'resource', and 'resource extraction'. Similarly, the term

[6] We denote the effect of a change of an exogenous variable as 'discontinuous' when it is powerful enough to switch the nature of the game from conflict to bargaining or vice-versa. By contrast, a 'continuous' effect occurs when the nature of the game (either bargaining or conflict) is not altered by the exogenous change.

'community' stands for any entity that has at least potential property rights over a natural resource, but that cannot exploit it directly as a consequence of, for example, lack of access to capital and technical expertise. The term 'firm' is used to denote any entity that does not have automatic access to the resource, but has access to the capital and the know-how necessary to exploit it.

2.1. Conflict

One common way to model conflict is as an attrition war (e.g., Dixit and Nalebuff, 1991; Bulow and Klemperer, 1999). Most attrition models assume that competing agents follow a strategy to gain property rights (or win other types of conflicts). In our case, the strategy for the firm involves unilateral logging attempts (without sharing the benefits with the community), while for the community it consists of setting up blockades to prevent this from happening and thus be able to exert *de facto* property rights. Blockades are costly to the community, while the firm incurs a cost for any credible logging attempt (e.g., labor costs would arise even if workers are hindered from logging).

Our model differs slightly from most other war-of-attrition models in that it uses an alternating action framework and allows for asymmetric motivations of the two actors. A similar model was presented by Burton (2004). We also follow Burton in modeling the conflict game as an infinite-time-horizon game. Unlike Burton the ensuing analysis explicitly considers the fact that conflict may potentially lead to bargaining and that the outcome of a potential bargaining phase may affect conflict resolution.

Assumptions of the conflict game

In each period the firm can choose whether to make a unilateral logging attempt or withdraw. The community then can choose whether to set up a blockade or withdraw. It is assumed that setting up a blockade in a given period will successfully stop the logging attempt in that period. The game is repeated an infinite number of times unless one of the parties withdraws. Logging requires forest area, variable inputs, and a specific factor, capital, that is available to the firm but not to the community. Firm's profits from logging are $v(w;L,K)$, where K is the exploitation capital, L is the area logged, and w is a vector of wages, other variable input prices, and output price. For simplicity of exposition we omit arguments other than L from v, except when needed for comparative static purposes. The assumption that logging requires a specific factor that is available only to the firm implies that the firm has the ability to exploit the resource unilaterally while the community may under some conditions be able to prevent such exploitation. We now summarize the assumptions used in the ensuing model of conflict.

Assumption set A

(A1) *The community and the firm have perfect information about each other's parameters.*

(A2) $v(w;L,K)$ *is monotonic, homogeneous of degree one, increasing and concave in L and K, and convex in w. Moreover,* $\max_L v(L) > 0$ (*logging is profitable*).

(A3) *The firm's discount rate* (r_F) *and the community's discount rate* (r_C) *are fixed and strictly positive. The discount factor for actor i* ($i = F, C$) *is defined as* $\delta_i \equiv 1/(1+r_i)$.

(A4) *There are fixed per-period costs of staying in conflict to communities, s* (*the 'blockading' costs*), *and to firms, c* (*the cost of unilateral logging attempts, not including the opportunity cost of capital*).

(A5) *As an alternative to logging, the firm may invest its capital in the next best activity, yielding exogenous profits of* $\overline{R}^F \equiv \sum_{t=0}^{\infty} \delta_F^t \overline{g}^F = \frac{\overline{g}^F}{1-\delta_F}$, *where* $\overline{g}^F$ *is the per period return in the next best activity and* $\overline{R}^F < \max_L v(L)$.

(A6) *The present value of the standing forest considered by the community is* $h_0 B(\overline{L} - L) \equiv h_0 \sum_{t=0}^{\infty} \delta_C^t b(\overline{L} - L) = \frac{h_0 b(\overline{L}-L)}{1-\delta_C}$, *where the function b is the per-period service provided by the standing forest,* $\overline{L}$ *is the total forest area prior to exploitation, and* h_0 *is the average value (or price) per unit of the environmental service as considered by the community. The function b is increasing and strictly concave in the level of standing forest. Furthermore,* $\overline{b} \equiv b(\overline{L})$ *and* $0 < h_0 < \overline{h}$, *where* $\overline{h}$ *is the true unit value of environmental services provided by the standing forest. Finally, we assume that* $B(\overline{L} - \hat{L}) = 0$, *where* $\hat{L} \equiv \arg\max\{v(L)\}$.

(A7) *The community cannot make side payments to the firm, that is* $\Pi^F \leq v(L)$, *where* Π^F *is the firm's total payoffs under a successful bargaining agreement. Similarly,* Π^C *is the community's total payoff under the same outcome.*

Remark about (A6): The last sentence of (A6) implies that logging to the extent that maximizes logging profits eliminates all standing value of the forest to the community. This assumption is made for simplicity.[7] The assumption that $0 < h_0 < \overline{h}$ reflects the fact that the standing forest has values that the community does not necessarily internalize (e.g., water retention, flood prevention, and erosion control services at the regional level, carbon retention and biodiversity preservation at the global level). Depending on the community's level of awareness, it may also not even consider all the local environmental values.

Remark about (A7): This assumption is justified for the following reasons. First, communities are mostly poor and financially constrained due to lack of access to credit. The lack of legal titles is an obstacle for communities to obtain credit for lack of collateral. Second, the value of the standing forest to the community is at least to a significant extent non-monetary, including ecological functions, cultural values, and subsistence functions (e.g., collection of non-timber forest products for self-consumption). (A7) has an important implication for the rest of the analysis. It implies that the ability of the community to establish and privately enforce *de facto* property rights (that is, win the attrition war) is a necessary condition for a successful bargaining agreement to emerge. If the firm is able to win a

[7] In principle, there might still be some benefits of the logged forest to the community. This could be incorporated in the model at the cost of further algebraic clutter without changing the basic results.

potential conflict, the community will effectively lose property rights to the resource and, hence, the firm will exploit unilaterally. From assumption (A7), the firm cannot benefit from negotiations in this case and thus has no incentive to negotiate with the community.

Equilibria of the conflict game

We now examine the equilibria of the conflict game. Suppose a conflict has continued until time t. The firm chooses a probability of withdrawal from the conflict for that period, denoted by $\beta_t \in [0,1]$. The model is stationary: there are no information gains and benefits and costs do not change over time. Thus, the problem faced by each actor is identical in each period until one actor chooses to withdraw. We therefore restrict our analysis to stationary solutions only, that is $\beta_t = \beta$ for all t. We now examine the incentive for each actor to remain in conflict for an additional period.

Consider first the firm's incentives. It can either attempt to log without community consent, incurring a cost c, or withdraw. If the firm withdraws, there are two possibilities denoted by an index variable, p. If there are gains from trade in bargaining (represented by $p = 1$), bargaining will be successful and the firm receives negotiated payoffs Π^F; if there are no such gains from trade ($p = 0$), the firm obtains its outside option $\overline{R}^F$. Thus, the payoff from withdrawing is

$$R^w \equiv p\Pi^F + (1 - p)\overline{R}^F. \tag{1}$$

By contrast, if the firm remains in conflict, its payoffs depend on the community's reaction. Let $\gamma_t \in [0,1]$ be the (subjective) probability that the firm attaches to the community's withdrawal. For stationary solutions, $\gamma_t = \gamma$ for all t. If the community withdraws, the logging attempt is successful, yielding a logging profit for the firm of $v(\hat{L})$. By contrast, if a blockade occurs, the firm faces the same decision again. Let R^l denote the expected payoff of a logging attempt. We can write

$$R^l = -c + \gamma v(\hat{L}) + (1 - \gamma)\delta_F R^l.$$

Solving for R^l, we get

$$R^l = \frac{-c + \gamma v(\hat{L})}{1 - (1 - \gamma)\delta_F}. \tag{2}$$

Thus the expected net benefits for the firm from remaining in conflict an additional period are $R^l - R^w$. The firm is indifferent between withdrawing and remaining in conflict if these net benefits equal zero, which is equivalent to

$$\gamma = \gamma^c \equiv \frac{c + R^w - \delta_F R^w}{v(\hat{L}) - \delta_F R^w}. \tag{3}$$

For values of γ below the critical value in (3), the firm would prefer to withdraw immediately (choosing probability of withdrawal $\beta^* = 0$), while for $\gamma \geq \gamma^c$, it would remain in conflict ($\beta^* = 1$).[8]

Let us now consider the incentives of the community. If the firm has attempted to log unilaterally, the community can either accept this and withdraw, or it can set up/maintain a blockade. If the community withdraws immediately, it incurs no costs, but loses the forest to logging, yielding zero benefits to the community (by assumption (A6)). If the community maintains a blockade, it is assumed that the forest is protected in the current period, yielding a benefit of $h_0\overline{b}$, but the community also incurs blockading costs s. In addition, the longer-run fate of the forest depends on the firm's reaction to the blockade. If the firm withdraws (probability β), there are two possibilities. Either negotiations over a logging agreement will succeed ($p = 1$), in which case the community receives payoffs Π^C, or there are no gains from negotiation ($p = 0$). In the latter case, the community receives the value of the standing forest also in all subsequent periods, which can be written as $\delta_C h_0 B(\overline{L})$. Thus, the community's net benefits from remaining in conflict (blockading) are

$$R^b = h_0\overline{b} - s + \beta[p\Pi^C + (1-p)\delta_C h_0 B(\overline{L})] + (1-\beta)\delta_C R^b, \tag{4}$$

or

$$R^b = \frac{h_0\overline{b} - s + \beta[p\Pi^C + (1-p)\delta_C h_0 B(\overline{L})]}{1-(1-\beta)\delta_C}.$$

The community is indifferent between maintaining a blockade and withdrawing if the net benefits from blockading (here given by R^b) are equal to zero, that is if

$$\beta = \beta^c \equiv \frac{s - h_0\overline{b}}{p\Pi^C + (1-p)\delta_C h_0 B(\overline{L})}. \tag{5}$$

For lower values of β, the community would withdraw immediately ($\gamma^* = 0$), while for $\beta \geq \beta^c$, it would remain in conflict ($\gamma^* = 1$).

There are three stationary equilibria, two of which are pure strategy equilibria and one which is a mixed strategy equilibrium. The mixed strategy equilibrium occurs if each actor is indifferent between remaining in conflict and withdrawing. The firm withdraws with a constant probability given by equation (5), while the community withdraws with a constant probability as given in (3). The outcomes of the mixed strategy equilibrium are discussed in Kornhauser *et al.* (1989) and Burton (2004). However, as argued there, the knife-edge requirement that both players are just indifferent between strategies implies that this equilibrium is highly unstable. Kornhauser *et al.* (1989) have shown that slight deviations from

[8] Strictly speaking, the firm is indifferent when $\gamma = \gamma^c$. For simplicity of exposition, we assume that the firm remains in conflict in this case.

the equilibrium lead to major responses in choices. In our case, if one of the agents chose a probability of withdrawal just slightly below the equilibrium level, the agent would win the conflict. Due to this instability we focus our analysis on pure strategy equilibria.

There is one pure strategy equilibrium where the firm always withdraws immediately, and the community always blockades ($\beta^* = 1$, $\gamma^* = 0$), and another where the firm always attempts to log and the community always withdraws ($\beta^* = 0$, $\gamma^* = 1$). For some parameter values, 'always withdraw' is clearly the dominant strategy. Consider first the case where the costs of logging always exceed the gains, that is $v(\hat{L}) < c + R^w$. Then the net benefits from a logging attempt in (2) are always negative, regardless of the community's probability of withdrawal. In this case the firm always withdraws ($\beta^* = 1$). In what follows we focus on the case where logging is profitable (that is $v(\hat{L}) > c + R^w$).

Similarly, if the net cost of blockading even one period ($s - h_0\overline{b}$) exceeds the expected value of winning the conflict, $p\Pi^C + (1-p)\delta_C B(\overline{L})$, the community would always choose not to blockade $\gamma^* = 1$, regardless of the firm's strategy. Thus, as long as logging is profitable, the firm would always log. Finally, if the community's benefit from protecting the forest for even one period ($h_0\overline{b}$) exceeds per-period blockading costs (s), the community's dominant strategy is to always blockade ($\gamma^* = 0$), regardless of the firm's strategy. Thus, it would be preferable to the firm to withdraw immediately.

If $h_0\overline{b} \leq s \leq h_0\overline{b} + p\Pi^C + (1-p)\delta_C B(\overline{L})$, there is no dominant strategy for either actor. We can, however, examine how changes in parameter values will affect γ^c and β^c. Inspection of equation (3) indicates that γ^c is increasing in c and R^w. This is intuitive. For example, if logging becomes more costly, the firm is generally more reluctant to attempt logging. It will require a larger expected probability of community withdrawal to make it worthwhile for the firm to opt for a logging attempt. Also, from (2), R^w is higher for $p = 1$ than for $p = 0$. Similarly, inspection of (5) shows that β^c is increasing in s and decreasing in p and δ_C. This is also intuitive. Higher blockading costs, the lack of gains from trade from negotiations, and a higher time preference for present costs over future benefits, will all raise the expected costs of blockading *vis-à-vis* the expected benefits. Thus the community becomes more reluctant to stay in conflict (or in other words, requires a higher expected probability of firm withdrawal to do so).

From the previous analysis, we have

Proposition 1. *The likelihood that the community wins the conflict and thus that privately enforced community property rights emerge increases if:* (*i*) *bargaining is a feasible alternative to conflict* ($p = 1$); (*ii*) *the community's discount factor is high (discount rate is low) and the costs of fighting an attrition war are low vis-à-vis those of the firm.*

As explained earlier, the outcome of the community–firm interaction is asymmetric: if the firm is able to win a potential conflict, the community will effectively lose property rights to the resource and, hence, the firm will exploit it unilaterally. Since the firm cannot benefit from negotiations in this case, it has no incentive to negotiate with the community. If, however, the community is able to win the war of attrition, then it effectively is able to exert property rights over the resource and bargaining may be successful.

2.2. Inside options in bargaining and third-party interventions[9]

Inside options are defined as the payoffs obtained by each player while parties temporarily disagree and negotiations are ongoing. (A8) below provides our assumptions on inside options.

(A8) *Each player receives a flow of payoff g^i in each period while negotiations continue. For the firm this payoff is given by $g^F = \overline{g}^F$; for the community it is given by $g^C = h(L)b(\overline{L})$, where $h_0 \leq h(L) \leq \overline{h}$. We also refer to 'the inside option' or d^i as the return to player i from perpetual disagreement (that is, present value of receiving g^i in each period forever). These are for the firm $d^F = \overline{R}^F$ and for the community $d^C = h(L)B(\overline{L})$.*

Thus, while the inside option of the firm is fixed corresponding to the firm's exogenous returns to its capital in the next best activity, the community's inside option may be affected by interventions of third parties, such as NGOs, international donor agencies, and others. Cash payments and other benefits given by these third parties are often directed to enhancing the value of the environment to communities with the purpose of internalizing a greater portion of the environmental externalities. Given the naturally limited amount of financial resources available to third-party agents and the large number of areas where such agents can act, interventions generally prioritize areas where the environmental threat is judged to be great. Some important conservation groups, such as Conservation International and several others, have explicit strategies of intervention consisting in focusing their activities on global 'hotspots', that is areas that are under high pressure of deforestation and at the same time rich in biodiversity.[10] In other words, third-party interventions are often guided by the '*support communities which face the greatest environmental threats*' (SGET) principle.[11]

The existence of SGET behavior is built into the communities' and firms' expectations.[12] The fact that third parties normally exhibit SGET induces

[9] The analysis here focuses on the case where the community wins the attrition conflict, which is the interesting one from our perspective. If the community is not able to enforce its rights (loses the attrition war), there is no community–firm bargaining. Of course in this case governments or other entities may still intervene to prevent the firm from logging, but this is just the standard public policy regulation problem.

[10] See www.conservation.org and www.biodiversityhotspots.org.

[11] Of course, not all interventions are guided by the SGET principle. Later we consider other types of intervention.

[12] Under SGET interventions we may assume that $h(L) = h_0 + \tilde{h}(\overline{L} - L)$. Thus, the unit price that the community receives for the environmental service that it provides, $h(L)$, is comprised of the benefit per unit of environmental service directly

firms and communities to expect that the community's valuation of the standing forest would be enhanced by the support from third parties; that is the community's inside option becomes endogenous and increasing in the level of logging being negotiated. With perfect information, the first offer will fully take into consideration the fact that, if the negotiations were to become protracted, the community could easily announce the logging threat and thus enhance its inside option by attracting support from third parties (which is increasing in the logging threat being negotiated). However, given perfect information the negotiation never actually gets protracted. The first offer takes into consideration all the relevant information. Thus, (A8) does not require actual outside intervention, the mere fact that such a possibility is known to exist on the basis of observed past behavior is sufficient to affect the outcome of the bargaining through its effect on the community's inside option. Of course under certain conditions (influenced by the community's inside option among other variables as we will see below) there might not be any offer at all, there is no solution to the bargaining, which means that there is no logging. Hence, while third parties do not in fact intervene, they still influence the outcome of the bargaining (including whether or not it is successful). This also implies that the importance of SGET interventions is likely to be large even if only a small subset of third-party agents applies such a rule.[13]

The next four remarks are essential to understand the meaning of the bargaining model.

Remarks

(1) With perfect information, positive time discount rates, and assuming certain feasibility conditions, the (perfect) first offer in an alternating offers bargaining game fully incorporates all the relevant information. The first offer is instantaneously accepted and the bargaining process takes no real time. Or, alternatively, depending on the parameters of

obtained by the community (h_0) plus the expected premium for environmental services paid by third parties, $\tilde{h}(\overline{L} - L)$. The expected unit price premium paid by third parties is assumed to increase at a decreasing rate with the *scarcity* of the environmental service supplied ($\tilde{h}' < 0$ and $\tilde{h}'' < 0$). The term $\tilde{h}(\overline{L} - L)$ may include the provision of technical support, education, and conservation monetary payments to the communities in order to raise environmental values and awareness provided through SGET interventions.

[13] If the bargaining parties are risk neutral, their first offer will use the probability of intervention by an SGET ruler in calculating the expected level of the community's inside option associated with a given level of L. The *expected* unit price premium for the environmental service $\tilde{h}$ could be written as $\tilde{h}(\overline{L} - L) = q(\overline{L} - L)m$, where $0 \leq q \leq 1$ is the probability that any third-party agent may intervene using an SGET rule, and m is the payment premium per unit of standing forest. The probability q is assumed increasing in L. Note that there is no need that the actual payment premium, m, be also increasing in L. Even if it is fixed, the function $\tilde{h}(\overline{L} - L)$ is increasing in L. Thus, as long as q is non-negligible (as long as some third-party agents may intervene using an SGET rule), the expected inside option of the community is increasing in L.

the model there might be no offer at all in which case the game is over and there is no logging.

(2) The first offer (or lack of offer) takes into consideration the fact that, if there was no instantaneous agreement and negotiation took real time instead, third parties would be informed about it and that their expected support to the community would increase with the magnitude of the perceived environmental threat (represented by the expected deforestation resulting from the bargaining process).

(3) The bargaining agreement is thus instantaneous, but the actual agreement takes full consideration of what would happen if the process of alternating offers took real time.[14]

(4) The community's inside option is not dependent on the bargaining outcome of the specific game under analysis, it only depends on the ex-ante expectations that the firm and community have regarding SGET interventions based on past observed behavior by third parties.

SGET interventions cause the unit price of environmental services to increase when environmental services become scarcer. It would, however, be inappropriate to assume that such interventions cause the total environmental value to increase as the environment is degraded. To avoid this possibility we assume that $h(L)B(\overline{L} - L)$ is non-increasing in L. Below we summarize the assumptions concerning SGET interventions:

Assumption set B

(B1) *With SGET interventions, the unit price of environmental service perceived by the community increases at a strictly decreasing rate as environmental services become scarcer,* $h'(L) > 0$ *and* $h''(L) < 0$.

(B2) *With SGET interventions, the total value of the environmental service,* $h(L)B(\overline{L} - L)$*, is non-increasing in* $L \in [0, \overline{L}]$*; that is,* $h'(L)B(\overline{L} - L) - h(L)B'(\overline{L} - L) \leq 0$.

In the analysis below in section 2.5, we probe the implication of this type of intervention by comparing the outcome of the bargaining game with SGET interventions ($h'(L) > 0$) and without ($h'(L) = 0$). In addition, in section 3, we compare the effects of other types of intervention (not guided by the SGET principle) with and without SGET interventions.

2.3. Bargaining

We now analyze the outcomes of community–firm bargaining when the community wins *de facto* property rights. We assume a Rubinstein-type bargaining where community and firm make alternating offers to define a mutually agreed logging contract. This is a bargaining game with inside and outside options. Unlike in conventional bargaining games, however,

[14] If this was not the case, the resulting bargaining agreement would not be stable *ex post*; the community's inside option would increase as a response to intervention and thus the community would have an incentive to renegotiate the agreement. Here we avoid modeling renegotiation explicitly to keep the model as simple as possible, and instead use the same logic followed by Rubinstein (1982).

the size of the 'cake' is here endogenous and its size has consequences for its distribution. The firm and the community bargain not only for their respective shares of the extracted output but also for the intensity of the exploitation, that is for the determination of the value of the resource extracted. For presentation purposes we consider bargaining over the distribution of the total net benefits and bargaining over the level of logging separately; that is, we first study how benefits are distributed conditional on a logging level, and then we analyze the determination of the logging level.[15]

Below we show that with SGET interventions the distribution and the size of the cake negotiated over are no longer separable. The intuition for this result can be anticipated as follows. When considering its desired level of logging under a negotiated agreement, the firm will take into account the fact that greater logging may induce third-party interventions, which in turn raise the community's inside option, leading to a greater share of 'the cake' for the community. Therefore, the firm prefers a smaller level of logging intensity than the one that would maximize the size of 'the cake'. If side payments could be made by the community to the firm, then choosing a logging level that maximizes 'the cake' would always be Pareto-improving; the community could compensate the firm and keep the rest of the benefits from a larger 'cake'. However, given assumption (A7), this is not possible here. The community cannot make side payments to convince the firm to accept a higher logging level. Thus the firm is stuck with having to trade off an increased logging level with trying to keep the community's inside option (and thus its share of 'the cake' obtained in bargaining) down. As we show below, this will lead to a negotiated logging intensity below the level that would maximize 'the cake', unless the community has perfect bargaining power.

Bargaining over payments

Muthoo (1999) has shown that the solution to the alternating-offers bargaining game with inside and outside options can be presented in the form of an asymmetric Nash Bargaining Solution (NBS). Thus, the payments to the community and firm out of a given total revenue (or, equivalently, conditional on a given level of L) are obtained by solving

$$\max_{\Pi^F,\Pi^C}[\Pi^F - d^F]^\tau[\Pi^C - d^C]^{1-\tau} \quad \text{s.t.} \quad \Pi^F \geq d^F, \Pi^C \geq d^C, \Pi^F + \Pi^C = \Gamma(L), \tag{6}$$

where $\tau = r_c/(r_c + r_F)$ is the firm's bargaining power *vis-à-vis* the community, and $\Gamma(L)$ are the total net benefits to the two players under

[15] This does not mean that we assume that the two processes are sequential. The approach is often used in other areas of economics, e.g. in production theory it is common to define a (dual) cost function conditional on any arbitrary level of output and then define an optimal level of (profit maximizing) output by maximizing revenue less the input cost as represented by the cost function, thus choosing one particular level of output (Chambers, 1988). Thus, one can always separate the problem into two stages for presentation purposes.

the logging agreement ('the size of the cake'). The latter include the firm's logging profits as well as the value of the remaining forest to the community, that is

$$\Gamma(L) = v(L) + h(L)B(\overline{L} - L). \tag{7}$$

The constraints in (6) imply that each player has to obtain at least the value of his inside option (defined, as in (A8), as the sum of per-period benefits from disagreement while negotiating over time), and that total payments have to add up to the total net benefits to be divided. These conditions are discussed further in section 2.4.

Assuming an interior solution, and using (A7), equilibrium payments can be written as

$$\Pi^F = \overline{R}^F + \tau G(L) \tag{8}$$

$$\text{and } \Pi^C = h(L)B(\overline{L}) + (1-\tau)G(L), \tag{9}$$

$$\text{where } G(L) = \Gamma(L) - \overline{R}^F - h(L)B(\overline{L}). \tag{10}$$

$G(L)$ is the surplus left after paying both players their inside options. Thus, each player obtains the value of his inside option plus a share (τ) of the surplus ($G(L)$) that is inversely proportional to the player's discount rate.

Bargaining over logging intensity

We now consider bargaining over logging area, which in turn determines the total net benefits to be divided, Γ. Note that from equations (8) and (9), however, L determines not only Γ but also its distribution between the players. The firm's preferred choice of L (denoted by L^F) is the one that maximizes its own payoffs under the logging agreement. From (8), this is equivalent to the level of L that maximizes the surplus ($G(L)$), that is L^F is defined by

$$\Gamma'(L^F) = h'(L^F)B(\overline{L}). \tag{11}$$

Thus, the firm would want to equate the marginal benefit of logging to the marginal cost of logging faced by the firm. We expect this to be the level of logging resulting when the firm has perfect bargaining power ($\tau = 1$).

By contrast, the community's preferred level of logging (L^C) is the one that maximizes Π^C, given by (9). Thus

$$\Gamma'(L^C) = -\frac{\tau}{1-\tau}h'(L^C)B(\overline{L}). \tag{12}$$

Contrary to the firm, the community considers the effect of logging on its own reservation utility as a benefit. However, the community will be able to fully impose its optimal level of logging (L^C) only if it has full bargaining power, that is if $\tau = 0$. In that case (12) becomes

$$\Gamma'(L^C|_{\tau=0}) = 0. \tag{13}$$

When the community has perfect bargaining power, it receives all the surplus beyond the firm's inside options, and therefore does not consider the effect on its own inside options. Concavity of v and h in L implies that $L^C|_{\tau=0} > L^F$.

The bargained level of L will generally lie somewhere in between the values preferred by the two players. The bargaining game that determines L can be represented by the following Nash bargaining problem[16]

$$\max_L [\overline{R}^F + \tau G(L)]^\tau [h(L)B(\overline{L}) + (1-\tau)G(L)]^{1-\tau}. \tag{14}$$

The nature of this bargaining game is the following: each player bargains for a level of L that is as close as possible to the level of L that maximizes his or her benefits. In principle both players would like the total benefits (including the environmental benefits) to be as large as possible, but only to the extent that increasing total benefit does not reduce their respective incomes. In the appendix (section A.1) we show that the first-order condition can be written as

$$\Gamma'(\tilde{L}) = \kappa h'(\tilde{L})B(\overline{L}), \tag{15}$$

where $\kappa \equiv [\frac{(\frac{\tilde{\Pi}^C}{\tilde{\Pi}^F}+1)\tau^2-\tau}{\tau^2\frac{\tilde{\Pi}^C}{\tilde{\Pi}^F}+(1-\tau)^2}]$, $\tilde{L}$ denotes the equilibrium level of logging emerging from bargaining, and $\tilde{\Pi}_i$ is the equilibrium payment to player i, defined by equations (8) and (9) and evaluated at $\tilde{L}$.

Lemma 1. $0 \leq \kappa \leq 1$, $\kappa(\tau=0)=0$ *and* $\kappa(\tau=1)=1$.

Proof. See appendix (section A.2). □

Lemma 1 implies that the cases where either player has perfect bargaining power ($\tau=1$ or $\tau=0$) are boundary cases of equation (15); that is, for $\tau=1$, condition (15) reduces to equation (11), and the firm's preferred level of logging emerges ($\tilde{L} = L^F$). The firm exploits the fact that increasing L raises the community's inside options. Similarly, if $\tau=0$, the equilibrium level of logging is $\tilde{L} = L^C|_{\tau=0}$, as defined in equation (13). If both parties truly bargain ($0 < \tau < 1$), the solution will only partially capture the effect of L on h (that is, $0 \leq \kappa \leq 1$). We thus have:

Lemma 2. *Assume SGET interventions are in place* ($h'(L) > 0$). *For* $0 \leq \tau \leq 1$, $L^F \leq \tilde{L} \leq L^C|_{\tau=0}$. *Moreover,* $\frac{\partial \tilde{L}}{\partial \tau} < 0$.

Proof. See appendix (section A.2).

Lemma 2 implies that the higher the bargaining power of the firm, the lower the level of logging negotiated. Thus, contrary to what is often assumed, a higher bargaining power of the community leads to more intense resource exploitation.

[16] Proof available from the authors upon request.

If $h'(L) = 0$, that is in the absence of SGET interventions, then it is clear that $L^F = L^C = \tilde{L}_{NI}$, where $\Gamma'(\tilde{L}_{NI}) = 0$. In this case the level of $\tilde{L}_{NI}$ maximizes the size of the 'cake' available for distribution between the players and is independent of the degree of bargaining power ($\partial \tilde{L}_{NI}/\partial \tau = 0$). Lemma 3 summarizes this result:

Lemma 3. *Assume that no SGET interventions are in place* ($h'(L) = 0$). *Then* $L^F = L^C = \tilde{L}_{NI}$ (*where* $\tilde{L}_{NI}$ *is the NBS in the absence of intervention*) *and* $\partial \tilde{L}_{NI}/\partial \tau = 0$.

2.4. Outside options revisited

There are two ways in which outside options matter for bargaining results (Muthoo, 1999). First, the NBS presented above is valid only if the resulting payment to player i ($\tilde{\Pi}_i$) is at least as large as the value of player *i*s outside option. Otherwise, player *i* will simply obtain the value of his outside option in bargaining and the other player will receive the residual net benefits from bargaining (Binmore, 1985). Second, if the sum of outside options exceeds the total net bargaining benefits, bargaining will fail. Players in this case will obtain their respective outside option.

Our analysis in section 2.1 implies that the community's and the firm's outside options in bargaining (denoted as R^C and R^F, respectively) depend crucially on which of the two parties is able to establish *de facto* property rights. In the case considered here, where the community wins the war of attrition, outside options are given by

$$R^C = h_0 B(\overline{L}) \quad \text{and} \quad R^F = \overline{R}^F. \tag{16}$$

Now note that if $G(\tilde{L}) \geq 0$ (there are gains from bargaining), the payment to the community derived under the NBS always at least weakly exceeds the value of the community's outside option

$$\Pi^C = h(\tilde{L})B(\overline{L}) + (1-\tau)G(L) \geq h_0 B(\overline{L}), \tag{17}$$

since $h(\tilde{L}) \geq h_0$. This happens because the community's inside and outside options are closely related; they both reflect the value of the standing forest in the absence of logging. The only difference is that inside options may be positively affected by greater third-party interventions in response to negotiations. Therefore, the community can never lose, but may in fact gain, from negotiations in terms of both an increase in its inside option and a share of logging profits.

Because the firm's inside and outside options are identical, namely the value of the firm's capital in the next best alternative activity, the payment to the firm under the NBS also always at least weakly exceeds the value of the firm's outside option

$$\Pi^F = \overline{R}^F + \tau G(L) \geq \overline{R}^F. \tag{18}$$

By the same argument, we have

Lemma 4. *If* $G(\tilde{L}) \geq 0$, *and the community can establish de facto property rights, then* $R^F + R^C \leq \Gamma(\tilde{L})$. *Thus, bargaining takes place.*

Proof. The result follows directly from adding up equations (17) and (18), and using equation (10). □

2.5. The effects of SGET interventions

The socially optimal level of logging (L^*) is the one that equates marginal profits from logging to the true marginal environmental damages for society as a whole

$$v'(L^*) = \overline{h} B'(\overline{L} - L^*). \tag{19}$$

This needs to be distinguished from the optimum for the community–firm complex (L^{CFC}), which is given by the level of logging resulting if the community and the firm could coordinate to maximize the total net benefits from an agreement, $\Gamma(L)$. L^{CFC} is identical to $L^C|_{\tau=0}$ and – using (7) – is given by

$$v'(L^{CFC}) + h'(L^{CFC})B(\overline{L} - L^{CFC}) = h(L^{CFC})B'(\overline{L} - L^{CFC}). \tag{20}$$

There are two differences between the social optimum and the optimum for the community–firm complex. First, as is well known, the community–firm complex does not generally consider externalities beyond the local level and thus undervalues environmental damages from logging ($h(L) \leq \overline{h}$). If outside interventions are responsive to logging, there is an additional effect: the community and the firm, by increasing the area logged, can induce third-party interventions that increase the benefits to the community obtained from the remaining forest, that is they can increase the size of the cake to be divided. This implies an additional marginal benefit of logging to the two actors in negotiations. Thus, third-party interventions that increase the unit value of the standing forest when threatened could lead to an even greater over-exploitation of the resource than without intervention. Inspection of (19) and (20) shows that $L^{CFC} > L^*$. When the firm has some positive bargaining power ($\tau > 0$), the above effects are, in part, counteracted by the fact that the firm considers the effect of logging in increasing the community's inside option. Formally, we have:

Proposition 2 (Role of interventions on environmental distortion).

(a) *Without intervention, bargaining will lead to a solution that implies* $\tilde{L}_{NI} > L^*$.

(b) *With SGET interventions:*
  - (b.1) *If* $\tau = 0$, *then* $\tilde{L} > \tilde{L}_{NI}$, *that is the initial distortion is worsened by intervention.*
  - (b.2) *If* $\tau = 1$, *then* $\tilde{L} < \tilde{L}_{NI}$, *that is the initial distortion is at least partially counteracted by intervention.*
  - (b.3) *If* $0 < \tau < 1$, *then the effect of intervention on the distortion is ambiguous.* $\tilde{L} > \tilde{L}_{NI}$ *if and only if* $v'(\tilde{L}) - h(\tilde{L})B'(\overline{L} - \tilde{L}) < 0$.

Proof. See appendix (section A.3).

Proposition 2 implies that the greater the bargaining power of the community, the more likely it is that the distortion is worsened by intervention ($\tilde{L} > \tilde{L}_{NI}$). The intuition of this result is the following: increasing L beyond $\tilde{L}_{NI}$ leads to a reduction in the amount of standing forest that the community can use for non-logging purposes, and it reduces the size of the total pie to be shared with the firm ($\Gamma(L)$). However, with SGET interventions the community increases its share of the pie when $\tilde{L} > \tilde{L}_{NI}$. Hence, SGET will induce the community to seek a level of L which is larger than $\tilde{L}_{NI}$ along the bargaining process. If the community has absolute bargaining power ($\tau = 0$), then it will be able to force a level of L which is above $\tilde{L}_{NI}$. If the community has no bargaining power ($\tau = 1$), it will not be able to force any increase in L.

There is of course a critical level of τ below which the perverse result of the SGET intervention will hold. However, part (b.3) of the proposition implies that the distortion is more likely to be worsened by SGET intervention where logging reductions are most needed. To see this, note that $v'(\tilde{L}) - h(\tilde{L})B'(\overline{L} - \tilde{L})$ is the *true* marginal value of forest to the community–firm complex (or the effect of logging on total net benefits when interventions are not sensitive to logging). If this is negative, further deforestation reduces the total benefits of the community–firm complex. This can be considered the case where adequate interventions are most needed. However, the proposition shows that, in this case, SGET interventions make things worse (that is, they increase the initial distortion). This result is consistent with studies showing that decentralization has had mixed impacts on the environment (see footnote 5).

3. The effect of alternative strategies of third-party interventions

We now discuss the environmental impacts of various other interventions. In particular, we discuss three general types of intervention: (i) interventions affecting *de facto* property rights; (ii) interventions affecting bargaining power; and (iii) changes in the opportunity cost of labor.

3.1. Interventions affecting de facto property rights

One way in which third-party actors can try to influence the outcome of community–firm interactions is by affecting the outcome of the latent conflict over *de facto* property rights. In particular, third parties can intervene to affect parameter values to induce a shift in the outcome of the property rights game from open access and unilateral logging by the firm to community property rights and negotiation. For example, by proposition 1, this could be achieved through an increase in c or a decrease in s. Third parties could, for example, lower the level of s by improving the capacity of communities to blockade.

Proposition 3 (Unilateral vs. bargained logging). *If assumption B2 holds, then the bargain-determined level of logging is less than or equal to the unilaterally determined level, that is* $\tilde{L} \leq \hat{L} \forall \tau \in [0, 1]$.

Proof. See appendix (section A.4).

Thus, interventions shifting the outcome of the attrition war from unilateral logging to a situation where the community can enforce its property rights are expected to reduce resource extraction.

3.2. Interventions affecting bargaining power (with and without SGET)

Third-party actors may intervene by changing the effective relative bargaining power in favor of the community. For example, third parties can attempt to lower the community's discount rate through anti-poverty measures, subsidized credit lowering the marginal cost of capital, or by improving tenure security or increasing economic stability. Such interventions reduce the level of r_C (increase δ_C) and thereby reduce τ. To see the impact of such interventions on logging we need to distinguish two effects: (i) a continuous effect on the bargaining outcome; and (ii) a potential discontinuous effect on the outcome of the attrition war.

In the case where bargaining takes place and SGET intervention is in place, lemma 2 applies, and thus $\partial L/\partial \tau < 0$. Thus, contrary to conventional views, interventions improving the community's bargaining power harm the environment by leading to increased logging under a bargained agreement. If SGET is not in place, then lemma 3 applies; interventions that increase the community bargaining power have no effect on logging. That is, the policy intervention is ineffective in achieving environmental improvements. These are the possible continuous effects.

The (discontinuous) effect on the outcome of the attrition war is that an increase in the discount factor (δ_C) lowers the critical level of β^C in equation (5). As stated in proposition 1, this implies that the community's ability to stay in conflict increases. This does not mean, however, that the community will necessarily win property rights; it only implies that it will have a greater chance to win the contest. If the increase in δ_C is not sufficiently large, the outcome of the conflict game may not be altered. We summarize these results in proposition 4.

Proposition 4 (Effects of increases in community bargaining power). *Interventions that increase the community's bargaining power may cause an increase in resource extraction. In particular, this is the case when bargaining takes place and SGET policies are in place (continuous effect). By contrast, an increase in community's bargaining power increases its ability to secure de facto property rights (discontinuous effect). This increased ability does not necessarily mean, however, that the intervention will cause the community to win the conflict; neither does it ensure that resource extraction will decrease.*

3.3. Interventions affecting the opportunity cost of labor

We can distinguish two types of changes affecting the opportunity cost of labor. First, local interventions may increase the marginal product of labor in a segment of the labor market, affecting the opportunity cost of labor of the community, but not of the labor used by the firm. For example, intervention may increase access to improved agricultural or processing technologies or provide alternative employment opportunities within the community, in a setting where the firm does not hire community labor for resource extraction activities. Second, economic growth or macro-level interventions directed to the labor market may change wages faced by both the firm and the community labor.[17]

The effect in the first case is straightforward. Assuming the firm draws its labor out of the general labor market and not from the community, the only effect of an increase in the community members' opportunity cost of time ($\tilde{w}$) is to raise the cost of blockading (s). By proposition 1, this means that communities will be less likely to win the attrition war, and thus it is more likely that the outcome will be a loss of property rights for the community. Thus, bargaining is less likely to take place, and communities are less likely to benefit from the exploitation of the resource. By analogy to the discussion in section 3.1, a shift from a negotiated outcome to unilateral logging by the firm is likely to induce an increase in the extent of logging.

The impact of interventions that increase market wages faced by community members and the firm is more complex. There are three effects on the outcome of the conflict game: (i) s increases as before, (ii) $v(\overline{L}; w)$ decreases, and (iii) Π^C decreases. In general, the net effect on the outcome of the attrition war is indeterminate. If, however, the firm's operation is very capital-intensive, and, hence, less labor-intensive than the community's blockading operation, then it is more likely that the first effect will dominate. In this case the net effect will be again that the community is less likely to acquire property rights, and the effect on logging is exactly as discussed in the case of a more local change in the opportunity costs of labor. If, however, a bargaining equilibrium exists before and after the change in market wages, then the wage effect in a bargaining context will under plausible conditions be in the expected direction, that is less logging.[18]

We present the main effect of labor market interventions in proposition 5 below.

Proposition 5 (Effects of increases in opportunity costs of labor). *Increasing the community's opportunity cost of labor causes an increase of blockading costs. If blockading costs are sufficiently sensitive to the opportunity costs of labor, this may prevent the community from achieving property rights. In this case, the result may be increased environmental pressure.*

It is usually thought that economic development reduces the pressure on natural resources and induces more tenure security. By contrast, proposition 5 indicates that in the absence of public enforcement of property rights, economic development, by raising communities' opportunity costs of property rights self-enforcement, may enhance the potential for invasion of community lands by commercial interests and increase resource extraction.

[17] An example of the second type of intervention is a job creation program supported by the government and of sufficient magnitude to affect the economy's market wage.

[18] Inspecting the first-order conditions it can be shown that a sufficient condition for this result is that $\partial^2 v/\partial L \partial w$ be negative. Using Hotelling's lemma, $\partial^2 v/\partial L \partial w = -\partial m_F/\partial L$, where m_F denotes the optimal level of labor use by the firm, that is employment by the firm should be increasing in the area logged.

4. Conclusions

Consider a community that satisfies all the desirable conditions for collective action that have been emphasized in the literature on the management of local commons. In the view of this literature, we would expect resources to be managed efficiently then. If, however, this community is subject to sufficiently powerful external interests, its desirable collective action characteristics would not necessarily prevent the community from losing effective property rights and would not protect the common resource from excessive degradation. The reason for this is clear. While collective action may influence certain aspects of the strength of a community's ability to face conflict with external actors, there are other factors, generally ignored by the collective action literature that will determine the final outcome of a potential conflict. Even if the community is able to withstand outside challenges it may still be in need of negotiating joint exploitation of the resource with outside agents. Once again, the theory of collective action gives little guidance on how such bargaining would take place and what its consequences would be.

In this paper we have developed a framework that emphasizes important community interactions with external agents ignored by the collective action literature. We have shown that the nature of these interactions critically affects the management of natural resources. Interactions are important not only because communities may unwillingly be faced with external agents (e.g., commercial interests demanding communal resources, especially during times of commodity booms). Cooperation with external agents may also be the most effective way of exploiting certain resources, particularly those requiring large capital investments for their exploitation. We have derived a conceptual approach that naturally leads to an explanation of the birth of effective property rights or, alternatively, their abortion.

Conditional on the development and community enforcement of property rights, we have identified important factors that determine the outcomes of negotiations between communities and external agents. In addition, we have shown some unexpected results concerning the effect of third-party interventions on the environment that should be important to policymakers interested in mitigating the negative environmental consequences of resource exploitation. In particular, our results imply that the effectiveness of third-party interventions depends crucially on initial conditions. Certain interventions often favored by NGOs, governments and international organizations, have been shown to be ineffective or even counterproductive. Though we have highlighted policies that are likely to have paradoxical effects, there are other policies that have the expected impacts in ameliorating the environmental externalities of resource extraction.

An emerging stylized fact suggesting that increasing the rights over natural resources for local communities has often failed to halt natural resource degradation and sometimes even worsened their management is consistent with many of the results shown in this paper. These counterproductive effects appear to emerge from the fact that devolution has generally assigned partial and mostly ambiguous property rights over the resources to the communities instead of formal and publicly enforced rights. This makes it harder for communities to access capital markets and the technologies needed to exploit their natural resources. Some communities thus become disadvantaged *vis-à-vis* firms if bargaining takes place and some others simply lose any potential rights on the resources. The relatively handicapped position of communities, in turn, induces interventions to shield them from unfair contest that sometimes are counterproductive.

Though under certain conditions private enforcement of property rights endogenously emerges, it is clear that this process is only an imperfect substitute for legal and publicly enforced property rights. Failure to publicly establish and enforce such rights increases the likelihood that the process of devolution may not only worsen resource management but also cause certain seemingly plausible policies to backfire. The key message of this paper is that under partial and contestable property rights the road to effective intervention is indeed quite uncertain.

References

Agrawal, A. (2001), 'Common property institutions and sustainable governance of resources', *World Development* **29**: 1649–1672.

Alston, L.J., G.D. Libecap, and B. Mueller (1999a), 'A model of rural conflict: violence and land reform policy in Brazil', *Environment and Development Economics* **4**: 135–160.

Alston, L.J., G.D. Libecap, and B. Mueller (1999b), *Titles, Conflict, and Land Use: The Development of Property Rights and Land Reform on the Brazilian Amazon Frontier*, Ann Arbor: University of Michigan Press.

Angelsen, A. (2001), 'Playing games in the forest: state–local conflicts of land appropriation', *Land Economics* **77**: 285–300.

Baland, J.M. and J.P. Platteau (1996), *Halting Degradation of Natural Resources: Is There a Role for Rural Communities?*, Oxford: Clarendon Press.

Bardhan, P. (1993a), 'Analytics of the institutions of informal cooperation in rural development', *World Development* **21**: 633–639.

Bardhan, P. (1993b), 'Symposium on management of local commons', *Journal of Economic Perspectives* **7**: 87–92.

Barr, C., E. Wollenberg, G. Limberg, N. Anau, R. Iwan, M. Sudana, M. Moeliono, and T. Djogo (2001), 'The impacts of decentralisation on forests and forest-dependent communities in Malinau District, East Kalimantan', *Decentralisation and Forests in Indonesia Series*, Case Study 3, Bogor, Indonesia: Center for International Forestry Research.

Binmore, K. (1985), 'Bargaining and coalitions', in A. Roth (ed.), *Game-Theoretic Models of Bargaining*, Cambridge: Cambridge University Press.

Bohn, H. and R.T. Deacon (2000), 'Ownership risk, investment, and the use of natural resources', *American Economic Review* **90**: 526–549.

Bose, P. (1998), 'Formal–informal sector interaction in rural credit markets', *Journal of Development Economics* **56**: 265–280.

Bray, D., L. Merino, P. Negreros, G. Segura, J.M. Torres, and H. Vester (2003), 'Mexico's community-managed forests as a global model for sustainable landscapes', *Conservation Biology* **17**: 672–677.

Bulow, J. and P. Klemperer (1999), 'The generalized war of attrition', *American Economic Review* **89**: 175–189.

Bulow, J. and K. Rogoff (1989), 'A constant recontracting model of sovereign debt', *Journal of Political Economy* **97**: 155–178.
Burton, P.S. (2004), 'Hugging trees: claiming *de facto* property rights by blockading resource use', *Environmental and Resource Economics* **27**: 135–163.
Casson, A. and K. Obidzinski (2002), 'From new order to regional autonomy: shifting dynamics of 'illegal' logging in Kalimantan, Indonesia', *World Development* **30**: 2133–2151.
Chambers, R.G. (1988), *Applied Production Analysis: A Dual Approach*, Cambridge: Cambridge University Press.
Dixit, A. and B. Nalebuff (1991), *Thinking Strategically*, New York: Norton, chapter 8.
Feder, G. and G. Feeny (1991), 'Land tenure and property rights: theory and implications for development policy', *The World Bank Economic Review* **5**: 135–153.
Hotte, L. (2001), 'Conflicts over property rights and natural-resource exploitation at the frontier', *Journal of Development Economics* **66**: 1–21.
Kaimowitz, D. (2002a), 'When you decentralize, democratise', CIFOR-POLEX electronic newsletter, October 15, 2002, Center for International Forestry Research, Bogor, Indonesia, http://www.cifor.cgiar.org/
Kaimowitz, D. (2002b), 'In good times and bad: community–company partnerships', CIFOR-POLEX electronic newsletter, 30 July 2002 Center for International Forestry Research, Bogor, Indonesia, http://www.cifor.cgiar.org/
Kornhauser, L., A. Rubinstein, and C. Wilson (1989), 'Reputation and patience in the "war of attrition"', *Economica* **56**: 15–24.
Larson, A.M. and J.C. Ribot (2004), 'Democratic decentralization through a natural resource lens: an introduction', *The European Journal of Development Research* **16**: 1–25.
Lewis, D.R. (1995), 'Native Americans and the environment: a survey of twentieth century issues', *American Indian Quarterly* **19**: 423–450.
Mayers, J. and S. Vermeulen (2002), 'Company–community forestry partnerships: from raw deals to mutual gains?', *Instruments for Sustainable Private Sector Forestry Series*, London: International Institute for Environment and Development.
Muthoo, A. (1999), *Bargaining Theory with Applications*, Cambridge: Cambridge University Press.
Ostrom, E. (1990), *Governing the Commons: The Evolution of Institutions for Collective Action*, Cambridge: Cambridge University Press.
Palmer, C. (2004), 'The role of collective action in determining the benefits from IPPK logging concessions: a case study from Sekatak, East Kalimantan', Working Paper No. 28, Center for International Forestry Research, Bogor, Indonesia.
Resosudarmo, I.A.P. (2004), 'Closer to people and trees: will decentralization work for the people and the forests of Indonesia?', *The European Journal of Development Research* **16**: 110–132.
Ribot, J. (2002), *Democratic Decentralization of Natural Resources, Institutionalizing Popular Participation*, Washington, DC: World Resources Institute.
Rubinstein, A. (1982), 'Perfect equilibrium in a bargaining model', *Econometrica* **50**: 97–110.
Walker, P. (2000), 'Democracy and environment: congruence or contradiction?', *Commons Southern Africa* **2**: 4–6.
World Development Report (2000/2001), Attacking Poverty, World Bank, Washington, DC.
World Development Report (2003), Sustainable Development in a Dynamic World, World Bank, Washington, DC.

Appendix

A.1. Derivation of first-order condition (15)

Using a logarithmic transformation and the definition $d^C(L) = h(L)B(\overline{L})$, the objective function in (14) can be rewritten as

$$\max_L \tau \ln[\overline{R}^F + \tau G(L)] + (1-\tau)\ln[d^C(L) + (1-\tau)G(L)].$$

The first-order condition for the bargaining problem specified in (14) can thus be written as

$$\frac{\tau G'(L)}{\overline{d}^F + \tau G(L)} = -\frac{1-\tau}{\tau}\frac{d^{C\prime}(L) + (1-\tau)G'(L)}{d^C(L) + (1-\tau)G(L)}, \text{ or equivalently,}$$

$$\frac{\tau^2 G'(L)}{\Pi^F} + \frac{(1-\tau)d^{C\prime}(L) + (1-\tau)^2 G'(L)}{\Pi^C} = 0.$$

Some further manipulation yields

$$\left[\tau^2\frac{\Pi^C}{\Pi^F} + (1-\tau)^2\right]G'(L) + (1-\tau)d^{C\prime}(L) = 0.$$

Substituting for $G'(L) = \Gamma'(L) - d^{C\prime}(L)$ (from equation (10) and $d^C(L) = h(L)B(\overline{L})$), we can rewrite

$$\left[\tau^2\frac{\Pi^C}{\Pi^F} + (1-\tau)^2\right]\Gamma'(L) + \left[\tau - \left(\frac{\Pi^C}{\Pi^F} + 1\right)\tau^2\right]d^{C\prime}(L) = 0.$$

This expression is of course equivalent to equation (15).

A.2. Proof of lemmas 1 and 2

Substituting for $\tau = 0$ and $\tau = 1$ in the expression for κ given below (15) immediately yields the second part of lemma 1. Moreover, we can rewrite κ as

$$\kappa(L;\alpha,\tau) = \left[\frac{(\alpha+1) - \frac{1}{\tau}}{\alpha + \left(\frac{1-\tau}{\tau}\right)^2}\right],$$

where $\alpha \equiv \alpha(\tau) = \frac{\Pi^C}{\Pi^F} = \frac{h(\tilde{L})B(\overline{L}) + (1-\tau)G(\tilde{L})}{\overline{R}^F + \tau G(\tilde{L})}$.

It is easy to see by inspection, that the direct effect of τ on κ is positive (that is, $\frac{\partial\kappa}{\partial\tau} > 0$). Moreover, the effect of α on κ is also positive since

$$\frac{\partial\kappa}{\partial\alpha} = \frac{\alpha + \left(\frac{1-\tau}{\tau}\right)^2 - \left[(\alpha+1) - \frac{1}{\tau}\right]}{\left[\alpha + \left(\frac{1-\tau}{\tau}\right)^2\right]^2} = \frac{\left(\frac{1-\tau}{\tau}\right)^2 + \frac{1}{\tau} - 1}{\left[\alpha + \left(\frac{1-\tau}{\tau}\right)^2\right]^2} > 0$$

for $0 < \tau < 1$. Also, inspection of the definition of α shows that $\frac{d\alpha}{d\tau} > 0$. Therefore, it follows that $\frac{d\kappa}{d\tau} \equiv \frac{\partial\kappa}{\partial\tau} + \frac{\partial\kappa}{\partial\alpha}\frac{d\alpha}{d\tau} > 0$. Together these two results imply that $0 \leq \kappa \leq 1$ (first part of lemma 1). Lemma 2 follows directly from the previous results, equation (15), and the concavity of Γ. □

A.3. Proof of proposition 2

From equations (15), (7), and (A8) we have that

$$v'(\tilde{L}) = h(\tilde{L})B'(\overline{L} - \tilde{L}) + h'(\tilde{L})[\kappa B(\overline{L}) - B(\overline{L} - \tilde{L})]. \tag{a.1}$$

In the absence of intervention, $h'(\tilde{L}) = 0$. Result (a) follows immediately from (a.1) together with the concavity of v, and the fact that $h(L) < \overline{h}$. If $\tau = 0$, then $\kappa = 0$, so the second term on the right-hand side (RHS) of (a.1) is negative, implying that the distortion is worsened (result b.1). If $\tau = 1$, then $\kappa = 1$, so the second RHS term in (a.1) is positive, implying that the distortion is reduced (result b.2). For $0 < \tau < 1$, $0 < \kappa < 1$, the sign of the second RHS term in (a.1) is ambiguous. The closer to zero τ is, the more likely the sign of the expression in (b.3) is negative. □

A.4. Proof of proposition 3

By the concavity of v, $\tilde{L} \leq \hat{L}$ if and only if $v'(\tilde{L}) \geq v'(\hat{L})$. Now compare the first-order condition for $\tilde{L}$ (equation (15)) to that for $\hat{L}$, which is given by $v'(\hat{L}) = 0$. Then $v'(\tilde{L}) \geq v'(\hat{L})$ holds $\forall \tau \in [0, 1]$ if and only if $N \equiv h(\tilde{L})B'(\overline{L} - \tilde{L}) + h'(\tilde{L})[\kappa B(\overline{L}) - B(\overline{L} - \tilde{L})] \geq 0$ for all $\tau \in [0, 1]$, (or equivalently, for all $\kappa \in [0, 1]$). Let $M(L) \equiv h(L)B(\overline{L} - L)$. Since N reaches a minimum at $\kappa = \tau = 0$, it suffices to show that $N|_{\kappa=\tau=0} \geq 0$. Moreover, since in this case $N = -dM/dL$, the condition $N \geq 0$ for all $\tau \in [0, 1]$ holds if and only if $dM/dL \leq 0$. That is, if assumption B2 holds. □