State - Local Community Games of Forest Land Appropriation

Arild Angelsen

WP 1997: 7

ISSN 0804-3639

Working Paper
Chr. Michelsen Institute
Development Studies and Human Rights
Bergen Norway

State - Local Community Games of Forest Land Appropriation

Arild Angelsen

WP 1997: 7

Bergen, April 1997

CHR. MICHELSEN INSTITUTE
Development Studies and Human Rights

Working Paper WP 1997: 7

State - Local Community Games of Forest Land Appropriation

Arild Angelsen

Bergen, April 1997

Summary:
This paper explores possible strategic interactions between the state and local community in games of tropical forest land appropriation. Two key questions are addressed. First, how does the structure of the game influence the extent of deforestation? Second, under which circumstances does higher forest appropriation by the state promote local deforestation? Three different cases are discussed, corresponding to a development over time towards increased forest land competition and integration of the local community into the national economy. Particular attention is given to the assumptions made about the local economy and the local costs of state deforestation. The local response to more state appropriation depends critically on these assumptions, and less on the structure of the game (Cournot or Stackelberg). The state will fuel local deforestation if state deforestation is associated with provision of infrastructure (roads) which reduces the local costs of agricultural expansion, or if the local economy is isolated (autarky) and local behaviour is determined by survival needs rather than income maximization.

Indexing terms:
Deforestation
Game theory
Economic models

To be ordered from Chr. Michelsen Institute, Fantoftvegen 38, N-5036 Fantoft, Bergen, Norway. Telephone: +47 55574000. Telefax: +47 55574166

Contents

1 Introduction[1]

Several studies of deforestation within the political economy tradition focus on the conflict between the state or state sponsored users and local, traditional users in the utilization of tropical forest resources (e.g., Colchester, 1994; Colchester and Lohmann, 1993; Bromley and Chapagain, 1984). There have, however, been few (none?) attempts on formal modelling of such conflicts and the strategic behaviour they may give rise to.[2] This paper attempts to formalize the interaction between the state and a local community in forest land appropriation by applying relatively simple game theoretic models.

A central issue to be addressed is the effect on local forest clearing of higher forest appropriation by the state. Does state deforestation stimulate or replace local deforestation? Under which circumstances does the state fuel local "land grabbing"? Further we want to explore the impact on the overall level of deforestation (state and local) of different kinds of strategic interaction between the state and the local community (structure of the game).

The models of this paper are complementary to Angelsen (1996b), which studies the effects of external land appropriation on farmers' choices related to tenure security, and Angelsen (1994; 1996a), which study the effects on agricultural land expansion. These models assume parametric interaction. The present paper focuses on *strategic* behaviour and interactions, that is, where the players take into account the effect of their choice on the other player's choice of forest appropriation.

There is a substantial literature which uses game theory to study resource problems. A large share of this literature analyzes resource management issues by using binary choice models, for example, prisoner's dilemma (PD) or assurance games. Baland and Platteau (1996) and Ostrom *et al.* (1994) are among the best examples of the usefulness of such an approach, which -- due to its simplicity and flexibility -- can be used to study a variety of resource games. The Cournot game presented in this paper can be considered a continuous choice version of the conventional (binary choice) PD game. The continuous choice model offers, however, a richer approach as one can study the local response to exogenous changes in situations where one, both before and after the change, has non-cooperation in a PD game.

Another large sub-category of the literature deals with dynamic games, which in addition to the multi-period strategic interaction between economic agents, also incorporates the resource dynamics (differential games). The latter is particularly important in games involving renewable resources with high growth rates, for example, fish (e.g., Levari and Mirman, 1980). In our model, which is a game of land appropriation, this aspect is of much less relevance. Compared to the static games studied in this paper, dynamic games could offer additional insights by studying the

---

[1] Thanks to Rögnvaldur Hannesson, Karl O. Moene, Ottar Mæstad, Karl R. Pedersen, Ussif Rashid Sumaila, and Arne Wiig and other colleagues at CMI for comments to a draft version of the paper.

[2] A comprehensive review by Kaimowitz and Angelsen (1997) on economic models of deforestation does not find any such models.

interaction over time. The approach of this paper is, however, to explore the implications of the underlying assumptions in relatively simple games rather than to use simplistic assumptions in more complex, dynamic games. Hopefully, static (Cournot) or simple sequential (Stackelberg) games reveal important structures and incentives of real-life games which, obviously, are dynamic.

A critical assumption for applying game theoretic models of only two players is that the local community and the state can be viewed as single actors. Are there mechanisms, for example, in terms of local resource management institutions, uniform ways of thinking and responding, etc. within the local community which make it appropriate to study the local community as one agent? If not, the situation is better studied as one of open access, that is, games with a very large number of players. As is well known from the literature, the Nash-Cournot equilibrium converges to the competitive market equilibrium when the number of players increases. The latter situation has already been discussed in Angelsen (1994; 1996a). The game models of this paper explore another extreme with only two players. Thus the models of the present and the complementary papers analyze two extreme situations, while we keep in mind that actual behaviour shows great variation between these.

The outline of the paper is as follows. Section two presents the basic elements of the models. Three different cases or games are discussed in the following sections. In section three we focus on a poor, isolated local community. The interaction with the state is studied as a static game with simultaneous moves (Cournot). Section four discusses a situation with higher forest land scarcity and a local-led land race, that is, the local community is the leader in a Stackelberg game. Section five analyzes a case with intense resource scarcity and competition, and a local community integrated into the regional/national economy. The state is assumed to be the Stackelberg leader in this case. Section six compares the different cases, discusses possible developments over time in the local response, and the possibilities for cooperation in forest management. The final section concludes.

2 Preliminaries

We consider a given forest area (H^T) which has three uses: it can be converted to agricultural land by the local community (H^L), to plantations, logging or other large scale projects by the state (H^S), or it can remain virgin/natural/primary/pristine/old-growth forest (H^F).

(1) $$H^T = H^L + H^S + H^F$$

We assume that the state and local community each choose the level of H^S and H^L, respectively. New forest land is allocated on a first-come-first-served-basis.[3]

[3] Forest clearing may give more permanent land rights, as assumed in model IV in Angelsen (1996a). In this case the income and cost variables should be interpreted as discounted values. Tenure insecurity could then be included by reducing the discounted values, a practice known as risk discounting. If local tenure security is inversely related to the level of state appropriation (as in the model of endogenous tenure security in Angelsen, 1996b), this could also be included in the model in a relatively straightforward manner. To keep the

Local income

The income to the local community and the state are functions of land area converted for their own use, as well as the remaining natural forest. The local forest benefits of primary forest would be in the form of non-timber forest products and various protective functions, whereas the state would benefit from it in the form of, for example, eco-tourism and protective functions, as well as more intangible benefits such as existence values and a green image.[4] The net income to the local community is given by;

$$(2) \qquad L = l(H^L, H^S) = r(H^L) + t(H^F) - \int_0^{H^L} c(H^T - H^S - x, H^S)dx$$

$r(H^L)$ is the gross revenue of forest clearing for agricultural production, for simplicity assumed to be a function of land area only (decisions about, for example, labour input are not included). $t(H^F)$ gives the income from primary forest as a function of total forest area. We do not distinguish between gross and net benefits of virgin forest. We assume decreasing returns, for example, because land is of heterogeneous quality (t_1, $r_1 > 0$, t_{11}, $r_{11} < 0$).

The last element in (2) gives the aggregate cost of agricultural production. The properties of the local cost function are critical for some of the later results. $c(H^F,H^S)$ is the marginal costs of land expansion. First, a larger primary forest area will reduce the costs as new land is more easily available ($c_1 < 0$), but this effect is diminishing ($c_{11} > 0$). Second, state forest clearing has a cost reducing effect on the marginal costs of expansion, as it provides infrastructure, particularly roads ($c_2 < 0$), also at a decreasing rate ($c_{22} > 0$). The net effect of increased state appropriation on the costs is therefore ambiguous: $\frac{\partial c}{\partial H^S} = c_2 - c_1 \gtrless 0$. A land scarcity effect increases the marginal costs, whereas an infrastructure effect reduces the cost of agricultural land expansion. From the assumptions made, the first effect will increase relative to the second as H^S increases: $\frac{\partial c^2}{\partial^2 H^S} = c_{11} + c_{22} > 0$.[5] We then have three possibilities: (1) the expression (c_2 - c_1) is negative for all relevant combinations of H^S and H^L, (2) it is positive for all relevant combinations, and (3) it is negative for low levels of H^S (and H^L) and positive for high levels. Intuitively, the last two possibilities appear to be the most realistic ones.

State income

The state revenue is determined in a similar manner, except that local forest clearing does not have any cost reducing effects through provision of infrastructure. We assume

---

focus on the main mechanisms of the game we shall, however, abstract from the issue of tenure insecurity, noting that the chosen model formulation can be given alternative interpretations.

4 Virgin forest is to be considered a public good both in the sense that there is *no rivalry* between local and state uses in consumption of services derived from *a certain virgin forest area,* and *exclusion is impossible.* (The latter requirement is, in fact, redundant as there would be no incentive to exclude others since there is no rivalry and the public good is provided for free.) Note that the non-rivalry assumption relates to the two actors in our model at the aggregate level, and not, for example, between villagers in the utilization of fuelwood from a given forest area. Finally, we note that the *total* forest benefits depend on total virgin forest area; thus there is rivalry in land allocation.

5 We assume $c_{12} = c_{21} = 0$.

that the state is only concerned with maximizing own income (a predatory state) and not total income (a developmental state). This assumption is discussed further in case 1 and relaxed in Appendix 1.

(3) $$S = s(H^S, H^L) = v(H^S) + g(H^F) - \int_0^{H^S} h(H^T - H^L - y)dy$$

v() is the gross income from forest appropriation by the state, whereas *g()* is the state's benefits from primary forest. The benefit functions are strictly concave (g_1, $v_1 > 0$, g_{11}, $v_{11} < 0$). The marginal cost of forest appropriation, $h(H^F)$, is lower the larger the area of virgin forest, but this effect is diminishing ($h_1 < 0$, $h_{11} > 0$).

The formulation in (1) implicitly assumes that state and local land uses are mutually exclusive. This may be a fair assumption for land uses which involves forest clearing and permanent use of the land, for example, permanent agriculture, plantations, hydropower and infrastructure developments. For other uses, particularly logging, this may not be the case. Logging companies are basically interested in the big trees, not the land. Farmers' main interest is in the land (soil) for cultivation. Thus, as observed throughout Asia, shifting cultivators may follow in the wheel tracks and clear logged forest. Related to our model, this could be interpreted as each hectare of state deforestation having a strong infrastructure component; the infrastructure effect will be strong relative to the land scarcity effect ($c_2 - c_1 < 0$).

Three key assumptions

We identify three critical assumptions in the modelling of state local interactions, cf. also Appendix 2: (i) the effect of state deforestation on local expansion cost, (ii) the degree of openness of the local economy, and (iii) the structure of the game. Each of these reflects the empirical variation found in developing countries, and they are briefly examined below.

First, *the effect of state forest appropriation on the marginal costs of local forest clearing*, as discussed above. The strength of the land scarcity effect *v.* the infrastructure effect of higher state forest clearing depends on particularly two factors. In a forest abundant situation the infrastructure effect will be relatively stronger, as included in the assumptions about the cost function. It also depends on the type of forest conversion by the state: logging has a stronger infrastructure component relative to area directly cleared compared to, for example, plantations or commercial agriculture.

Second, *the openness of the local economy.* As shown elsewhere (Angelsen, 1996a), the response of farm households depends critically on the market assumptions. In particular, it is crucial whether an off-farm labour market exists or not, for example, through migration, such that the opportunity costs of labour can be taken as exogenous in the model. In that case the model becomes recursive: the production decisions can be separated from the consumption decisions and studied as a profit maximizing problem. If some prices are *not* market-determined, the production and consumption decisions must be solved simultaneously and the behaviour of the local community is studied as a utility maximizing problem; see Angelsen (1996a) for a further discussion.

The distinction between profit and utility maximizing local behaviour relates particularly to the labour market assumption. This depends, *inter alia,* on the openness of the local economy and the existence of an off-farm sector and its size relative to the agriculture/forestry sector. It also relates to the time horizon for the analysis; the small, open economy assumption is relatively more relevant for long term analysis when migration is an option. In the first two cases we assume a local autarky, i.e., the local community's deforestation decisions are studied as a utility maximizing problem. In the third we use the conventional profit-maximizing approach, which corresponds to the small, open economy assumption.

Third, *the structure of game.* We analyze three types of games. In the first case we assume a static game with simultaneous moves (Cournot). Then we look at sequential, two period games (Stackelberg). In the second case the local community moves first (leader) and the state second (follower). In the third case, we reverse the sequence, and let the state be the leader.

In each game we study the Nash equilibrium, being defined as "a set of strategies, one for each player, such that given the strategies being played by others, no player can improve her pay-off by adopting an alternative strategy" (Heap *et al.,* 1992: 101). The equilibrium in the Cournot game is often referred to as the Nash, Nash-Cournot or Cournot equilibrium; we use the term Cournot equilibrium as all equilibria studied in this paper (including Stackelberg) are Nash equilibria.

The Cournot equilibrium is at times referred to as a zero conjecture or independent adjustment equilibrium; the players do not expect any change in the opponent's decision variable when they change their own decision variable, and the equilibrium is reached after an adjustment process. An alternative, more appropriate and "modern" interpretation of how the equilibrium is reached is the following: when the players move simultaneously, both assume the other to make a rational choice, they have rational expectations about the opponent's choice, and then both select simultaneously the best strategy given that the opponent does the same.

The structure of the game is similar to a standard Cournot game of duopoly (e.g., Shapiro, 1989; Friedman, 1983), and have also similarities to games of public goods provision (e.g., Cornes and Sandler, 1986).[6] A special feature of this paper is a careful specification of the local objective function (preferences and market assumption) and the cost structure, and the analysis shows that conventional conclusions from this literature cannot readily be replicated in state-local resource games.

In a leader-follower or Stackelberg game, the follower observes the leader's choice and chooses the optimal strategy based on that in a similar manner as in the Cournot game.

[6] Whereas there are some similarities with the standard duopoly games, one should also note some important differences. First, there is no competition in an output market in our model, only in forest appropriation. Second, and related to the first, there is no price as such in the model; thus we only have games of quantity competition. Third (and more relevant to dynamic models), there are no separation between investment and production decisions, as the income is a function of only land investments (forest clearing). Fourth, as will be seen below, the local response curve may be forward bending.

The leader, choosing first, anticipates the response of the follower, and includes the follower's response in his optimization problem.

Three cases

As already indicated, formal modelling of state-local interactions in forest resource use represents a new research area. It is therefore hard to find factual evidence for which games that will apply in different empirical contexts. Even in empirical research it may be difficult to reveal the exact structure of the game and the sequence of the moves. Indeed, this is a general problem in applying game theory: the theory provides few empirically verifiable criteria for which structure of the game that should be assumed in the model. The discussion of the empirical relevance of the different structures of the game therefore becomes somewhat tentative, and clearly calls for further investigations. One argument could be that the Stackelberg games represent situations where one of the players is more aggressive than the other.

By varying the three key assumptions discussed above we get 12 different games, cf. Appendix 2. We have chosen to focus on three cases. The case studies have been selected partly based on their perceived empirical relevance, and partly to review the implications of different assumptions: how robust are the conclusions to variations in the assumptions?

Case 1 deals with a poor, isolated local community, where the interaction with the state is studied as a Cournot game. Case 2 discusses a situation with higher forest land scarcity and a local-led land race, that is, the local community is the leader in a Stackelberg game. Case 3 analyzes a situation with intense resource scarcity and competition, and a local community integrated into the regional/national economy. The state is assumed to be the Stackelberg leader in this case. In some respects, the three cases correspond to a possible development over time in terms of (i) increased resource scarcity, (ii) increased integration of the local community in the regional/national economy, and (iii) more aggressive behaviour by one of the players.

3 Case 1: Poor, isolated local community

In the first case we consider the interaction between state and local deforestation in the context of a poor, isolated local community. This case could describe the situation for many tribal communities. Their livelihood, based on forest income from hunting, gathering and extensive forms of agriculture such as long-fallow shifting cultivation, is being undermined as the area of natural forest declines through state appropriation. Examples of this situation are found in the Amazon and Southeast Asia, e.g., Colchester and Lohmann (1994).

We have identified three key assumptions in state - local games: the type of game, the local economy, and the local cost effects of state deforestation. In the poor, isolated local community case we assume the following for each of these.

Type of game: The most difficult assumption relates to the type of game that should be modelled; it is hard *a priori* to determine the game formulation that most realistically describe the situation. We shall analyze a Cournot game in this case, that is, a static game with complete information, and both players choose their strategy simultaneously.

Local economy: In our case when the local community is isolated, the utility maximizing approach is the relevant one. We make the assumption that all income is derived from agriculture and direct forest uses (no off-farm income).

Local cost structure: Poor, isolated forest communities are normally associated with forest abundance, which suggest that the infrastructure effect will dominate. The technological level among such communities -- most transport is done by foot -- implies, however, that they may not make much use of state provided infrastructure. We shall therefore not make any *a priori* assumptions about which effect dominates.

The state's response curve

The objective of the state is to maximize income as given in (3). The state will then choose the amount of land for plantations, logging, etc. such that the following first order condition is satisfied;[7]

(4) $$s_1 = v_1 - g_1 - h(H^F) = 0$$

The first element gives the marginal gross income from forest conversion, whereas the last two are the costs in terms of reduced forest benefits (opportunity costs) and the direct costs related to forest clearing.

The optimal amount of land clearing by one agent is a function of the amount appropriated by the other. We define the optimal levels of H^S as a function of the local community's choice, i.e., the *response or reaction function* for the state;

(5) $$H^{S*} = H^S(H^L)$$

To explore the characteristics of the response function, we differentiate (4) to obtain;

(6) $$\frac{dH^{S*}}{dH^L} = -\frac{s_{12}}{s_{11}} = -\frac{g_{11}+h_1}{v_{11}+g_{11}+h_1} < 0$$

The response curve of the state of backward sloping in an H^L- H^S diagramme for two reasons. More local forest clearing implies that the remaining forest becomes more valuable, i.e., the net marginal benefits of virgin forest (g_{11}) and the opportunity costs of conversion increase. Further, the marginal costs of forest conversion will be higher as the remaining forest is less suitable or accessible (h_1).

The iso-profit curves for the state are defined by setting $S = \bar{S}$. The shape of the curves is found by total differentiation of (3);

(7) $$\frac{dH^L}{dH^S} = -\frac{s_1}{s_2} = -\frac{v_1-g_1-h(.)}{-g_1+\int_0^{H^S} h_1 dy}$$

Whereas the response curve shows the *optimal* response to changes in the other player's choice, the iso-profit curves simply show the change necessary to maintain the same

---

[7] It follows from the assumptions made that $s_{11} < 0$.

income. s_2 is always negative, whereas s_1 is positive for small values of H^S, zero in optimum (cf. (4)), and negative for larger values. Thus the state's iso-profit curves will therefore be inverted C-shaped in an H^L-H^S diagramme.

We have assumed a rather narrow objective function for the state, in the way that only own income is maximized. The implications of including local income in the state's objective function (a developmental state) are examined in Appendix 1. Under realistic assumptions the response curve will still be downward sloping, but the location and slope will change. If the land scarcity effect dominates, for example, the curve will move downwards. Nevertheless, since the qualitative results only depend on the slope of the response curve we do not pursue the case with a more developmental state.

The local response curve

Local behaviour is studied as a problem of balancing the utility of consumption and the disutility of labour. This is known as the Chayanovian model in agricultural economics. The cost related to agricultural expansion and cultivation is expressed in terms of labour; $c(H^F,H^S)$ therefore represents the labour input required for a marginal expansion of agricultural land. Formally, the problem is one of maximizing;

$$(8) \qquad U = U\left(r(H^L) + t(H^F), \int_0^{H^L} c(H^T - H^S - x, H^S)dx\right) = u(H^L, H^S)$$

We assume the utility function to be well-behaved, cf. Angelsen (1996a). The optimality condition is given by;

$$(9) \qquad u_1 = 0 \Leftrightarrow r_1 - t_1 - zc(H^T - H^S - H^{L*}) = 0; \; z \equiv -\tfrac{U_2}{U_1}$$

Net marginal income from forest conversion (r_1 - t_1) should in optimum equal the marginal labour requirement for land expansion multiplied by the shadow wage rate (z). z can also be given the interpretation as the virtual price of labour. As discussed in Angelsen (1996a: appendix 1), the use of virtual prices facilitates the comparative statics. The substitution effect is given by keeping z constant, whereas the income effect is determined by the change in z.

(9) implicitly defines the optimal local deforestation (H^{L*}) as a function of H^S, or the response function.

$$(10) \qquad H^{L*} = H^L(H^S)$$

The inverse of the slope of the response curve H^L-H^S diagramme is;

$$(11) \qquad \frac{dH^{L*}}{dH^S} = -\frac{u_{12}}{u_{11}} = -\frac{t_{11} - z(c_2 - c_1) - c(.)z_{H^S}}{r_{11} + t_{11} + zc_1 - c(.)z_{H^L}} \gtrless 0; \; z_{H^S} \equiv \frac{\partial z}{dH^S}, z_{H^L} \equiv \frac{\partial z}{dH^L}$$

The denominator in (11) is negative, corresponding to the second order conditions for maximum ($u_{11} < 0$). The response of the local community to higher H^S, i.e., the sign of u_{12}, is ambiguous. The analysis of the sign of the numerator in (11) is done in two steps. In the first step, we assume that z is fixed, corresponding to a small open economy approach (only substitution effects apply). There are three effects to consider. *First*, more land appropriated by the state means that the net marginal benefits of virgin forest increases (t_{11}), i.e., the opportunity costs of agricultural conversion increases. *Second,* the marginal costs of land expansion will be higher as the remaining forest is less suitable for agricultural production or is less accessible (c_1). *Third,* state clearing provides infrastructure which has the opposite effect on land expansion (c_2). If the latter effect is sufficiently large, the response may be positive. As shown above, the third (infrastructure) effect will be relatively larger to the second (land scarcity) effect the lower the level of H^S, whereas the impact on the first effect cannot be determined from the assumptions made. However, we can conclude that if the infrastructure effect is sufficiently strong the expression ($t_{11} - z(c_2 - c_1)$) in (10) will be positive.

In the second step, we must also consider the effect of changes in the shadow wage rate (z), which reflects the income effects. We always have $z_{H^L} > 0$ as higher H^L increases income and labour input, both of which augment the shadow wage rate. The effect of higher H^S is more complicated. Assuming additive utility ($U_{12} = U_{21} = 0$), we get;

$$(12) \qquad z_{H^S} = -\frac{U_{22}U_1\int_0^{H^L}(c_2-c_1)dx + U_{11}U_2t_1}{U_1^2} \gtrless 0$$

There are two different effects on z. First, higher H^S affects the total costs as shown by the first element in the numerator. If the land scarcity effect is strong ($c_2 - c_1 > 0$), more state deforestation implies higher labour input and therefore higher z. If the infrastructure effect is strong, however, more state deforestation will reduce z. Second, higher H^S will reduce the income by lowering the primary forest area, which reduces z. In the case where the infrastructure effect is strong, (12) is therefore unambiguously negative.

In the case of small infrastructure effects, (12) may be positive or negative. I have in Angelsen (1996a; 1996c) used and discussed an additive utility function with a subsistence consumption level. This formulation gives, in accord with economic intuition, that the income effect dominates the substitution effect when consumption is close to the subsistence level, or when the preferences are such that marginal utility of consumption above the subsistence level is rapidly declining. This implies that the absolute value of U_{11} will be large and the second element in the numerator dominates. Hence in poor local communities we could expect $z_{H^S} < 0$.

Returning to the numerator of (11), there is now a fourth effect to consider related to the change in z (income effect). A lower z will pull in the direction of more local forest conversion as the (subjective) costs are lowered; a higher z will reduce local deforestation.

In summary, if the infrastructure *or* the income effects (or both) are strong, we get a forward bending local response curve ($u_{12} > 0$). In our case we have assumed the local community to be poor, which implies strong income effects. The qualitative response will in this case be as in a "full belly" model, that is, when the local preferences are such that they minimize labour efforts given a subsistence target.[8]

[8] An extreme version of the utility maximizing approach is to assume that the local community has lexicographic preferences: the households shall reach a subsistence level of

The local indifference curves are defined by setting $U = \overline{U}$, and the curvature is found by differentiation of (8);

$$(13) \quad \frac{dH^S}{dH^L} = -\frac{u_1}{u_2} = -\frac{r_1 - t_1 - zc(.)}{-t_1 - z\int_0^{H^L} (c_2 - c_1)dx}$$

u_1 goes from being positive to negative as H^L increases, and is zero in optimum. The shape of the indifference curves depends on the sign of u_2, which may be either positive or negative. When the infrastructure effect is small, $u_2 < 0$. The local iso-profit curves are then inverted U-shaped.

Note that the conditions for inverted U-shaped indifference curves are not the same as the condition for a backward bending response curve, although they are related. The latter condition ($u_{12} < 0$) concerns the effect of higher state clearing on the *marginal* utility of local agricultural expansion, whereas the first ($u_2 < 0$) reflects the effect on *total* utility. Moreover, the sign of u_{12} is influenced by the relative strength of the income effect, whereas u_2 is not.

Given our assumptions about the cost function, it is possible for a certain range of values of H^S that $u_{12} < 0$ and $u_2 > 0$. In addition, it may well be that the infrastructure effects are small ($u_2 < 0$) but that the response curve is forward bending due to strong income effects ($u_{12} > 0$). To simplify the presentation, we shall in the following assume a forward bending response curve due to strong income effects and that the indifference curves are inverted U-shaped, i.e., there are small infrastructure effects of state deforestation.

Cournot equilibrium

The Cournot equilibrium is given where the two response curves intersect (*A*) in Figure 1. This is the only point where the level of forest clearing, for both players, is the best reply to the level chosen by the other. In other words, there is consistency for both players between their own optimal level of forest clearing and the level chosen by the other.

---

consumption or income (Q) at minimum labour costs ("full belly" preferences). The optimization problem is very simple in this case: the local community gets a basic income from natural forest, $t(H^F)$, and then clears as much forest as required to reach the subsistence target, given by $r(H^L) + t(H^F) = Q$. This also defines the response curve of the local community. Differentiation yields the inverse of the slope of the response curve; $dH^{L*}/dH^S = t_1 / (r_1 - t_1) > 0$, i.e., the response curve is forward sloping. More state deforestation reduces the local forest income, and this has to be compensated for by expanding agricultural land area. The slope depends on the marginal income from the two types of land use. If the marginal benefits from non-timber forest products are small relative to the benefits from agricultural land, state forest clearing only has modest effect on local agricultural expansion.

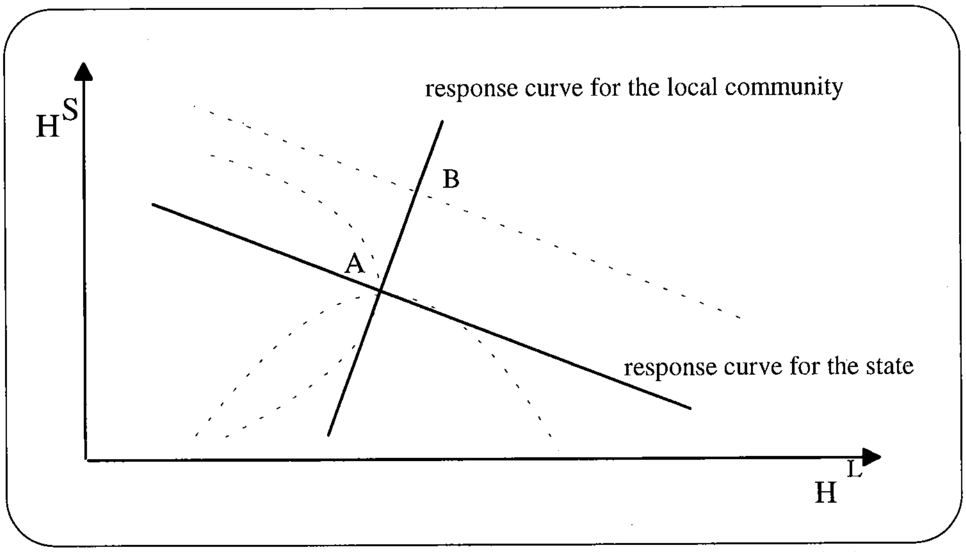

Figure 1: The response curves for the local community and the state in the poor, isolated community case.

The condition for stability of the system is;[9]

(14) $\quad u_{11}s_{11} - u_{12}s_{12} > 0$

As seen from (11) and (6), we have u_{11}, s_{11}, $s_{12} < 0$; $u_{11} < u_{12}$; $s_{11} < s_{12}$. It then follows that the necessary condition for a stable equilibrium is met. Graphically, this implies that the local response curve, when moving south, must intersect with the state's response curve from above.

Consider an exogenous shift in the state's response curve, represented by the dotted line in the figure. For any given value of H^L the state wants to appropriate more land than before. This could be due to, for example, higher prices of plantation products, technological progress, or less value attached to virgin forest. The local response will be more forest clearing, and the new equilibrium is in point *B*.

State deforestation fuels local deforestation in this case. The main mechanism is that state appropriation of forest reduces local forest income, which must be compensated for by expanding the local agricultural area. If state deforestation in addition provides infrastructure such that the cost of agricultural expansion is reduced, this gives an additional argument for local land expansion.

An illustration of the empirical relevance of this case is given in a review of local studies on poverty and tropical forest degradation by Kates and Haarmann (1992). They identify two major sources of displacement of indigenous hunter-gatherers or poor farmers; one is by (state-sponsored) commercial activities, the other by spontaneous immigrants or government planned resettlement programmes. This leads to degradation of forest resources on which the traditional users depend, and forces them to expand their activities into new forest areas.

[9] See, for example, Shapiro (1989: 386)

4 Case 2: Increased forest land competition; local-led land race

When forest land scarcity and competition increases, one possibility is that we move from a Cournot game to a Stackelberg game with the local community as the leader and the state as the follower. This game would then describe a race for primary forest where the local community is the "aggressive" player, and clear forest in order to squeeze the state. As discussed towards the end of this section, this game could describe an important aspect of the process of deforestation in many locations in Indonesia and Latin America.

Why is it fair to assume the local community to be a Stackelberg leader? Besides the need to test the implications of different game assumptions, there are some reasons that make the case with the local community as the leader a relevant one to study. One could argue that the local community has greater flexibility than the state in adjusting its forest clearing, for example, because the state's decisions must move through a bureaucracy, and often require heavy capital investments. Further, the local community may know the decision procedures of the state, and therefore be able to predict the state's actions.

We make no *a priori* assumptions about the local economy, and discuss the autarky (utility maximizing) case which could be considered the most general one as both income and substitution effects are present. We further assume in this game that the land scarcity effect of state deforestation is large compared to the infrastructure effects. This is related to the type of game studied; the Stackelberg game with a local leader appears to be most reasonable in a situation where state deforestation is costly to the local community (cf. Appendix 2).

Local behaviour and the Stackelberg equilibrium

The problem for the local community as a leader is to maximize utility as given in (8), subject to the response function for the state as given in (5). The state will as a follower be on its response curve. The optimal level of forest clearing by the local community is such that the following condition is met;

$$(15) \qquad u_1 + u_2 \frac{dH^{S*}}{dH^L} = r_1 - t_1 - zc(.) + \frac{dH^{S*}}{dH^L}\left[-t_1 - z\int_0^{H^L}(c_2 - c_1)dx\right] = 0$$

The first part of the expression (u_1) is similar to the Cournot case, cf. (9). In addition, the local community takes into account the state's response on local forest clearing, $\frac{dH^{S*}}{dH^L} < 0$. In the case where state deforestation is costly to the local community (the land scarcity effect dominates), $u_2 < 0$ and the indifference curves are inverted U-shaped in the H^L-H^S diagramme, cf. (13). Compared to a Cournot game we have added a negative element in the optimality condition. Local forest clearing has become *less costly* on the margin because local deforestation reduces state deforestation, which both increase the forest income (t_1) and reduces the costs of agricultural expansion.

The Stackelberg equilibrium is presented in Figure 2. The local community's preference direction is south, and the equilibrium is given in point *B* where the local indifference curve tangents the state's response curve.

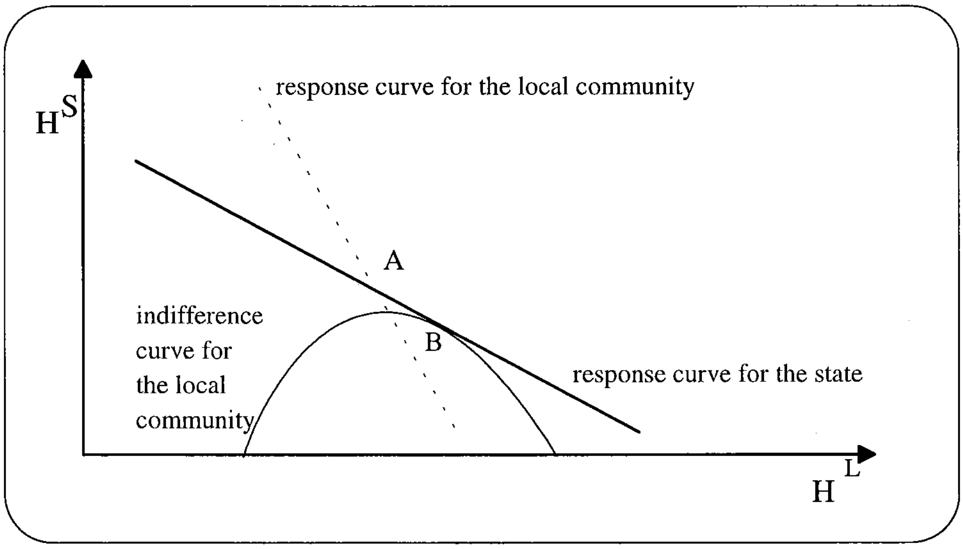

Figure 2: Local community as the leader in a Stackelberg game.

Compared to a Cournot equilibrium (A), the local community will clear more and the state less forest. The local community is aware of its strategic position as the leader, and uses it to "squeeze the state" from converting as much forest as the state would have done in a Cournot game.

A Stackelberg game with the local community as the leader gives more overall deforestation compared to a Cournot game as the absolute value of the slope of the state's response curve is less than one. The local community will receive a higher utility, whereas the state's profit will be lower in *B* compared to *A*. Note that the above results do not depend on the slope of the local response curve; hence the conclusions so far are valid both in situations where either income or substitution effects dominate.

Local response to higher state deforestation

The effect of an exogenous upward shift in the state's response function is found by differentiation of (15);

$$(16)\qquad \frac{dH^{L*}}{dH^S} = -\frac{u_{12}+\frac{dH^{S*}}{dH^L}u_{22}+\frac{\partial(dH^{S*}/dH^L)}{\partial H^S}u_2}{u_{11}+\frac{dH^{S*}}{dH^L}u_{21}+\frac{\partial(dH^{S*}/dH^L)}{\partial H^L}u_2}$$

$$= -\frac{t_{11}-z(c_2-c_1)-c(.)z_{H^S}+\frac{dH^{S*}}{dH^L}\left(t_{11}-z\int_0^{H^L}(c_{22}+c_{11})dx-z_{H^S}\int_0^{H^L}(c_2-c_1)dx\right)+\frac{\partial(dH^{S*}/dH^L)}{\partial H^S}\left(-t_1-z\int_0^{H^L}(c_2-c_1)dx\right)}{r_{11}+t_{11}+zc_1-c(.)x_{H^L}+\frac{dH^{S*}}{dH^L}\left(t_{11}-z(c_2-c_1)-z_{H^L}\int_0^{H^L}(c_2-c_1)dx\right)+\frac{\partial(dH^{S*}/dH^L)}{\partial H^L}\left(-t_1-z\int_0^{H^L}(c_2-c_1)dx\right)}$$

We assume the denominator to be negative (second order conditions for maximum). The numerator consists of three terms. The first term, which gives the Cournot response (u_{12}) can be either negative or positive. We showed in the analysis of case 1 that if both the infrastructure and the income effects are small, this effect is negative. We are now considering the case when the infrastructure effect is small, hence the sign depends on the strength of the income effect relative to the substitution effect.

The second term relates to the change in the local costs (benefits) of higher (lower) state clearing. Consider first the case when z is determined exogenously (small, open economy). For a given slope of the state's response curve, more state clearing implies that on the margin, state clearing is more costly to the local community. However, as higher local forest clearing reduces state clearing, this effect will push in the direction of higher local deforestation. The gain from squeezing the state is higher.

Then we must take into account that z will change in an autarky. As argued earlier, if the income effect is weak, then $z_{H^S} > 0$, and the second effect in (16) is unambiguously positive ($u_{22} < 0$). If, on the other hand, the income effect is sufficiently strong, the sign will change.

The third term relates to the changes in the slope of the state's response curve. From the assumptions made$\partial(dH^{S*}/dH^L)/\partial H^S$: determine the sign of this effect.
denotes the change in the slope of the response curve as one moves north. If this is negative, i.e., the response curve becomes steeper, the "state squeeze per hectare local forest clearing" is higher, hence the third effect is positive and this contributes to higher H^L following an increase in H^S.

Thus, we cannot in general determine the sign of (16). Intuitively, one could expect the first and most direct effect to dominate over the second and third. This will be the case if the slope of the state's response curve is close to zero (second effect small), and the slope of the state's response curves in the relevant region is relatively constant (third effect small).

In the case with *small income effects* the first effect is negative, the second positive, whereas the third is ambiguous. If we maintain that the first effect dominates the second and third, we conclude that higher state deforestation gives *less* local deforestation.

In the case when the *income effects are dominating*, e.g., the consumption is close to the subsistence level, the picture is reversed. In this case the first effect is positive and the second is negative. Now we could expect that higher state forest clearing also gives *more* local deforestation, as in case 1.

Empirical relevance

Two major conclusions emerge from the analysis of this case. First, compared to a Cournot game there will be more local and less state deforestation, and more overall deforestation. The local community gains and the state loses compared to a Cournot game. These results do not depend on the relative strength of the income and substitution effects.

Second, the local response to an exogenous increase in state deforestation is similar to case 1. If there are strong income effects, the result is more deforestation. More state deforestation reduces forest income, and the need to meet a subsistence target dominates in local decisions, thus agricultural land expansion will increase. If the income effects are small, or we are in the open economy case where only substitution effects apply, then more state deforestation implies less local deforestation, as local land expansion has become more costly.