Seeing the Forest and the Trees: A Spatial Analysis of Common Property Deforestation

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Abstract: The paper presents and tests a theory of the deforestation of common property forest over space. In contrast to previous deforestation theories, ours is structural, specifying which features contribute to the supply of potential agricultural land within a given community and which affect demand for forest conversion. The model shows how the location and the total amount of deforestation within a community are jointly determined. At the level of an individual plot of land of uniform distance and quality, the probability of deforestation depends upon its characteristics relative to those of other plots of land and the total deforestation demand. Aggregate community characteristics, like education, group size and inequality, work by shifting the total demand for forest conversion, which is also affected by the quality of the deforested land. We test this theory using data from 318 Mexican ejidos and find support for these hypotheses; within a given property, parcels of forest that are relatively closer, of lower slope and of lower altitude are at higher risk of deforestation. With regards to demand-side variables, we find the encouraging result that secondary education has a negative effect on overall demand for forest conversion. Demand is decreasing in inequality, which we measure using the Gini coefficient of private parcels within the ejido, a number which is established at the founding of the community. Further analysis shows that inequality operates by affecting both cooperation and individual incentives and that cooperation among small groups of members may decrease overall deforestation.

1 Introduction

The depletion of forests in developing countries, particularly tropical forests, has been of increasing concern to policymakers over the past 25 years. This focus has largely been due to the fear of biodiversity and carbon sequestration loss, although local negative externalities such as the effect the water supply and soil erosion are also worrying. The empirical literature on this topic is relatively recent, beginning with Chomitz & Gray (1996)'s work and increasing rapidly over the late 90s. The model they present, that of a profit-maximizing farmer who chooses to put a given piece of land into its most profitable activity has, with minor modifications, been the basis of many subsequent papers. Analysis at the pixel (see Puri & Griffiths (2001), D.K. Monroe & Tucker (2002), Godoy & Contreras (2001), Vance & Geoghegan (2002), Chomitz & Thomas (2003)) or municipal (Deininger & Minten (1999), Pfaff (1999)) level has been used to operationalize this approach, which generally takes the form of a probit of deforestation on physical attributes of a pixel, where municipal or household characteristics are sometimes included to control for their effect on land conversion demand. The current paper proposes to impose further structure on the subject by using a model of supply and demand for agricultural land within a community context. The community perspective is a more focused lens than that previously used to analyze deforestation, and this enables us to refine the prediction of deforestation to both where and how much forest will be lost in a given community. It also allows us to examine how the identity of these community members affects both the aggregate and individual deforestation decisions, and gives us some insight into how cooperation might change land use decisions.

According to the Mexican National Forestry Commission (CNF), 80% of the country's forests are located in *ejidos*, communities resulting from the post-Revolution land reform which hold their property as commons. Their large forest holdings make them a logical place to begin addressing the deforestation problem. In this paper we consider only those *ejidos* which do not have permits to extract wood for sale, about 80% of those that hold forests, because we believe that the dynamics of deforestation in commercial forestry *ejidos* are quite distinct from what we describe below. Our focus on the *ejidos* necessitates an approach that takes into account characteristics of the community which might change its land demand either through its effect on individual incentives or by modifying the collective action problem.

Our theory begins by recognizing that *ejidatarios* make deforestation decisions within the borders of their own land, not over the entire forested area of Mexico. This necessarily implies that they compare the quality of difference pieces of land in their community and decide whether or not they are better off leaving it in forest or converting it to pasture/agricultural land. They begin converting the parcels most profitable in agriculture first and then continue the process until they satisfy their total land demand. The implications of this theory are that what matters for the deforestation risk of a given parcel is not just its absolute quality or distance, but rather these characteristics relative to those of other parcels within the *ejido*. Furthermore, the demand for land is determined by the characteristics of potentially converted land (the supply) as well as the characteristics of the community that influence their collective land demand problem.

The inspiration for the model in the current study comes from two papers outside of the deforestation literature. These consider the problem of pollution distribution given heterogeneity in firms (Xabadia, Goetz & Zilberman (2003)), and location (Goetz & Zilberman (2003)) in a continuous time optimal control framework. Like these authors, we solve the problem in two stages, although due to the nature of our data and the small value-added of the dynamic framework for our problem, we limit ourselves to a static framework. First, we consider the optimal spatial allocation of land given a constraint on aggregate land demand. The second decision is, given the optimal use of land over space, how to allocate land into different activities. It is the solution of this second problem that is the constraint on the first.

We find that, indeed, it is the characteristics of a given parcel of land relative to all of the other hectares within a community that drive the spatial allocation decision. In particular, the probability of deforesting a given parcel is decreasing in relative distance, altitude and slope. On an aggregate level, these features are again important, with pasture demand decreasing with the average distance, slope and altitude of the deforested area. Increases in aggregate deforestation demand result in the conversion of increasingly less profitable, that is, more distant and lower quality parcels of forested land. Finally, we find, in contrast to Cardenas (2003) and Dayton-Johnson (2000) that inequality has a significant and substantial negative effect on overall deforestation demand.

At an individual level, analysis of the people who choose to use the commons reveals that they are more likely to: be older, have more young children, have been a leader in the community, and have secondary education. There is also a positive correlation between commons use and migration to the U.S.. Then we examine the hypothesis that a group within an *ejido* might cooperate, even in the presence of others that do not. We use land endowments and commons use to divide community members into potential cooperators and non-cooperators. This division reveals that potential deforesters are amongst the poorest in the *ejidos*, while potential cooperators are more likely to have been *ejido* employed off-farm and somewhat wealthier. A larger potential cooperating group has a negative effect on forest loss over the time period that we consider.

The remainder of this paper is organized as follows: we begin by describing the data and some key characteristics that motivate the design of our model. Section 3 describes deforestation in the *ejidos* using summary statistics. Section 4 presents a simple spatial/common property deforestation model, section 5 the empirical strategy and section 6 some preliminary results of the estimations. Section 7 analyzes the characteristics of community members who choose to use the commons and attempts to disentangle some of the community dynamics hidden in our general model. The final section concludes.

2 Data

The data come from a survey of 450 *ejidos* conducted throughout Mexico in 2002. The survey consisted of two sections, a community questionnaire and an indirect census. Basic characteristics of the community, forest exploitation and governance were collected. The second part of the survey was an indirect household questionnaire applied to 50 randomly chosen *ejidatarios*, where the information was collected from one key informant. It includes data about participation in government programs, household size, migration, age, employment, land and cattle-holdings, and use of the commons. Out of the entire sample, we use only the 323 communities with complete information that do not have forestry projects. It is our belief that communities that undertake active wood exploitation are subject to a different deforestation dynamic than those that do not (this dichotomy is detailed in Alix-Garcia, de Janvry & Sadoulet (forthcoming)).

The National Ecology Institute (INE) provided the National Forestry Inventories for 1994 and 2000. The inventories are based upon maps of scale 1:250,000 and 1:125,000, respectively. Though initially not comparable, the maps have been reinterpreted for comparability by the Institute of Geography at the Autonomous University of Mexico. The details of this process are described in Velasquez, Mas & Palacio (2002). Slopes and altitudes have been calculated using digital elevation models of scale 1:250,000, and soil maps provided by the National Ecology Institute at the same scale. Municipal data for 1990 and 2000 come from the National Institute of Statistics and Geography (INEGI), and state-level agricultural prices come from CIMMYT's online data base.

3 Stories with Statistics

3.1 Reasons for deforestation in *ejidos*

Table 1 shows summary statistics on deforestation. Although there were 323 *ejidos* not practicing forestry in the sample, because we are not interested in the behavior of large outlying communities, we cut 1% of the observations from each tail, leaving us with 318 communities. Overall increase in pasture land per community between 1994 and 2000 is 234 hectares, with a wide variance, and a substantial portion of the communities (41%), do not deforest at all, or have increases in their forest cover over the period. The total forest coverage in our sample in 1994 is 919,959 hectares, 73,848 of which are lost in the period between 1994 and 2000. According to the earlier forest inventory, 72% of the Mexican territory, or over 141 million hectares, is covered with forest. The overall deforestation rate in Mexico over this period is about 1.3% (Segura 2000), while in our sample it is about 1.4% per *ejido* per year.

See Table 1.

How does this deforestation happen and who decides that it will happen? In order to guide our thinking on this question, we actually asked the communities participating in our survey *why* they deforested and who made the decision. This question was not responded to by all participants, but rather only those that experienced deforestation, and even in these cases there were some non-responses. There were, however, sufficient responses for us to present some of them here. The answer to the first half of the question, why, can be seen table 2, where we see the “two main reasons” why a given area of the *ejido* was deforested between 1994 and 2000. Not all respondents gave two reasons (i.e. the columns do not add up to 200), but what is clear from the responses is that the expansion of agriculture and pasture land are the overwhelming source of forest conversion in these communities - 50% of respondents gave these as their main reasons for conversion. Forest fires comes in a distant third with 9%, and conversion from wood extraction is practically non-existent. This latter outcome results from the fact that none of these *ejidos* possess forestry permits, and hence their extraction is limited to wood for domestic use.

See Table 2.

For those who responded that agriculture and pasture were the main sources of land demand, we asked the further question of what were the two main factors that influenced this increased demand in both categories. For pasture demand, we see that the profitability of cattle herding dominates the drive for pasture expansion with 60%, followed up closely by the use of cattle for insurance with 48%. Agricultural expansion is driven both by profitability (43.1%)and by the need to parcel out land to existing and new members (28.4 and 36.5%).

See Table 3.

The last set of questions, the responses to which are shown in table 4, addressed who made the decisions regarding forest conversion. In both cases, the majority of respondents said that conversion “just happened”, suggesting a community choice not to explicitly regulate forest management. However, a sizable number of communities, 32% in the case of pasture and 48% for agriculture, also responded that permission was given by the community assembly.

See Table 4.

After the empirical section, we will revisit some of these responses in order to decipher what kinds of communities find themselves in these different categories. The first conclusion that we draw from these tables is that deforestation is driven by expansion of the agricultural frontier, not by wood extraction for sale. Furthermore, pasture expansion is the result of the profitability of cattle, as well as a need for insurance, while agricultural expansion comes from the need for more land for both existing and actual members, probably for subsistence requirements. Most importantly, however, we see that in a sizable number of cases, communities make a concerted decision to approve deforestation activities. Those communities where deforestation "just happens" have also made a conscious decision *not* to regulate conversion.

3.2 Physical characteristics

Here we consider the physical features of the parcels that *ejidos* choose to deforest. Table 5 gives us the ranks of deforested parcels as opposed to non-deforested parcels across the entire sample. "Pixel rank" refers to the rank of a pixel within a given ejido, with the lower rank being assigned to the pixel with the lowest distance, slope or altitude within the forested pixels of the ejido. Because each pixel is one hectare, this number gives the number of other forested hectares that have a value less than the observed pixel. Ties in the ranking are given the same rank. The rank reflects the number of one hectare parcels with distance, slope or altitude less than the corresponding value of the parcel in question. We also show the absolute value of distance from the nearest houses in kilometers, of slope in degrees and of altitude in meters. In all cases, we see that the deforested pixels are much closer, lower and less sloped that those that are untouched. In the empirical section, we spend some time comparing the predictive power of absolute versus relative measures within the *ejidos*.

See Table 5.

These tables suggest features that should be included in our model. In both the individual plot and overall deforestation levels, physical characteristics - slope, distance and altitude, have strong correlations with the deforestation decision. Table 4 tells us that a community decision making framework is required. Keeping in mind these facts, we move on to describe a general model of community deforestation over space.

4 Model

In discussing land clearing at either a plot or municipal level, the most commonly applied deforestation model is appropriate for the case where there is one landowner making a decision over one plot. In the situation where a group of people must decide what to do over a large, well-defined space composed of many plots, the model must be extended, which is the case we present in this section. We use this section to give a general intuition for the model and subsequent sections break down the aggregate into two parts that simplify interpretation.

As we discussed briefly in the introduction, the model contains two components, a description of allocation over space that depends upon land characteristics and prices of final goods, that one can think of as a sort of land supply for a given *ejido*. The second part is the choice of how much total land to convert from forest to pasture overall. This choice depends upon the "supply" of land within the community, as well as on feature that determine overall land demand. These are community features which affect members' demand for new agricultural land, and since we are in a common property, necessarily include features that affect collective action. The main outcome of the problem is that the decision of where to deforest depends upon overall demand, which is a function of community characteristics, and the individual features of each forested parcel relative to the other parcels in the *ejido*. Community demand additionally depends upon the aggregate physical characteristics of the deforested land in the community, which gives us a system of equations describing equilibrium deforestation for each community.

The next sections formalize this logic.

4.1 Spatial allocation

For the first stage we consider only the decision that is made over space - that is, what to do with a piece of land of with a specific combination of distance and quality characteristics, given that the community wants to convert particular amount of forest land into pasture. The notation and assumptions are as follows:

1. Each piece of forested land is characterized by quality q and distance d (transactions costs). Let $g(q)$ and $h(d)$ be the independent distributions of the forested land along these two characteristics.

2. Quality, distance, and prices determine an index of profitability of the forested land in pasture or agricultural production $\pi^p(p^p, q, d)$ and in forest production $\pi^f(p^f, q, d)$, where p^p and p^f are prices of pasture and forest products, respectively. Profitability in pasture is more sensitive to both land quality and distance, because of the frequent travel required to oversee animals or crops. Thus we assume $\frac{\partial \pi^p}{\partial q} > \frac{\partial \pi^f}{\partial q} > 0$ and $\frac{\partial \pi^p}{\partial d} < \frac{\partial \pi^f}{\partial d} < 0$ for all values of q and d.

3. Let $\delta_p(p^p, p^f, q, d)$ be the proportion of land q, d converted to pasture from the standing forest.

4. The optimal amount of conversion from forest to pasture is denoted C^p, given initial area in pasture written as T^p and forest T^f, with $T^p + T^f = T$.

Given these conditions, the optimal allocation of land over space C^p is the solution to the problem:

$$\max_{\delta^p} \int_0^d \int_{q_L}^1 [\delta_p(p^p, p^f, q, d)\pi^p(p^p, q, d) + (1 - \delta_p(p^p, p^f, q, d))\pi^f(p^f, q, d)]T^f g(q)h(d)dqdd$$

$$s.t. \int_0^d \int_{q_L}^1 \delta_p(p^p, p^f, q, d)T^f g(q)h(d)dqdd = C^p$$

$$and \leq \delta_p(q, d) \leq 1$$

The first order condition of the associated Lagrangian is:

$$\pi^p(q, d) - \pi^f(q, d) - \gamma = 0 \ \ \forall q, d$$

where γ is the is the Lagrange multiplier associated with the total conversion constraint. Since the function is linear in $\delta^p(p^p, p^f, q, d)$, the optimal allocation consists of corner solutions:

$$\begin{aligned} \delta_p(p^p, p^f, q, d) = 1 \quad &\Leftrightarrow \quad \pi^p(p^p, q, d) - \pi^f(p^f, q, d) \geq \gamma \\ \delta_p(p^p, p^f, q, d) = 0 \quad &\Leftrightarrow \quad \pi^p(p^p, q, d) - \pi^f(p^f, q, d) < \gamma \end{aligned} \tag{1}$$

where the threshold γ, that can be either positive or negative, is determined by

$$\int_0^d \int_{q_L}^1 \delta_p(p^p, p^f, q, d)g(q)h(d)dqdd = \frac{C^p}{T^f} \tag{2}$$

Hence land units are ranked by decreasing value of the differential potential for pasture and forest, and land with the highest relative potential for pasture, i.e., with better quality and closest to the village, will first converted into pasture. As the total demand for new pasture rises, the frontier moves towards more remote areas, possibly of lower quality. From this optimal spatial allocation of pastures, one can derive an index of marginal profitability for land converted to pasture by:

$$\overline{\pi}^p = \int_0^d \int_{q_L}^1 \delta_p(p^p, p^f, q, d)\pi^p g(q)h(d)dqdd = \overline{\pi}^p(h^c(\cdot), g^c(\cdot), p^p) \quad (3)$$

where $h^c(\cdot)$ and $g^c(\cdot)$ are the distributions of land quality and distance over the area that is deforested. This marginal profitability index is also a function of prices and a negative function of the share of the forested land that is to be converted to pasture. A similar expression can be written for the average profitability of the land remaining to forest.

4.2 Ejido level pasture allocation

In this section we consider the optimal choice of new pasture land in any given time period, given that this land will be optimally allocated over space. In the interest of not obscuring our point, we do not specify a specific way in which the dynamic within the community occurs, instead applying a simple "black-box" social planners problem. Both pasture and forest are sources of income. Write the additional income generated by new pasture as a function of the amount of land converted to pasture, C^p, the marginal profitability of that land, $\overline{\pi}^p$, the land previously in pasture, T^p, and the stock of cattle in the village, X^p (this may include other variables affecting revenue generation):

$$R^p = R^p(C^p, T^p, \overline{\pi}^p, X^p)$$

Similarly, the income generated by the remaining forest is function of land allocated to the forest, its average profitability, and some other characteristics, X^f:

$$R^f = R^f(T^f, \overline{\pi}^f, X^f)$$

The common property nature of the problem is captured by the function $\psi(Z)$, which ranges from ϵ to 1. When $\psi(Z) = 1$, this implies that the problem takes full account of the value of the public good - the forest. This is the case of full cooperation. Smaller values of $\psi(Z)$, which indicate that the entire value of the common property forest is not being taken into account, reflect lower levels of cooperation. This function is decreasing in community characteristics that negatively affect cooperation, such as group size, lower education, smaller land endowments and inequality. The optimal allocation of the total *ejido* land converted to pasture solves the problem:

$$\max_{C^p} R^p(C^p, T^p, \overline{\pi}^p(h^c(\cdot), g^c(\cdot), p^p), X^p) + \psi(Z) R^p(T^f - C^p, \overline{\pi}^f(h^c(\cdot), g^c(\cdot), p^f), X^f)$$

The solution gives a semi-structural equation:

$$C^p = C^p(+T, -T^p, +\overline{\pi}^p, -\overline{\pi}^f, +X^p, -X^f, +Z) \quad (4)$$

or in reduced form:

$$C^p = C^p(+T, -T^p, p^p, p^f, h^c(\cdot), g^c(\cdot), +X^p, -X^f, +Z) \quad (5)$$

To summarize, the choice of how much pasture to convert depends upon the profitability of the land converted and the profitability of land not converted, which themselves are increasing functions of quality and prices, and decreasing functions of distance. Pasture conversion is increasing with total land available and decreasing with the amount of already established pasture. The latter results from the decreasing marginal returns to pasture land. Characteristics which inhibit cooperation lower the value of standing forest to the *ejido* and therefore increase forest conversion.

5 Empirical Strategy

The theory suggests a system of equations. First, we can combine equations (1) and (2), which imply the use of a probit or logit at the level of a piece of land j of homogenous characteristics in *ejido* i.

$$Pr(\delta^p_{ji} = 1) = f(\text{Has land converted, Has of higher quality, Has at closer distance, Prices}) + \epsilon_{ji}$$

Recall that the hectares at closer distance and higher quality refer only to those hectares that are forested in the initial period. We use one hectare pixels as the unit of observation. To correct for the correlation between the unobservables of neighboring pixels, we use Conley's spatial covariance weighting matrix. These weights are based upon a non-parametric estimation of the covariance between observations that is a function of their distance from each other. We allow for spatial covariance within *ejidos*, not between. A detailed description of this technique is available in Conley (1999).

The equation above allows us to create proxies for the distributions of quality and distance of the deforested land, $h^c(\cdot)$ and $g^c(\cdot)$, that we need in order to estimate the *ejido*-level land demand. For the moment, we use the mean value of the pixels that are expected to be deforested:

$$h_i^c = \overline{d}^c = \frac{1}{\sum_j Pr(\delta_{ji}^p = 1)} \sum_j Pr(\delta_{ji}^p = 1) d_{ji} \tag{6}$$
$$g_i^c = \overline{q}^c = \frac{1}{\sum_j Pr(\delta_{ji}^p = 1)} \sum_j Pr(\delta_{ji}^p = 1) q_{ji}$$

Using (6), we can then get a reduced form for pasture/agricultural land expansion at the *ejido* level from (5) which depends upon the distribution of quality and distance, $h^c(\cdot)$ and $g^c(\cdot)$, the total area and pasture land area in the initial period, T, T^p, characteristics of pasture and forest production, X^p, X^f and community characteristics Z. It is worth noting that empirically, it will be impossible to tell which characteristics work through the collective action problem and which simply change overall land demand for other reasons. The estimation equation is then:

$$\text{Total deforestation } = \beta_1 \text{Quality and distance proxies} +$$
$$\beta_2 \text{Total area and pasture area, 1994} + \beta_3 \text{Community characteristics} + \mu_i$$

6 Preliminary Results

To clarify the difference between the current study and previous ones, it might be useful to first look at a few suggestive estimations. Table 6 considers a fixed-effect regression of deforestation on physical attributes as generally expressed in the deforestation literature, compared to the same regression in column two using relative values. The third column uses the residuals from the first equation to see if the ranked values are able to explain some of the remaining variation in the data. We see that the variables in column (1) are able to explain about 3% of the variation in the data, and that the relative characteristics explain about 4% of the variation. The third column is the most interesting, as it shows that the relative characteristics explain an additional 4% of the variation in the data after having run estimation (1), all of which is 'within' as opposed to 'between' variation.

See Table 6.

Table 7 shows the results for the pixel level regressions, where the dependent variable is equal to one if a given hectare area was deforested between 1994 and 2000. The first column shows the marginal effects from the reduced form probit, while the second shows a probit IV. The third column includes the absolute values of distance, slope and altitude to see how they affect the coefficients of the relative values. The coefficients have the expected signs - the probability of deforestation decreases in the rank of distance, slope and altitude, although the interaction terms are oddly positive. The effects are small even for large changes. We also see that holding constant the total forest area, demand for conversion increases the probability that any one pixel will be converted. In comparing estimations (2) and (3), we see that the relative distance effect dominants the absolute one, while including the absolute value of slope takes the power away from the relative measure. The price coefficients are not significant perhaps because, while we would liked to have had these prices at a local level, here they are only at a state level. This regression is interesting in the extent to which it verifies our theory. More interesting, however, is the movement of deforestation across space given changes in overall demand.

See Table 7.

Table 8 shows how increases in the predicted amount of deforestation changes the rank characteristics of the area deforested. The differences here are large and significant, indicating that as deforestation increases, it progresses to more remote areas of higher slope and altitude.

See Table 8.

A visual representation of this phenomena can be seen in figures 1, 2, and 3. The first figure shows the actual areas deforestd in an *ejido* in Chiapas between 1994 and 2000 in red. Houses are shown in black, while pasture in the base year is in yellow. The actual deforestation in this community was 543, while the predicted total value was 456. Figure 2 shows the predicted deforestation at a parcel by parcel level. The pink areas are forest at risk, with darker colors indicating higher probabilities of deforestation. Our model doesn't do too badly in locating the areas of forest loss, although it estimates relatively high risk near the houses in the southern part of the *ejido* where no deforestation actually takes place. Figure 3 simulates a 50% increase in predicted demand. Comparing these two figures we can see how an increase in overall deforestation increases the risk for areas close to the houses and those at lower altitude and slope.

See figures 1, 2 & 3.

Table 9 shows the estimation of the change in pasture demand from 1994 to 2000. In the data, 129 of the 318 ejidos do not increase their pasture demand. 101 of these had no change while the rest actually had reforestation. Physical variables are important in both significance and magnitude in determining pasture expansion. An increase of a thousand hectares in the total area of the ejido increases pasture demand by about 45 hectares. The effect of average distance to converted pixels is negative as expected, and large - a one standard deviation increase in distance decreases deforestation by 114 hectares. An increase of the same magnitude in slope decreases the area deforested by 312 hectares, while a similar increase in altitude decreases it by 127. The interaction term between altitude and slope is positive and positive, which is counterintuitive. It indicates that for a given altitude, an increase in slope actually increases overall deforestation. The f-test for significance of all of the physical variables has a p-value of .007.

With regards to the community level variables, an increase in the number of ejido members has a positive effect, with a one standard deviation increase in membership causing a 91 hectare increase in pasture expansion. We measure inequality using the Gini coefficient of private land parcels within the *ejido* - that is, the land division which was established at the founding of the *ejido*, where land and rights can only be passed on to one child. Changes in this variable have quite strong effects, with a one standard deviation increase in inequality decreaseing pasture demand by 71 hectares. One hypothesis for why this occurs might be that interest groups form to regulate the commons at high levels of inequality. A second possibility is that high inequality reflects an unequal distribution of constraints, which, at a given wealth level, causes users at the low end of the land-holding distribution to exploit less land than they would like, resulting in an overall decrease in deforestation even in the absence of cooperation (see Baland & Platteau (n.d.) for a thorough treatment of this argument). We will examine these hypotheses in a later section, though at this point it is important to note that this effect is significant even holding constant wealth - represented by municipal level marginality.

Figures 4 and 5 give a visual representation of the importance of community characteristics. The two *ejidos* pictured here are both around 9,000 hectares, with between 80 and 87% of the area forested in 1994. Their average altitudes and slope of forested areas are similar, though number 441 has more varied terrain. The most substantial difference between the two is their levels of inequality. 441 has as Gini coefficient of .42, and around 650 members compared to *ejido* 250's Gini of .23 and 212 members. Despite its lower membership, we see a much larger area at higher deforestation risk in *ejido* 250.

See figures 4 & 5.

A final community variable of interest is the proportion of households with secondary education, which has a negative and significant effect. It is important to note that these effects are significant even while holding constant the distribution of the initial level of poverty across municipalities (represented by the 1990 marginality index) as well as economic growth (represented by the change in the index from 1990 to 2000).

See Table 9.

7 Community behavior

Up to this point, we have maintained the "black box" model of community behavior, which is consistent with any number of collective action models and useful given that our unit of analysis is not the individual but rather the community. In this section we examine both community level data on governance as well as household level data collected in the survey and sketch out some of the ways in which these characteristics may affect overall deforestation. The first subsection analyzes some hypotheses about how inequality might affect participation and decision-making in our communities, while later sections analyze the individual characteristics of those using the commons.

7.1 Simple statistics on inequality

One of the most robust results in terms of the overall deforestation estimations is the negative effect of inequality on forest loss. As we saw above, changes in this variable have quite strong effects, with a one standard deviation increase in inequality decreasing pasture demand by 71 hectares. We also briefly discussed how inequality might operate through either the community's overall ability to cooperate or directly through household incentives. To see the latter, consider an example given by Baland and Platteau (2002) whereby inequality in the distribution of credit constraints among fishermen (at a given wealth level), even in the absence of cooperation, decreases the number of boats that they put in the water, increases the overall efficiency of the outcome as well as the incomes of even the poorest fishermen.

Given that our specification does not allow us to disentangle the cooperation versus incentive effects of inequality, this section is dedicated to using simple summary statistics to shed some light on this mystery by examining commons use, political participation and rule-making. The utility of undertaking this exercise comes in being able to draw relevant policy implications, which are clearly different in the two cases. Our data does not enable us to examine the levels of conversion of different members of the *ejido*, however, we can see who is using the commons and what they are using it for. Recalling that we measure inequality using land endowments, table 10 shows summary statistics on commons use for parcel owners in the upper and lower 20 percent of the parcel distribution for each ejido. We do not include here *ejidos* where the Gini coefficient for parcel distribution is equal to zero. The sample is also considerably smaller than that in our deforestation regressions because not all communities responded to this question.

If the incentive hypothesis above holds in our case, and those with relatively smaller holdings are constrained in their use of the commons, then we should see more intensive use of the commons by those with larger private landholdings. We have no measure of intensity, given that our questions merely asked if a member used the commons for agriculture, pasture, or both. However, livestock husbandry likely requires more land than growing corn for subsistence use, and so one might consider this use a proxy for higher appropriation. Table 10 shows some evidence in support of the Baland/Platteau hypothesis. In communities with low inequality, there is no difference between the lowest and highest quintile of landowners in their likelihood of not using the commons at all, while in high inequality communities, we see that the land poor have a significantly higher "non-use" than those with more abundant land. Also in the most unequal communities, it is much more common for land-rich households to have cattle or both cattle and agriculture in the commons than it is for those in the lowest quintile. There is no significant difference between these propensities in the more egalitarian villages, though the sample size here is quite small to be able to make an unequivocal statement. It is also useful to note that the lower deforestation in the high inequality communities does not result from their having fewer cattle - these villages have average sized herds of 9.1, as opposed to 5.5 for low inequality villages (t-test for difference = 3.4). Obviously, these numbers should be taken as suggestive, since we are not holding wealth constant here.

See Table 10.

The other possibility is that inequality works through the decision-making process of the community over the commons, which usually takes place in community assemblies headed by an elected council, are affected by inequality - this is the “Z”, or cooperation effect we discussed above.

Table 11 suggests that some mitigation of appropriation may operate through this mechanism. First, we see that more unequal ejidos are considerably larger that more egalitarian ejidos (as measured by the distribution of their parceled land) - on average 70 members larger. Normally, one would expect larger *ejidos* to have more deforestation, not less. We also see that less egalitarian *ejidos* seem to have a greater concentration of power in the hands of certain families or *ejido* members; on average, 41 percent of ejidatarios or their family members have been in leadership positions in these communities, while this number is 49 percent for those with lower inequality. In addition, participation in meetings is somewhat lower in the unequal communities, both by measuring the number of *ejidatarios* who always attend meetings (as measured by our census), and the proportion of members who attended the most recent meeting. It is interesting to note that if we look at participation according to the divisions presented in table 10, by land-holding quintile, we see that those in the lowest 20% of the land distribution always participate 63% of the time, while those in the highest 20% always participate 74% of the time (t-test for difference, 5.4). This combination of facts suggests that a relatively smaller proportion of ejido members are participating in the collective decision making process in unequal *ejidos*, and that this proportion is dominated by larger land holders.

See Table 11.

The above statistics imply that inequality in land distribution within the *ejidos* may operate through both mechanisms - directly by curbing the incentives of some to convert land and indirectly through the formation of a smaller group to manage the use of the commons. In the next section, we will provide some evidence that allows us to differentiate between the two effects.

7.2 Who uses the commons?

This discussion about the mechanism through which inequality acts does not give us a definitive idea about how exactly the community organizes itself to manage its forest resource. A myriad of game theories have been proposed to explain the management of common property resources, some of them even specific to the *ejidos.* One example is McCarthy, de Janvry & Sadoulet (2001)'s theory of costly cooperation, which hinges on the transactions costs of cooperating in pasture management.

A slightly different story is told in Alix-Garcia et al. (forthcoming), where instead of everyone cooperating at the same level, as occurs in most game theoretic models, subgroups of cooperators and non-cooperators operate simultaneously. In many villages, one observes a core group of households who seem to work together, setting and obeying rules limiting the amount of cattle in the commons or the wood extracted for domestic use. Moreover, this group exists despite the fact that there often are people around it who are not obeying the rules. This is the concept of a coalition of cooperators.

The intuition of the model is as follows. Households derive benefits from the forest. These benefits may vary across households and include current benefits such as firewood, house-building materials, and non-wood products as well as future benefits. Both current and future benefits depend upon the quality of the forest, accessibility, and its state at time zero. There may also be benefits from cutting the forest, or encroachment, which include profits from agriculture and cattle, or insurance from cattle. These benefits are decreasing with the size of parceled or private landholdings and increasing with family size, population pressure, and the quality of potential agricultural or pasture land. Finally, there is a cost to encroachment that encompasses the work needed to remove forest and the risk of punishment incurred from being caught encroaching.

The conditions derived from the model sort the households into three distinct groups as a function of land endowments, outside employment options, and the opportunities available on ejido land. These characteristics determine in which of three categories a household will derive the highest net benefits: those who have nothing to gain from encroachment, those who will always be better off encroaching than cooperating, and those who, as a group, will be better off cooperating than encroaching, even when others are encroaching.

The first group is comprised of households who have a low demand for common land because they either support themselves with outside jobs, have sufficient private land, or the potential agricultural land is too far away to make it worth the effort of going and clearing it. They accrue no gains from cutting down the forest, and potentially benefit from its continued existence. We call them "passive cooperators", as no incentive is needed to induce them to curb their deforestation activities. The second group is composed of households with high cattle to land ratios, or high household size to land ratios, or little chance of accessing future benefits from the forest (e.g., they may not be ejidatarios). They are better off cutting down more trees than not. For this reason, we label them "unrestrained encroachers".

The last group is composed of "cooperators." Cooperation gains are equal to the difference between a cooperator's benefits when he is part of the group that does not encroach on the forest (or clears at a lower level), and the benefits he would receive if cooperation broke down and all members of the group were to cut forest at their optimal individual level. These households have access to current and future benefits, with high costs to encroaching. While the structure of benefits makes these households prefer a cooperative solution, it is not sufficient to prevent individual defaulting at the margin on the group's decision. This is the usual incentive that leads to a non-cooperative equilibrium, even in the case of recognized benefits from cooperation. Sustainability of the coalition requires, as in most cooperation cases, an enforcement mechanism. The coalition of cooperators is thus composed of households that have voluntarily given themselves a mechanism of enforcement and punishment that prevents the unraveling of their collective choice. They typically commit to the cooperative encroachment level by a show of hands in the assembly. This type of mechanism is not unusual in developing countries (see Baland & Platteau (1996) for similar examples).

In what follows we would like to first describe the users of the commons, and then exploit this description to form a proxy for a cooperating group in order to see if a sub-group of "cooperators" can actually have an effect on overall deforestation. Although we do not know individual levels of deforestation (if we did, they would have been used in the previous section), we do know from our census if a given *ejido* member uses the commons for pasture or agriculture. The census is composed of a random sample of 50 members from each community. The regression shown in table 12 is a fixed effects logit equalling 1 if the member uses the commons for agricultural or pasture purposes and zero otherwise. This gives us a good deal of information about the people choosing to undertake activities in the commons. We find that the probability of use is negatively correlated with the size of their private parcel within *ejido* boundaries but that this relationship is insignificant. Older members who have had someone in their family as a leader in the *ejido* are more likely to use the commons, as are those with more young children. Strangely, those who have household members who have finished secondary school are also more likely to use the commons, though one might think that they would have better outside working options. It is interesting to note that those with secondary education on average have much larger cattle herds, 9 head, compared to those without, who have an average of 6 (t-test for difference = 4.9). We also see a positive correlation between having migrants in the United States and commons use. Here again we appeal to a cattle story. This positive relationship probably occurs as a result of the investment of remittances into cattle; the mean herd size for non-migrant families is 6, while for families with migrants it is 11 (t-stat = 9.5).

See Table 12.

Use does not equal deforestation, nor does non-use equal cooperation, which would involve farmers using commons land at a lower level than they would in a non-cooperative solution. We can, however, make some educated guesses about who might be more likely to use the commons more intensively (and therefore convert forest). If we make the assumption that those with smaller parcels are more likely to need more land from the commons then we can divide these *ejidatarios* into four groups along a continuum of likelihood to deforest. This division is described in table 13, along with labels which we described above. Encroachers are those with the most incentive to convert forest because they have a very small land endowment per household member. "Possible cooperators" have large land endowments, but use the commons anyways. "Passive cooperators" need not be passive, but are labeled in this way because they have large amounts of land and do not farm or put cattle in the commons. One might think of them as the potential cooperation leaders, as their main benefits come from using the standing forest. Finally "cooperators" are labeled as such because they seem to have a strong incentive to encroach (small land endowment), but do not do so.

See Table 13.

Table 14 summarizes some the other information we have on people in these categories. Here we see that encroachers are the poorest members of the *ejido*, as measured by their participation in Progresa, an educational subsidy program. The possible cooperators are not nearly as poor, but and high migration to the United States and large cattle herds. This latter fact gives them countervailing incentives: first, to manage the common pasture well because they have the highest stake in it, and second, to abuse the pasture more since they have the biggest need for it. Leaders are more likely to come from the "possible cooperator" group, though the differences across this variable are not very large. "Cooperators" are the most likely to have someone in their household working off-farm, have very small cattle herds and are the least likely to be receiving the maize subsidy program Procampo.

See Table 14.

In order to create a proxy for cooperation, we must use the predicted values of commons use rather than the actual ones. We combine these predicted probabilities with the categorization of members according to land class. Taking the mean of this calculation gives us the proportion of members that we expect to see in each group. In order to find the number of group members in the cooperation categories, we simply multiply this by the number of members in 1990. The next question is how these proxies affect deforestation.

Table 15 shows the correlation coefficient, regression coefficients and bootstrapped confidence intervals of the effect of cooperation group size on deforestation. These coefficients come from adding our proxy for the number of cooperators in each community to the deforestation regression of table 10. We create an upper bound for the encroacher group just as explained above. The lower bound is composed of just those who do not encroach and have no incentive to do so, the “passive cooperators”. We also include a possible upper bound on the non-cooperative group, which is the “encroachers” category plus the number of non-members in the community. We show only the coefficients of interest here, given that we have already examined the larger table. We find that the simple correlations all have the expected sign - negative for the lower and upper bounds on the size of the cooperation group and positive for the upper bound on non-cooperators. Once we put these into the regression, however, we find that a possible lower bound on cooperation has no significant effect on overall deforestation, although the point estimate is negative. The upper bound, however, has quite a large and significant effect–a one standard deviation increase in group cooperation size (189 members) would lead to an 142 hectare decrease in forest loss over the period. Finally, the upper bound on non-cooperation shows a positive though insignificant effect on deforestation.

See Table 15.

8 Preliminary conclusions

In the previous pages we have presented a theory of the deforestation of common property deforestation over space. In contrast to previous deforestation theories, ours is more structural, specifying which features contribute to the location of forest loss and which to the overall community level demand for forest conversion. One of the main implications of the model is that at the level of an individual plot of land of uniform distance and quality, the probability of deforestation depends upon its characteristics relative to those of other plots of land. Aggregate community characteristics work by shifting the demand for forest conversion, which also depends upon the characteristics of the parcels that are chosen for deforestation.

We tested this theory using data from 318 Mexican ejidos and found support for these hypotheses. Specifically, we see that within a given ejido, parcels of forest that are relatively closer, of lower slope and of lower altitude are at higher risk of deforestation. Given that the Mexican government is currently designing programs of payments in exchange for standing forest, one implication is that this payments should be higher for land within an ejido with these types of characteristics. Similarly, between ejidos, targeting should focus on those with large tracts of accessible forests on land of good quality for agriculture or pasture. We also find that expanding the agricultural/pastoral frontier into increasingly remote and highly sloped land has negative effects on the value of this land.

With regards to community variables, we find the encouraging result that secondary education has a negative effect on overall demand for forest conversion, providing further justification for the types of educational subsidy programs already in place in Mexico. Inequality also has an important impact on overall land demand. Our measure of inequality is inequality in the private parcels that are distributed to members at the founding of the *ejido*. These parcels can only be inherited by one family member. Using individual data, we see some evidence that inequality operates through constraints on those with smaller endowments, though it is also possible that it works through the formation of interest groups to manage the commons more efficiently.

We also spend some time analyzing the characteristics of the community members that use the commons, finding that older individuals who have been leaders, have migrants from their household to the U.S., have household members with secondary education, and larger families are more likely to use the commons. There is a positive correlation between education and cattle-holdings, as well as between migration and cattle-holdings, an effect that quite possibly has its roots in the use of cattle as a savings mechanism. This suggests that policies to support alternative forms of savings in rural areas could reduce deforestation.

When we divide community members into groups with potential to deforest according to their use characteristics and their land endowment, we find that those that are most likely to cooperate are the least likely to have been leaders, have the smallest cattle herds, do not receive subsidies for farming and are the most likely to have off-farm employment. Other likely cooperators have more frequently been in leadership positions and have high participation in meetings. Those most likely to convert forest to pasture or agriculture have medium sized cattle herds, are the least likely to have off-farm employment and are the poorest sub-group. We also find that larger cooperation groups are associated with considerably lower deforestion.

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9 Tables

Table 1: Summary Statistics on Deforestation, 1994-2000

Characteristic	Mean	SD
Number of *ejidos*	318	
Increase in pasture/ag land, 1994-2000	234	562
Percentage of *ejidos* with deforestation	59	

Table 2: Answers to question: "Why was this area deforested?"

Reason	Percentage positive responses	SD
For agriculture	50	(50)
For pasture	51	(50)
For wood	4	(21)
Forest fire	9	(29)

Table 3: Answers to question "Why did you decide to convert this land?"

Reason for pasture expansion	Percentage positive responses	Reason for agricultural expansion	Percentage positive responses
Good business	60.0	Good business	43.1
	(49.1)		(49.8)
Insurance	48.9	Land for existing members	28.4
	(50.2)		(45.3)
Bad quality of existing pastures	12.5	Land for children of members	20.4
	(33.2)		(40.5)
Land for new members	9.3	Land for new members	37.5
	(29.3)		(48.7)
Observations	96		88

Table 4: Answers to question: "Who decided to expand the pasture/agricultural land?"

Decision Maker	Pasture Expansion	Agricultural Expansion
Community Assembly	31.5	40.7
	(46.7)	(49.4)
Committee Decision	2.2	4.6
	14.6	(21.1)
Just Happened	65.2	54.6
	(47.9)	(50.1)
Observations	88	86

Table 5: Pixel Characteristics by Deforestation

Characteristic	Not Deforested	Deforested
Distance rank	5,949	2,987
	(8,187)	(6,324)
Slope rank	5,224	2,102
	(7,934)	(5,261)
Altitude rank	5,467	2,509
	(8,235)	(5,967)
Distance	8.3	7.8
	(3.7)	(4.0)
Slope	11.7	6.5
	(9.6)	(7.5)
Altitude	754	580
	(746)	810
Observations	821,426	111,407

Table 6: Fixed-effect regressions comparing absolute and relative characteristics

Dependent variable = 1 if hectare deforested between 1994-2000			
Characteristic	(1) Deforestation on absolute value of characteristics	(2) Deforestation on relative characteristic values	(3) Residuals of (1) on relative characteristic values
Distance	-.011	$-4.4x10^{-6}$	$-2.7x10^{-6}$
	(.0002)***	$(1.2x10^{-7})$***	$(8.6x10^{-9})$***
Slope	-.005	$-4.5x10^{-6}$	$-3.4x10^{-6}$
	(.0001)***	$(1.1x10^{-7})$***	$(7.7x10^{-9})$***
Altitude	-.06	$-3.1x10^{-6}$	$-1.8x10^{-6}$
	(.003)***	$(1.0x10^{-7})$***	$(7.1x10^{-9})$***
Distance*slope	-.0002	$2.1x10^{-10}$	$1.5x10^{-10}$
	(.00001)***	$(5.2x10^{-12})$***	$(3.6x10^-13)$***
Distance* altitude	.003	$1.4x10^{-10}$	$3.1x10^{-11}$
	(.0002)***	$(4.7x10^-12)$***	$(3.2x10^{-13})$***
No. parcels of lower slope and distance		$-3.1x10^{-6}$	$-4.0x10^{-6}$
		$(1.8x10^{-7})$***	$(1.2x10^{-8})$***
Constant	.27	.17	.16
	(.002)***	(.0007)***	(.00005)***
Observations	952,356	952,356	952,356
R-squared	.026	.038	.04

Robust standard errors in parentheses. *,**,*** represent significance at the 10, 5 and 1% levels.

Table 7: Pixel regressions

Dependent variable = 1 if hectare deforested between 1994-2000

Characteristic	Variable	(1) Reduced form	(2) IV	(3) IV plus
Pixel distance rank (/10000)	d	-0.03	-0.05	-0.03
		(0.02)***	(0.02)***	(0.02)*
Distance to houses in km				-0.003
				(0.002)*
Pixel slope rank (/10000)	q	-0.08	-0.08	-0.01
		(0.03)***	(0.03)***	(0.02)
Slope in degrees				-0.005
				(0.001)***
Pixel altitude rank (/10000)		-0.06	-0.06	-0.06
		(0.03)**	(0.03)***	(0.03)**
Altitude in meters				0.002
				(0.01)
Distance*slope rank (/1000000)		0.0005	0.0002	0.0003
		(0.0001)***	(0.0001)***	(0.0001)***
Distance*altitude rank (/1000000)		0.0001	0.0002	0.0002
		(0.0001)	(0.0001)**	(0.00001)**
Parcels with lower (/10000)		-0.10	-0.09	-0.06
slope and distance		(.03)***	(.03)***	(.03)**
Converted forest, 1994-2000 (1000s ha)	C^p		0.17	0.06
			(0.05)***	(0.02)***
Hectares of forest, 1994 (1000s ha)	T^f		-0.06	-0.08
			(0.03)**	(0.02)***
Total ejido area (1000s ha)	T	0.002		
		(0.001)		
Agricultural/pasture land, 1994	T^p	.002		
(1000s ha)		(0.003)		
Proportion of secondary forest, 1994	X^p, X^f	0.02		
		(0.04)		
Hours to town by bus		-0.01		
		(0.01)		
Average private parcel		-0.0003		
		(0.0003)		
Proportion of households with		-0.03		
secondary education		(0.03)		
Municipal population change, 1990-2000		-0.14		
		(0.57)		
Marginality Index, 1990		-0.02		
		(0.008)***		
Change in index, 1990-1995		0.0001		
		(0.03)		
Number of *ejidatarios*, 1990	Z	0.00001		
		(0.00002)		
Gini coefficient of private parcels		-0.12		
		(0.04)***		
Ejidatarios x Gini		-0.00004		
		(0.00007)		
Chile prices, 1993 (1000s pesos)	p^p	0.01	0.003	0.002
		(0.01)	(0.008)	(0.007)
Bean prices, 1993 (1000s pesos)		-0.02	-0.01	-0.005
		(0.02)	(0.01)	(0.01)
% growth bean prices		0.12	0.01	-0.03
1993-2000		(0.05)***	(0.06)	(0.05)
Observations		931,812	931,812	932193
R-squared		0.10	0.09	0.11
Log-likelihood		-305,386	-308,069	-301,995

Robust standard errors in parentheses. * significant at 5% level; ** significant at 1% level

Table 8: Changes in characteristics of deforested area with changes in overall deforestation

Characteristic	Variable	Actual forest loss	50% increase in forest loss	Doubling of forest loss	Ttest between (1) & (2)	Ttest between (2) & (3)
Distance Rank	$\overline{d}^c$	1,248	1,300	1,343	3.4	1.6
Slope Rank		989	1,054	1,146	5.0	3.9
Altitude Rank	$\overline{q}^c$	1,060	1,110	1,169	3.6	3.6

Table 9: First stage regression to determine overall pasture demand

Dependent variable = hectares in *ejido* deforested between 1994-2000

Characteristic	Variable	Coefficient	95% confidence Intervals	Mean
Total area of *ejido* (1000s ha)	T	45.4	(20, 76)**	3.9
			(5.9)	
Total ag/pasture land, 1994	T^p	-64.1	(-143, -10)**	1.0
				(1.7)
Mean distance to pixels	$h^c(\cdot), g^c(\cdot)$	-29.6	(-61, 1)*	8.3
with predicted deforestation				(3.8)
Mean slope of pixels		-18.88	(-39, 3)	9.3
with predicted deforestation				(6.4)
Mean altitude of pixels		-148.6	(-279, -49)**	.75
with predicted deforestation				(.85)
Distance*slope		0.34	(-2, 3)	73.3
				(59.0)
Distance*altitude		17.62	(2, 31)**	6.1
				(8.3)
Proportion of forested land	X^f, X^p	108.3	(-171, 290)	.24
in secondary forest				(.27)
Hours to pueblo by bus		-19.78	(-75, 22)	1.1
				(1.0)
Average private parcel size		-1.34	(-3, 4)	12.6
				(23.3)
Proportion of households		-240.0	(-381, -54)**	.53
with secondary education				(.26)
Municipal population change,		74.8	(-3,867, 3,739)	.015
1990-2000				(.013)
Marginality index, 1990		-25.6	(-85, 15)	-.13
				(.93)
Change in index, 1990-1995		-3.1	(-288, 219)	.09
				(.24)
Number of *ejidatarios*, 1990	Z	0.33	(-.33, .69)	153
				(275)
Gini coefficient of parcels		-395.9	(-818, -146)**	.25
				(.18)
*Ejidatarios**Gini		-0.90	(-2.4, .69)	41.8
				(101.3)
Bean prices, 1993 (1000s)	p^p	-78.5	(-173, 65)	2.5
				(.54)
Chile prices, 1993 (1000s)		9.8	(-46, 100)	2.7
				(1.1)
% growth in bean prices,		474.3	(-169, 888)	41.8
1993-2000				(101.3)
Constant		1,031.7	(411.1)**	
Observations		318		
R-squared		0.27		

Confidence intervals are bootstrapped 1000 times. *,** indicate significance at 10 and 5%, respectively

Table 10: Use of the commons in highest and lowest quintiles of landholding by inequality categories

Inequality		Do not use the commons at all	Have an agricultural parcel in the commons	Keep cattle in the commons	Have a parcel AND keep cattle in the commons
Low $\leq .24$	Lowest 20% of landholders	.24 (.05)	.10 (.03)	.14 (.06)	.09 (.02)
n=82	Highest 20% of landholders	.23 (.04)	.08 (.03)	.15 (.04)	.13 (.03)
	T-test for difference	1.1	.91	.31	1.6
High $> .24$	Lowest 20% of landholders	.28 (.03)	.16 (.03)	.11 (.02)	.06 (.02)
n=139	Highest 20% of landholders	.25 (.03)	.11 (.03)	.16 (.02)	.13 (.02)
	T-test for difference	2.0	3.4	3.0	4.6

Standard errors in parentheses

Table 11: Measures of participation by inequality levels

Variable	Low inequality	High inequality (Gini > .24)	T-test for difference
Ejido membership in 1990	118	188	2.3
Proportion of *ejidatarios* who always participate in meetings	.77	.66	3.5
Proportion of *ejidatarios* or their family who have been in leadership positions	.49	.41	3.0
Percent attendance at last assembly	81	76	1.1
Number of observations	160	160	

Table 12: Likelihood of using the commons
Dependent variable = 1 if use the commons for agriculture or pasture

Characteristic	Marginal Effect	Standard Error	Mean
Age of *ejidatario*	-.007	(.003)***	52
			(15.1)
Migrant in U.S.	.13	(.09)	.29
			(.45)
Has secondary education	.18	(.08)***	.49
			(.50)
Children less than 15	.07	(.03)***	.94
			(1.3)
Private land per capita	-.002	(.006)	3.9
			(10.4)
Has held leadership position	.63	(.08)***	.41
			(.49)
Observations	5,217		
Log likelihood	-2,268		

Conditional fixed effects logit.

Table 13: Likelihood of cooperating given commons use & land endowment

	Increasing likelihood of cooperating $\longrightarrow$			
Use the commons	yes	yes	no	no
Have > 1 ha land per capita	no	yes	yes	no
"Label"	Encroachers	Possible cooperators	Passive cooperators	Cooperators

Table 14: Characteristics of cooperating continuum

Characteristic	Encroachers	Possible cooperators	Passive cooperators	Cooperators
Always participate	78.8	67.2	71.0	61.4
in meetings	(40.8)	(46.9)	(45.3)	(48.6)
Have been leaders	40.3	42.5	40.6	29.9
(or family members have)	(49.5)	(49.3)	(49.1)	(45.8)
Number of cattle	5.8	13.7	6.6	1.5
	(12.0)	(27.8)	(24.6)	(6.2)
Receive Procampo	70.0	78.2	68.8	47.4
	(45.8)	(41.3)	(46.3)	(49.9)
Household member	24.6	30.7	29.0	35.8
has off-farm job	(43.1)	(47.5)	(45.4)	(47.9)
Have household	22.7	34.6	27.6	22.2
member in U.S.	(41.9)	(47.6)	(45.4)	(41.5)
Receive Progresa	61.1	48.8	54.1	53.8
	(48.5)	(50.1)	(49.8)	(49.8)
Observations	2,448	2,343	4,262	1,467
Obs (Progresa)	2,098	1,850	4,373	1,032

Table 15: Cooperation proxies and deforestation

Category	Correlation coefficient	Regression coefficient	95% Confidence Interval
Lower bound on cooperators	-0.08	-.34	(-1.5, 2.0)
Upper bound on cooperators	-0.12	-.75	(-2.3, -.20)
Upper bound on non-cooperators	0.04	.004	(-.02, .02)

Regression coefficients are marginal effect of proxy on total hectares deforested, 1994-2000, controlling for all the variables in table 10