An exploration of the positive effect of inequality on common property forests*

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Abstract: This paper analyzes the household level forces driving the positive impact of inequality on common property forest cover in Mexico. A game theoretic model demonstrates that when common property goods are complementary to private inputs in production, an increase in wealth inequality can lead to a decrease in exploitation of the commons. Data from 350 Mexican common properties show that as inequality increases, those on the lower end of the land distribution are less likely to use the commons. The data also show a negative correlation between inequality and poverty. Alternative hypotheses for these results are considered.

Keywords: inequality, collective action, deforestation, common property resources, wealth

JEL codes: D31, D63, O13, Q15, Q23

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1 Introduction

Empirical and theoretical analyses of common property resources have filled the pages of economic and natural resource management texts since the work of Hardin (1968). The results of these studies are particularly important for poor communities in developing countries, which are often dependent upon common property resources for their livelihood (Jodha 1986). Given that wealth is rarely distributed in an egalitarian fashion, understanding the mechanisms through which inequality effects the use of these resources is imperative.

There has been much debate on the role of inequality in solving collective action problems, with theoretical work suggesting that it can have either positive (Olson 1965), negative (Ostrom 1990), nonlinear (Dayton-Johnson & Bardhan 2002, Aggarwal & Narayan 2004), or ambiguous (Baland & Platteau 1997, Bardhan, Ghatak & Karaivanov 2002) effects on resource use. Empirically, Cardenas (2003) has found increased extraction of firewood from common property forests, and Banerjee, Mookherjee, Munchi & Ray (1997) show decreased economic efficiency in sugar cooperatives with higher inequality. Other authors (Dayton-Johnson 2000, Bardhan 2000, Molinas 1998) have found a U-shaped relationship between inequality and the provision of collective goods. In addition to the aforementioned empirical studies, there are two well-known books that take a case study approach to the topic and find that inequality can increase or decrease the efficiency of commons use (Ostrom 1990, Baland & Platteau 1996). Finally, a recent analysis of deforestation in Mexican common properties (Alix-Garcia 2007) shows less forest loss between 1994 and 2000 with higher inequality in private land distribution [1]. The last result provides the starting point for this paper.

The purpose of this study is to examine the household level dynamics behind the role of inequality in ameliorating the forest management collective action problem. In particular, this paper examines the identity of commons users in rural Mexico, where 80% of the forest is located in the commons. Mexico finds itself at the heart of the deforestation debate as it experiments with new policy options to regulate its high rate of forest loss, which at 1.3% per year is similar to that of Brazil (Segura 2000). This loss is

[1] Several papers from a 2001 Santa Fe Institute Workshop on inequality, collective action, and environmental sustainability show mixed results with regards to inequality and forest management (http://discuss.santafe.edu/sustainability/papers). The present paper is also related to the empirical studies of deforestation (a good review can be found in Barbier (2001)). It finds a place among the sub-group of authors concerned with common property forests in particular (Foster & Rosenzweig 2003, Ligon & Nairain 1999), though neither of these two consider the effect of inequality on forest use.

worrying on both global and local levels. Globally, forest loss results in biodiversity loss and the release of carbon dioxide, while local negative externalities include decreased water quality and increased soil erosion. The intention of this paper, therefore, is to understand the driving forces related to inequality that motivate the exploitation of the forest commons.

The paper begins by proposing an explanation for the observed positive impact of inequality on forest cover. This explanation is that when private inputs are complementary to inputs obtained from the common property forest, and when the household production function is concave, increases in inequality (holding constant wealth) reduce exploitation of the commons. In this situation, a mean-preserving spread of wealth will cause relatively poorer community members to decrease their use of the commons while wealthier members increase theirs, but not by a sufficient amount to compensate for the reduced use by the poor. I use household and community level data from 350 common property communities in Mexico, called ejidos, to test this theory and find that relatively poorer individuals in higher inequality communities are less likely to use the commons. In addition, the data show a negative correlation between inequality and poverty, a result consistent with the model.

Three alternative hypotheses for this result are discussed. First, it possible that the poor voluntarily limit their use of the commons because they are more dependent upon their preservation. Second, the result could stem from a concave forest production function rather than complementarity of inputs. In both cases the data provide evidence against these hypotheses. In the first case, the estimated negative relationship between non-agricultural income and the probability of commons use, suggesting that those with employment options other than farming are less likely to use the commons, undermines this alternative explanation. Higher investment in productive inputs and greater access to subsidies by the relatively wealthier suggest further support for the complementarity of inputs hypothesis. In the second case, the concavity of the forest production appears not to be sufficient to drive the inequality result. The third alternative hypothesis is that the wealthy actually prevent the poor from exploiting the commons; some circumstantial evidence against this possibility is also presented, and it is acknowledged that this effect might help explain the persistence of an inefficient distribution of inputs.

The paper proceeds as follows: Section 2 presents the theoretical model and Section 3 provides a description of the data, as well as documenting the relationship between the overall outcome of interest – deforestation – and the measure available at the household level – use of the commons. Sections 4 and 5 present econometric strategies and results. Section 6 examines alternative hypotheses and the final section concludes.

2 Theoretical framework

Previous work on deforestation in the Mexican commons estimates that higher initial levels of inequality lead to lower levels of deforestation, even holding constant the level of poverty and economic growth over the period. In Alix-Garcia (2007), a one standard deviation increase in the Gini coefficient of private land decreases forest loss by nearly 60 hectares (compared to an average forest loss of 234 hectares per ejido). This paper also tested for a non-linear effect of inequality on deforestation, but rejected a significant effect for a second-order Gini coefficient. The measure of deforestation in this paper was forest lost between 1994 and 2000, and the measure of land inequality was calculated using private land distribution prior to the 1992 land reform. The regression also controlled for a variety of community and municipal characteristics, including poverty, as well as physical characteristics of the land in question. The relevant results from the analysis, which in the original paper also considers the probability of deforestation within particular areas in the ejido, are shown in appendix 1.

This section proposes one possible explanation for the negative impact of inequality on deforestation – that common property is a complement to private inputs in the household production function, which, when the production function is concave, means that demand for commons land is increasing at a decreasing rate in wealth. The assumption of complementarity is particularly relevant for rural Mexico, where the forest commons are often converted to pasture or agriculture, both of which require private inputs to produce. The model presented here is based upon Bardhan et al. (2002), who show very generally how inequality affects use of a collective good through complementarities in production. For the case at hand, the collective good is common property in nature, so that there are negative externalities from individual exploitation.

The intuition is as follows: households use goods from the commons to produce output in combination with their private assets. In particular, they may graze their cattle on common property pastures created from the forest land. Alternatively, they might use labor or other agricultural inputs in combination with deforested common property land to produce cash or subsistence crops. An increase in an individual's private assets results in an increase in their demand for common property forest land. If the production function is concave, the demand for the commons is concave in wealth. An increase in inequality holding overall wealth constant means a decrease in a poor individual's wealth and an increase in a wealthy individual's. Because of the concavity of demand, the increase in the wealthy individual's extraction is less than the decrease in the poor individual's, so the aggregate outcome in terms of the common property forest is lower deforestation.

Consider the following formalization: There are n ejidatarios (members of the ejido) each of whom uses a purely private good k which is limited by the individual's endowment of this good, w, so $k \leq w$. the private good is used in conjunction with the common property land z in household production. Each household chooses to use the forest commons with effort level e. Let $E = \sum_{i=1}^{n} e_i$ denote the total extraction from the commons of all ejido members, where i indicates ejidatario i. Efforts aggregate into the common property good in the following way: $z = be_i - cE$, so there are negative externalities for increasing use of the commons. The household production function is the same for each household: $f(w_i, z_i)$, and household profits are $\pi_i = f(w_i, z_i) - e_i$. An individual household then takes as given the amount of effort chosen by other users and solves the problem:

$$max_{e_i \geq 0} \pi_i = f(w_i, be_i - cE) - e_i \tag{1}$$

The Nash equilibrium is given by n first order conditions:

$$f_z(w_i, be_i - cE)(b - c) - 1 = 0 \tag{2}$$

$$e_i \geq 0 \tag{3}$$

Using this condition, we can determine the optimal level of effort used by each individual:

$$e_i = \frac{g(w_i) + cE}{b},$$

which can be solved to obtain each ejidatario's reaction function:

$$e_i = \frac{g(w_i) + cE_{-i}}{b - c}. \tag{4}$$

If the following three assumptions hold:

1. $f(w_i, z_i)$ is a strictly increasing, strictly concave function that is twice continuously differentiable with respect to both arguments, $f_{wz} \geq 0$ for all (w, z), $lim f_z(w, z) = 0$ and it satisfies the Inada endpoint conditions,

2. $b \geq 0$ and $b - cn > 0$, and

3. $\frac{\partial f(w,z)}{\partial z}$ is strictly quasi-concave,

then the Nash equilibrium amount of common property land used in production, $g^N(w)$, is increasing and strictly concave in w [2]. These assumptions hold for many commonly used production functions in economics, including the Cobb-Douglas with decreasing returns to scale and the CES production function. Those for whom the marginal benefit of using the common property is less than the cost of doing so in terms of effort will choose not to use it at all.

The socially optimal level of extraction is determined by maximizing the sum of the individual profit functions.

$$max_{e_i \geq 0} \Pi = \sum_{i=1}^{n} f(w_i, be_i - cE) - E \tag{5}$$

which results in the first order conditions:

$$f_z(w_i, be_i - cE)(b - nc) - 1 = 0 \tag{6}$$

$$e_i \geq 0 \tag{7}$$

The difference between equations 7 and 3 is that the socially optimal equilibrium takes into account the negative externality that an individual's behavior imposes on the entire group, which is of size n. Given assumption (2) and the concavity of the production function, $g^*(w) < g^N(w)$, so the Nash equilibrium results in a higher level of commons use than is socially optimal.

The main question of interest here is the effect of a change in inequality on appropriation of the common property input z. Assume that there is a given distribution of $w = w_1, w_2, ..., w_n$, where the vector is sorted in order of decreasing wealth. Now suppose that there is a mean-preserving increase in the

[2] See Bardhan et al. (2002) for a rigorous proof of this statement.

spread of this wealth that creates a new distribution $\tilde{w}$ such that some users $k = m+1, ..., n$, have their wealth levels decreased while others, $r = 1, ..., m,$, have their wealth levels increased and the total amount of wealth in the community remains constant. Because the concavity of $g(w)$, $\tilde{z}_r > z_r$ and that $\tilde{z}_k < z_k$. This implies that$\sum_{r=1}^{m}(\tilde{z}_r - z_r) < \sum_{k=m+1}^{n}(z_k - \tilde{z}_k)$, in other words, extraction from the commons under w is greater than under $\tilde{w}$, so a mean-preserving increase in the spread of wealth results in a decrease in extraction from the commons. This decrease comes from the fact that under higher levels of inequality, the poor decrease their extraction from the commons while the rich increase theirs, but the increase in wealthy individuals' extraction is less than the poor's decrease. Another way to phrase the result is that when the poorer have less of the private input, w, they will demand less of the common property resource. Wealthier players, when they receive more of w, increase their demand for z, but since there are decreasing returns to its use, their increase in demand is less than the decrease in use of z by the poor.

A final interesting comparison to make is on total profits under perfect equality as opposed to a more unequal distribution $\tilde{w}$. This comparison depends upon the curvature of f as well as the magnitude of the private benefits from using the common property land (b) relative to the externality cost of appropriating that land (c). Those individuals who do not use the commons do not exert any effort in extracting from the commons, but they also do not use any of the commons as inputs into their production function, so the surplus of a non-user is given by:

$$\pi_i = f(w_i, 0) \text{ for } i = m+1, ..., n.$$

Using the first order conditions, one can write the surplus of those who use the commons as:

$$\pi_i = f(w_i, g(w_i)) - \frac{g(w_i) - cE}{b} \text{ for } i = 1, ..., m$$

The total amount of effort used in the commons, E, comes from summing up all of the individual efforts: $E = \frac{\sum_m g(w_i)}{b-cm}$. Combining these components results in the total surplus function:

$$\Pi = \sum_{i=m+1}^{n} f(w_i, 0) + \sum_{i=1}^{m} f(w_i, g(w_i)) - \frac{\sum_{i=1}^{m} g(w_i)}{b - cm} \tag{8}$$

The first term of this equation is the sum of concave functions and is therefore concave. Perfect equality amongst this group necessarily maximizes this sum. The sum of the joint profits of those who use the commons is more ambiguous, since the convexity of the externality term may overwhelm the concavity of the production function for larger values of $|c|$. In the particular case where all players use the commons under both perfect equality and under inequality, it may be the case that increases in inequality lead to increases in profits. A rigorous proof of this result is available in Bardhan et al. (2002). The intuition is that the joint profits function sums up individual profits less the externality effects of one player's appropriation on others' profits. This profit function is concave in the wealth distribution. However, joint profits also includes the total of the externality effects, a convex function. When the magnitude of the externality effects is large (a large $|c|$), this term dominates the effect of decreasing returns to scale in production, and total profits decrease with an increase in inequality.

This analysis leads to three hypotheses applicable to the ejido forest context:

1. In two ejidos with the same average level of wealth, an increase in inequality in one will decrease the level of forest extraction and conversion relative to the other.

2. Forest conversion in higher inequality ejidos will be lower for those on the lower end of the wealth distribution.

3. As inequality increases, overall profits *may or may not* decrease.

The first result provides a theoretical explanation for the negative correlation between inequality and deforestation in Alix-Garcia (2007). Testing the second and third are the purpose of this paper.

Note that the mechanism expressed results in an outcome which is the opposite of that generally found by the body of literature most commonly associated with Ostrom (1990), but also discussed in Baland & Platteau (1996). These authors find multiple cases where inequality harms collective action by weakening a group's ability to enforce rules regulating resource use. These incentives are more "social" in nature – one observes ostracism of rule-breakers, and in some cases other forms of punishments, including revoking use-rights of the commons. Field work by the author finds that these kind of pressures do exist in some ejidos – indeed, a previous paper (Alix-Garcia, de Janvry & Sadoulet 2005) proposed a model of partial cooperation for forest management in ejidos which do not sell wood. In the theory developed by this earlier paper, subgroups of ejido members restrain from deforesting, with the group's behavior enforced by social punishments, and there is no specific effect hypothesized regarding a members' *relative* wealth in the community. The model described in the present paper attempts to isolate the mechanism behind the empirical regularity that inequality decreases deforestation, but this model does not preclude the existence of other mechanisms that might also affect individuals' deforestation choices. One could easily generalize the production function described here to include individual and ejido-level characteristics that also affect individual's profits from felling the forest in favor of alternate sources of income.

Analysis of these hypotheses using cross-sectional variation in Mexican ejidos depends upon inequality operating on behavior *within* each community. Empirical support for this theory must go beyond the observation that those on the lower end of the wealth distribution *in the entire sample* use the commons less intensively; it requires that this happen to a greater degree in communities with higher levels of inequality. This could happen if wealthier individuals within ejidos have greater access to productive resources within the ejido. This could easily occur with production subsidies that are distributed through the governing body of the ejido, or if access to certain resources (such as credit) is limited to those with particular contacts outside of the ejido. Finally, although ejido land, which is used to calculate inequality in this study, cannot be collateralized by law, the possession of larger tracts of land may be correlated with ownership of other goods which can be used as collateral for loans.

3 Data and Summary Statistics

The data come from a survey of 450 randomly selected forest-holding ejidos conducted throughout Mexico in 2002. This paper uses only those ejidos in the sample which are not managing the forest for extraction of wood and which have complete household level data ($n = 350$). This is because organized wood extraction from the commons likely constitutes a unique community decision-making process, the modeling of which is beyond the scope of this paper (see Alix-Garcia et al. (2005)). The survey consisted of two sections, a community questionnaire and a household questionnaire. Respondents were three to four members of the community council, who are elected by popular vote. The community questionnaire collected basic characteristics of the community, as well as information regarding management of the commons. The household questionnaire, applied to 50 randomly chosen ejidatarios, was an indirect survey where 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 commons use.

The distribution of individual parcels within the ejido is used to calculate a Gini coefficient for each community. This measure has an advantage over other potential inequality measures because theoretically the land distribution was established at the founding of each ejido and is therefore not endogenous to later community decisions. There is some evidence that there has been informal adjustments of the original land distribution in the ejidos (see Munoz-Pina, de Janvry & Sadoulet (2003), however, the measure used in this paper gives the distribution prior to 1994, nearly ten yeras before the measure of commons access used here was taken. The median year of ejido formation in the sample is 1942. Private holdings outside ejido property, which are likely to have been acquired after the ejido's establishment, are not included in the calculation of the land Gini coefficient.

At an individual level, ejido land-holding is highly correlated with other wealth indicators. Table 2 shows correlations between parcel size and other wealth indicators. Larger parcel sizes are positively and significantly correlated with larger cattle holdings, vehicle ownership, and having a cement floor. They are negatively correlated with the receipt of Oportunidades, a program targeted at poor households, though not significantly so [3]. At the community level, a simple regression of the cattle Gini on the land Gini and a constant produces a coefficient of .19 (.07), and an R-squared of .02. This suggests that past inequality, as measured by the land Gini coefficient, is positively and significantly correlated with present inequality as measured by an important asset – cattle.

Insert Table 2 here.

Table 3 presents basic summary statistics of variables of interest at both the individual and community level.

Insert Table 3 here.

3.1 Deforestation and commons use

One key variable that the data does not contain is one that directly measures individual deforestation. Before presenting the empirical strategy and estimations, this section intends to establish the relationship between deforestation and the measure available at a household level – use of the commons. This categorical variable measures whether a household does not use the commons, uses them just for agriculture, just for cattle, or for both agriculture and cattle grazing. Aggregate statistics reveal that agriculture and cattle

[3]This program, begun in 1997, was initial known as Oportunidades. An thorough description of the program can be found in Levy (2006)

grazing are the main sources of deforestation in the ejidos. The 2002 survey showed that 50 and 51 percent of the respondents listed these as one of a maximum of two possible reasons for forest loss between 1994 and 2000. The other two possibilities on the survey – wood extraction and forest fire, received responses of 4 and 9 percent, respectively. It is important to understand that use of the commons is not equivalent in deforestation. Some ejidatarios may use the commons and not contribute to deforestation – many ejido commons include already established pastures and common agricultural areas in addition to forests. Furthermore, around twenty percent of ejidos report tree stealing by people from outside the community and various others complain of cattle incursions from neighboring herds. Because of these possibilities, it is important to measure the correlation between the use variable and deforestation.

Table 4 illustrates the relationship between different uses of the commons and deforestation. The first column contains the average percentage of ejidatarios using the commons by deforestation class. Subsequent columns show the percentage of users who exploit the commons for agriculture, cattle, or both. There seems to be a non-linearity between the percentage of users and the hectares of forest lost between 1994 and 2000. Those ejidos with very high deforestation have the same percentage of commons users as those with no forest loss. However, there is an increase in users from low to high deforestation levels (43 to 48 percent). If we consider the change from low to high deforestation, there appears to be a shift in commons use towards agriculture and away from cattle-grazing. The change from no deforestation to low levels of forest loss is associated with a *decrease* in the use of commons solely for agricultural parcels and an increase in its use for agriculture together with cattle herding.

Insert Table 4 here.

Table 5 shows the results from a simple regression of overall deforestation on the portion of households using the commons. The first column uses the whole sample and the second shows the same regression for the sample restricted to those ejidos where at least one person uses the commons. In both cases the coefficient is positive and significant. This corroborates the suggestion from the summary statistics that increases in commons use are positively and significantly related to deforestation.

Insert Table 5 here.

Finally, it is also useful to confirm that the relationship between inequality and deforestation observed in Alix-Garcia (2007) holds between the proportion of households using the commons and inequality. An OLS regression of average commons use on the Gini coefficient of land and various ejido level covariates, including total size, predicted proportion of the community receiving a subsidy for poor families, distance to nearest town, and regional dummy variables, gives a coefficient of -.26 (sd .12) for the Gini. This confirms that the relationship between inequality and commons use parallels that of inequality and deforestation.

In sum, one can be fairly confident that there is a significant relationship between the categorical household level variable of commons use and overall deforestation. The relationship between inequality and these outcomes is similar – both commons use and deforestation decrease with higher inequality. Forest loss increases in the percentage of ejidatarios using the commons, so one can feel comfortable that use of the commons as a 0/1 variable is a reasonable proxy for deforestation.

4 Who uses the commons?

This section proposes a test and presents results for the effect of inequality on commons use at the household level using the data collected in the indirect census. The theory suggests that intensity of commons use in higher inequality ejidos will be greater for the relatively wealthy. The measure of inequality is the Gini coefficient of the private parcels within the ejido, and the indicator of where an individual falls in this is the rank of their land holding within the village. This indicator is included in each regression in addition to the actual hectare value of their private land holdings because these two variables contain different information. The rank variable tells where an individual falls in the distribution independent of the size of their land holding; for example, two individuals in different ejidos may both hold 20 hectare parcels, but one may be the smallest and one the largest in his respective community. Including the actual size of the parcel controls for important commons demand-side effects associated with having land other than the commons for use in production.

The expected utility to household i in ejido j from deforesting the commons is:

$$U_{ij} = \alpha + X_{ij}\Gamma + R_{ij}\beta_1 + R_{ij}G_i\beta_2 + \gamma_j V_j + \epsilon_{ij} \tag{9}$$

where X_i is a vector of household characteristics affecting demand for commons use, V_j are either ejido level fixed effects or a vector of ejido level characteristics which might affect commons demand – including supply side characteristics. R is a variable indicating the track rank for the size of a household's parcel - that is to say, the smallest parcel in the community is given a rank of 1, the second smallest 2, etc. Parcels of the same size are given the same rank, and each rank is divided by the total number of observations in the community, which results in a relative rank. This last step is taken to remove any correlation between commons use and ejido size. This variable is then interacted with the inequality measure, G, which is the Gini coefficient of the parcels of land located within ejido boundaries. The vectors Γ, γ, and β are parameters to be estimated. The error term ϵ_{ij} is assumed to be normally distributed with mean zero and variance σ^2. We do not observe the latent variable U_{ij}, but only whether or not the individual uses the commons, C_{ij}, which takes on a value of one if they use the commons for any purpose, and zero otherwise.

$$C_{ij} = 1 \text{ if } U_{ij} > 0$$
$$C_{ij} = 0 \text{ if } U_{ij} \leq 0$$

This system is estimated using both a fixed effects linear probability model as well as a probit including ejido level covariates and standard errors clustered at the ejido level. A positive β_2 is consistent with hypothesis (2).

Alternatively, one can analyze the decision of different types of commons use using the categorical variable equal to zero for no use, one for agricultural use, two for livestock grazing, and three if both of these activities are undertaken in the commons. In this case, the utility of use k for individual i in ejido j is given by:

$$U_{ijk} = \alpha + X_{ijk}\Gamma + R_{ij}\beta_1 + R_{ij}G_i\beta_{2k} + \gamma_{jk}V_{jk} + \epsilon_{ijk},\ j = 0, 1, 2, 3 \tag{10}$$

The ejidatario i in ejido j makes the choice to engage in activity m in the commons when

$$U_{ijm} > U_{ijn} \text{ for all } n \neq m$$

This probability that an ejidatario chooses alternative k is then written as:

$$Prob(Y_i = k) = \frac{e^{\beta'_k x_i}}{\sum_{m=0}^{3} e^{\beta'_m x_i}}$$

The model is a multinomial logit, which is estimated below with the "no use" category omitted. This strategy requires the independence of irrelevant alternatives assumption (IIA), for which tests will be presented below.

4.1 Results

The simplest test examines whether or not a household uses the commons *for any activity*, rather than differentiating between possible uses. The results of the estimation of equation 9 are shown in Table 6. Column (1) shows fixed effects OLS results and column (2) the results from an OLS regression including ejido level covariates rather than fixed effects, with standard errors clustered at the ejido level. Column (3) gives the marginal effects from a probit with ejido level covariates and clustered standard errors. The fixed effects OLS estimator is used rather than the fixed effects logit since the former does not drop communities in which there is no variation in use (i.e., where everyone (31% of the sample) or no one (18% of the sample) uses the commons). (3) is included in order to provide a point of comparison for (1).

Insert Table 6 here.

For both estimates there is a non-linear effect of age on the probability of using the commons, with the probability increasing and then decreasing with age of the household head. This is not surprising, as one would expect household demand for goods from the commons to increase as family sizes grow and then decrease as children marry and possibly leave the house. Having a larger parcel or a non-agricultural job decreases the likelihood of commons use, as does having a larger parcel. However, the interaction of the Gini coefficient with the rank of the household's private landholdings is positive. This indicates that if we compare individuals in two different ejidos with the same level of inequality, the individual with the larger private landholding (i.e., the wealthier individual), is more likely to use the commons. Another way of stating the result is that a small increase in inequality has a negative effect on the probability of use, but this effect is diminished, and turns positive, the higher is an individual's land rank. This result is very similar to Cardenas (2003)' experimental evidence that relatively wealthier individuals in heterogenous groups chose higher extraction levels from the common property forest. In terms of magnitude, using the coefficients from the fixed-effects regression, the marginal effect of increasing inequality by one standard deviation for an individual with an average parcel rank is 3 percentage points.

The negative coefficient on land rank is initially puzzling – the theory predicts that those with higher relative wealth will be more likely to use the commons, all else held equal. However, one must keep in mind that the effect of land rank also depends upon its interaction with inequality. The marginal effect of a one standard deviation increase in rank in an ejido of average inequality is 1 percentage point. In an ejido with the highest level of inequality in the sample – .84 – this same increase in rank is associated with a 6 percentage point increase in the likelihood of commons use. There remains the question of whether to include insignificant terms in the calculation of marginal effects with interactions, and the land rank variable is insignificant in two out of the three regressions in this table and in various of the regressions in later tables in this paper. One interpretation of this lack of significance is that rank is only important in the way that it interacts with inequality.

Since for a large part of the included communities there is no variation in commons use, Table 7 shows results from the same specifications as in Table 6 with the sample restricted to communities within which there is variation in use. Since the results for most of the variables are quite similar, Table 7 shows only coefficients from the variables of interest: parcel rank, the Gini coefficient, and the interaction between the two. The fixed effects regression (1) shows coefficients of the same sign but of larger magnitude; in the entire sample, the coefficient on the interaction term is .36 while in the restricted sample it is .51. In the OLS regression including ejido covariates, on the other hand, while the signs of the coefficients are the same, none of them is statistically significant. Columns (3) and (4) show results from two different subsamples of this population: (3) is for ejidos with higher than average inequality and (4) for those with lower than average inequality, where average inequality is .249 [4]. Here the variable of interest is the rank of the private parcel: it is positive and significant in the high inequality sample, suggesting that those with relatively larger parcels are more likely to use the commons in high inequality ejidos. The coefficient is positive for low inequality ejidos, but not significant, which corroborates the prediction of the theory. The final column in the table shows fixed effects results for a regression that includes a dummy variable equal to 1 for ejidos with a Gini coefficient greater than the mean interacted with the parcel rank. Here again we see the predicted results – the effect of high inequality is an increase in the probability of use for those with larger parcels.

Insert Table 7 here.

A more nuanced approach examines the probability of engaging in the three different possible activities in the commons. Marginal effects from a multinomial logit using the categorical variable are shown in Table 8, with no use as the omitted category. Although only the key variables are shown, the estimation includes all of the covariates used in the probit above. Standard errors are clustered at the ejido level. The results

[4] Median inequality in the subsample is .26, and dividing the sample according to this number gave similar results. An alternative set of regressions dividing the sample into three equal-sized groups according to Gini coefficients showed significant land rank coefficients for the moderate and high inequality subsamples.

show that in two ejidos with the same level of inequality, the ejidatario with the higher ranked parcel will be more likely to engage in agriculture and in cattle grazing (relative to no use at all). Alternatively, as inequality increases, it results in an greater increase in the probability of use for those with higher ranked parcels. These results provide further evidence that the relatively poor use the commons less. Notice again that the effect of increasing the rank of one's private parcel is again only significant in its interaction with inequality. If one calculates out the marginal effect of increasing rank in an ejido of average inequality, even including the insignificant term, is positive, as the theory would predict.

Insert Table 8 here.

Interpreting these effects in light of the relationship between deforestation and the categorical variable, the inequality/rank interaction is of equal size (.35) for use of the commons for agriculture and for cattle. Recalling that the highest deforestation level is associated with a large proportion of the population using the commons for agriculture, this is consistent with the overall result that increases in inequality result in significantly lower deforestation, and that the less intensive use of the forest in high inequality ejidos may result from the fact that the poor are not deforesting in order to plant crops. Moderate levels of deforestation are associated with an increase in the proportion of ejidatarios using the commons for cattle, and the multinomial logit results show increases in use of the commons for cattle by the relatively wealthy in high inequality ejidos. It follows that at least some of the lower deforestation resulting from increases in inequality comes from relatively poorer ejidatarios not grazing cattle in the commons. These results corroborate the theory very well for cattle, which are clearly a good that can be used as a complement to common property land in production. The fit is not as clear for agriculture, perhaps because the required private inputs (fertilizer, seed, and labor) are not as expensive as cattle.

Table 9 shows results from both the Hausman and the Small-Hsiao tests for the independence of irrelevant alternatives. Unfortunately, the results of the tests suggest a violation of the IIA assumption. There are two other appealing alternative estimation strategies, the nested logit and the multinomial probit. The former option would require a natural partitioning into nests, to which the data does not readily lend itself. The latter case requires characteristics which differ across uses for each ejidatario which are not available in the data.

Insert Table 9 here.

5 Poverty and inequality

The previous section gives evidence that in more unequal communities, relatively wealthier residents are more likely to use the commons than poorer ones. This is consistent with the second hypothesis presented from the model. This final empirical section is intended to provide further support for the theory presented by showing some suggestive evidence for the third hypothesis – that poverty may be lower in ejidos with higher levels of inequality.

In order to test this hypothesis, poverty (P_j) in the community is assumed to be a function of inequality (G_j) and other exogenous community characteristics (X_j) – the size of the ejido, the proportion of households with members having completed secondary school, average private parcel size within the ejido, and kilometers to the nearest town. Poverty is also assumed to be dependent upon regional characteristics controlled for by dummy variables (D_r) for each of the 5 regions in Mexico.

$$P_j = \alpha + \beta G_j + \Gamma X_j + \sum_{r=1}^{4} \psi_r D_r + u_{jr} \tag{11}$$

A negative β is consistent with the theory. Since the data set does not include an wealth measure, the proportion of households possessing the proxies for poverty used in Table 2 – Oportunidades, cattle herd size, house with a cement floor, and vehicle ownership – are used as dependent variables. The equation was estimated using OLS with robust standard errors and the partial results of this analysis are shown in Table 10[5].

Insert Table 10 here.

The correlation between inequality and poverty is in most cases in the direction that one would expect were it to be the case that inequality decreases poverty – inequality increases the size of cattle herds and the percent of households with a cement floor, which are both indicators of wealth, and decreases the percentage of the ejido receiving Oportunidades. The correlation between inequality and cement floor is not significant, however, and the sign on effect of inequality on vehicle ownership is negative, though it is not close to statistically meaningful. In sum, the evidence regarding this hypothesis is not definitive,

[5]Not all of the communities are included in the second column, which contains only those where at least one household receives Oportunidades. This is because the Oportunidades indicator is only a good measure of relative wealth in communities which receive it – some villages were excluded due to distance from schools, so those villages where no one receives Oportunidades may either not receive it because they don't need it or because they are too remote.

though it taken as a whole, it does suggest a negative relationship between inequality and poverty.

6 Alternative hypotheses

The results of the previous section present evidence that in ejidos with higher land inequality, it is the relatively wealthier residents who use the commons more. The correlation between commons use and deforestation suggests that it then must be the wealthier residents within ejidos who are the source of forest loss in higher inequality communities. This is consistent with the idea of complementarity between private and common property inputs in the household production function, however, this is not the only scenario that could explain the result. Another plausible explanation for the result is that the poor restrain their use of the commons because they are more dependent on them for their livelihood than those on the upper end of the distribution, which gives them a large stake in the preservation of the resource. This possibility is discussed and formalized in Baland & Platteau (1997), who describe how this dynamic may occur in marine fisheries: as wealthier fishermen gain access to more effective technology that allows them to fish in deeper waters, they become less concerned when the local fishery is depleted. In the case of the ejidos, this dynamic could occur if the wealthy decide to deplete the forest commons when they have access to an alternative income source.

While there is no exogenous variation that allows for a test of the wealth-constrained versus self-restraint hypothesis, there are some facts which suggest that poorer ejidatarios, given larger inputs, might prefer to use the commons more rather than to preserve them. First of all, in all of the regressions shown in Table 6, the correlation between commons use and having non-agricultural income in the household is negative. Were the alternative hypothesis an adequate description of the Mexican ejidos, then we would expect this coefficient to be positive.

Household correlates between productive resources and private land holdings also suggest that productive inputs are lower for the relatively poorer. First, the size of private ejido land holdings is highly correlated with cattle holdings (see Table 2). Table 11 shows the coefficients from a simple fixed effects regression of various independent indicators of wealth and access to productive resources against land rank and a constant. The first column is cattle holdings, which reflect a current investment that could potentially be used to exploit the commons. It is strongly and positively correlated with rank. The second column has as a dependent variable whether or not a household has received Alianza para el Campo, a government program which includes a variety of production subsidies. Again, land rank is positively and significantly correlated with receipt of program funds. The final column shows the same results for Procampo, a subsidy for the production of maize intended to buffer farmers from the impact of NAFTA. Again, the coefficient is positive and significant. The magnitude and significance of these coefficients remains unchanged even when the actual size of an individual's parcel is included in the regression. All of these results together show that the owners of parcels that are more highly ranked have both made more significant productive investments and are more likely to receive production subsidies than others within their communities – i.e., they have higher levels of private inputs that can be used in conjunction with common property inputs.

Insert Table 11 here.

A second possible model, also proposed by Baland & Platteau (1997), which would give equivalent results to those presented here is a model in which the forest production function itself is concave, and where the only input to production is effort. In this case, a mean-preserving increase in inequality results in poorer members using the commons less while richer members use it more. As in the model presented here, the decrease in exploitation by the poor is less than the increase in exploitation by the rich, so when inequality increases, overall production goes up. This result relies on a very particular type of concavity – one in which overall production of the forest is concave, and that the level of use is so high that when some members decrease their exploitation, the marginal product from the forest increases. One can imagine a situation where increasing effort corresponds with moving onto decreasingly productive land, crowding of productive land which decreases its productivity, or increasing marginal costs of production. In the context of cattle herding, higher inequality might reduce the number of cattle grazing in the commons, allowing the land to regain its former productivity. A reduction in the number of cattle on the commons might also increase productivity by decreasing transportation costs, which would result in better herd management due to greater oversight. However, this sort of productivity gain seems most plausible in cases of very severe exploitation.

The survey does not contain any measure of forest productivity, however, one can measure overall poverty in terms of the percentage of the population receiving Oportunidades or owning the other two wealth indicators in the survey – a cement floor or a vehicle. If poverty depends upon income from the forest, and if forest production is concave in appropriation effort, one would expect that as effort increases, poverty would first decrease and then increase. For the indicators of wealth, one would expect to see the effect of increasing effort to first increase and then decrease wealth. In fact, there is some empirical support for this conjecture – a regression of the form of equation 11 including as additional regressors total cattle in the household data and total cattle squared reveals a u-shaped relationship. The same regression using average cattle herd size and herd size squared shows the same u-shape. Partial results from both of these regressions are shown in Table 12. The turning points in these relationships – ranging from 48 to 60 for average herd size and 867 to 1,200 for total herd size – are quite high relative to the averages across ejidos for these variables: 206 and 6, respectively. In actual fact, there are only two ejidos in the sample with average herd size greater than 48. The number with total herd sizes greater than the minimum turning point here is 20, though there are only 8 ejidos with a total herd size greater than 1,200. This suggests that reductions in use increase productivity when exploitation is quite high. This evidence is only very suggestive, however, given the endogeneity of cattle-owning to wealth, and the fact that poverty is related to, but not the same as forest productivity [6]. In addition, the cattle variable measures *total household holdings*, not number of cattle pastured in the commons, and is therefore an imperfect measure of effort.

Insert Table 12 here.

A final possible explanation for the household level results lies in the political realm. This is that as inequality increases, the wealthy use their influence in order to restrict the poor's access to benefit from higher productivity of the commons. In some ways, this is a variant of an Olsonian theme, though in this case the wealthy are providing more of the "collective good" – the forest – by restricting others' use of it rather than by limiting their own use [7]. This is not an implausible scenario, given Mexico's colonial history, and the way in which hierarchical power structures have persisted to the present. However, this argument assumes that there will be a large enough benefit from restricting access to the commons through the increase in productivity, an argument which relies, at least partially, on the same presumption as the previous alternative hypothesis – a concave forest production function.

Although the estimations above suggest that production may not be concave enough in effort to induce this sort of dynamic, it is likely that it plays a reinforcing role to the mechanism discussed here – perhaps powerful community members are the source of some of the correlation between wealth and receipt of government programs supporting production, for example. It seems unlikely, however, that the wealthy

[6] As above, not all communities are included in the Oportunidades regression.

[7] This possibility was suggested by participants in a seminar at the University of San Francisco.

directly try to restrict access to the commons. In fact, the evidence suggests that division of the commons through the 1992 land reform actually put more land in the hands of the poor than those of the wealthy. The 1992 reform implemented in 1994, allowed, among other things, a one-time only expansion of private parcels. The law that the forest remain in the commons was unchanged, though ejido members could have parcelized land which had been deforested at some previous time. Analysis of private land holdings from before and after the reform suggest those holding relatively smaller parcels prior to the reform received much greater increases in land, and that this reduced inequality in communities that chose to redistribute (Munoz-Pina et al. 2003). This finding implies that in one area where the wealthier members might exhibit control of ejido land – the redistribution during the land reform – they did so in favor of poorer members.

7 Conclusion

This paper began with the observation that an increase in land inequality in Mexican ejidos is correlated with a decrease in deforestation of common property forest. One potential explanation for this phenomenon is that increases in the inequality of private production inputs (wealth) reduce the poor's demand for commons land while increasing that of the rich. Because the rich do not increase their production enough to offset the decrease in commons use by the poor, the net result is that deforestation decreases.

Using household level observations from a 2002 survey of forest-holding ejidos in Mexico, it has shown that when inequality increases, the people who tend to use the commons less are those who are at the lower end of the wealth distribution, where wealth here is proxied by private ejidal land holdings. This proxy is strongly and positively correlated with other wealth measures in the data. The data also show a negative correlation between inequality and poverty, a result consistent with the theory. In addition, those with larger land holdings also make larger investments in livestock and are more likely to receive production subsidies. Though this evidence is far from definitive, it does suggest the complementarity of private and common resources.

Another potential explanation for the empirical results is that since the poor may depend more upon the commons for income, they restrict their own use in order to preserve it, while the wealthy overexploit the commons because their dependence on other income sources shortens their time horizon for commons use. The fact that the probability of using the commons is negatively correlated with off-farm income suggests that having alternative income sources actually decreases a household's use of the commons, which is the opposite of what one would expect were this hypothesis true. A model which predicts similar results relies on the concavity of the forest production function itself, and results in this paper suggest that this production function is not sufficiently concave to generate the increases in production from decreases in exploitation.

Because these results apply to within-ejido inequality, one must exercise caution in extracting broader policy conclusions. It is unclear how poverty and inequality alleviation efforts in Mexico might filter down to community-level inequality. Depending upon how targeting occurs, such efforts may or may not increase deforestation within communities. This paper, however, provides suggestive evidence that providing off-farm employment opportunities could help preserve common property forests.

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8 Appendix 1

Table 1: OLS Estimation of Deforestation from Alix-Garcia (2007)

Dependent variable = hectares in ejido deforested between 1994-2000

Characteristic	Coefficient	Mean
Total ejido area	42.9	3.9
	(11, 75)**	(5.9)
Total ag/pasture land, 1994 (1000s ha)	-71.9	1.0
	(-16.3, -1.2)**	(1.7)
Mean distance to pixels with predicted deforestation	-17.9	8.3
	(-28.7, -3.4)**	(3.8)
Mean slope of pixels with predicted deforestation	-7.6	9.3
	(-21, 11)	(6.4)
Mean altitude of pixels with predicted deforestation	57.9	.75
	(-32, 146)	(.85)
Standard deviation of distance	17.4	1.3
	(-23, 61)	
Standard deviation of slope	-27.6	5.9
	(-60, -7)**	
Standard deviation of altitude	-180.2	.09
	(-1,125, 608)	
Hours to pueblo by bus	-1.13	1.1
	(-72, 7)	(1.0)
Average private parcel size	-1.42	12.6
	(-3.4, 2.7)	(23.3)
Proportion of households with secondary education	-189.4	.53
	(-326, -27)**	(.26)
Marginality index, 1990	-62.9	-.13
	(-114, -5)**	(.93)
Number of ejidatarios, 1990	.50	153
	(.08, 90)**	(275)
Gini coefficient of parcels	-323.2	.25
	(-535, -72)**	(.18)
Ejidatarios*Gini	-.92	41.8
	(-2.3, -.02)**	(101.3)
Number of non-members, 1990	-0.07	143.5
	(-.13, .03)	(633)
State level bean prices, 1993	-.18	2,476
	(-.29, -.06)**	(541.5)
Yucatan region	557.5	.10
	(103, 885)**	
Southern region	224.3	.29
	(58, 348)**	
Observations	318	
Adjusted R-squared	0.23	

Confidence intervals are computed by bootstrapping 1000 times. ** indicates significance at the 5% level. These are partial results. The estimation also includes the interaction of slope and distance, the interaction of altitude and distance, the proportion of forested land in secondary forest in 1994, ejido hectares per ejidatario, municipal level population growth, change in the municipal marginality index, chile prices (1993), the growth in bean prices (1993-2000), and a constant, none of which are significant. There are also 6 regional dummy variables, of which the two significant ones are shown.

9 Tables

Table 2: Correlations between wealth indicators and private ejido parcel

	Dependent Variable			
	Cattle holdings	Owns vehicle	Receives Oportunidades	Cement floor
Parcel size in hectares	.413	.002	-.0007	.002
	(.016)***	(.0003)***	(.0004)	(.0003)***
Observations	11424	11424	8872	11356
R-squared	.054	.005	.0003	.004

These OLS regressions include a fixed effect at the ejido level and a constant.

Table 3: Basic Summary Statistics

Variable	Mean	Standard Deviation
Household variables		
Household uses the commons	.47	.50
Intensity of commons use (No use = 0, Agriculture = 1, Cattle = 2, Both = 3)	.88	1.1
Age of household head	52	15
Household head is a new member	.19	.39
Number of children > 15 at home	.95	1.3
Individual parcel size in hectares	11.4	22.2
A household member has secondary education	.49	.50
Own a vehicle	.33	.47
House has a cement floor	.71	.45
Observations	11,068	
Ejido variables		
Number of members in 1990	159	291
Gini coefficient of parcels	.25	.20
Kilometers to nearest town	37.3	39.6
Observations	346	

Table 4: Use of commons by deforestation class

Forest loss 1994-2000(ha)	% households using commons	% use from just agriculture	% use from just cattle	% use from agriculture & cattle
<= 0 n=136	48.2	35.8	45.5	18.7
0<200 n = 102	43.3	27.5	40.7	31.8
>=200 n=106	48.7	48.3	28.7	23.0

Table 5: Relationship between overall deforestation & average commons use
Dependent variable = hectares deforested 1994-2000

	Full sample	Ejidos using commons
% households using commons	2.51 (1.35)*	4.15 (2.1)**
Observations	328	212
R-squared		

These OLS regressions include a constant term.

Table 6: Correlates of commons use
Dependent variable = 1 if use, 0 if no use of commons

	Fixed Effects (1)	OLS (2)	Probit (3)
Age of household head	.0006 (.001)	.003 (.003)	.004 (.004)
Age squared	-2.13e-06 (9.73e-06)	-.00003 (.00003)	-.00003 (.00003)
New member (0/1)	-.020 (.021)**	-.017 (.078)	-.018 (.083)
Number of children over 15	.003 (.002)	.011 (.007)	.012 (.018)
Size of parcel in hectares	-.001 (.0003)***	-.001 (.0005)**	-.001 (.0005)**
Rank of parcel	-.044 (.021)**	-.109 (.078)	-.114 (.083)
Household has non-agricultural income (0/1)	-.015 (.007)**	-.018 (.009)*	-.018 (.010)*
Household with secondary education (0/1)	.012 (.006)**	.006 (.009)	.006 (.010)
Gini coefficient		-.072 (.198)	-.070 (.108)
Rank*Gini	.362 (.059)***	.562 (.273)**	.591 (.290)**
Observations	11172	11068	11068
R-squared	.012	.099	
Pseudo R-squared			.073

Estimations (2) and (3) also include ejido level covariates: average age of household head, average land rank, number of new members, parcel size, households with secondary education, households with non-agricultural income, households with migrants to the U.S., number of members, and ejido size in hectares.

Table 7: Effect of inequality and land rank on use: restricted sample
Dependent variable = 1 if use, 0 if no use of commons

	Fixed Effects OLS (1)	OLS (2)	OLS Gini > .28 (3)	OLS Gini ≤ .28 (4)	Fixed Effects OLS (5)
Parcel rank	-.035	-.007	.202	.049	.068
	(.052)	(.116)	(.071)***	(.048)	(.043)
Rank*Gini	.511	.443			
	(.129)***	(.376)			
Gini coefficient		-.375	-.331	-3.379	
		(.234)	(.319)	(.970)***	
Rank*High Gini					.101
					(.234)**
Observations	4771	4750	2441	2309	4750
R-squared	.02	.075	.132	.157	.02

All estimations include head of household age, age squared, if household head is a new member of the ejido, parcel size in hectares, number of children over 15, if the household has non-agricultural income, and secondary education. Estimations (2), (3), and (4) also include ejido level covariates: average age of household head, average land rank, number of new members, households with secondary education, households with non-agricultural income, households with migrants to the U.S., number of members, and ejido size in hectares.

Table 8: Effect of inequality and land rank on use: multinomial logit
Dependent variable = 0 if no use of commons, 1 if agriculture, 2 if cattle, 3 if both

Variable	Pr(agriculture)	Pr(cattle)	Pr(both)
Rank of private parcel	-.13	-.05	.04
	(.09)	(.04)	(.04)
Gini Coefficient	.015	-.23	.03
	(.12)	(.10)**	(.13)
Rank*Gini	.35	.35	.09
	(.22)*	(.12)***	(.14)
Observations	11,068		
Log pseudolikelihood	-11,153		

The columns contain marginal effects. These are partial results of a multinomial logit including household and individual level covariates: age of household head, age squared, new member, number of children over 15 living at home, parcel size, if household has non-agricultural income, if household has secondary education, number of ejidatarios in 1990, ejido size in hectares, average land rank, average age, regional dummy variables, and proportion of households with secondary education, new members, migrants, non-agricultural income, vehicles, and cement floors.

Table 9: Tests of IIA assumption

Omitted Category	Hausman	Evidence	Small-Hsiao	Evidence
1	-2.955	for H0	-3299.8	against H0
2	-.394	for H0	-3546.5	against H0
3	-3.178	for H0	-3542.7	against H0

H0 is that IIA holds.

Table 10: OLS regressions of poverty indicators on inequality

	Dependent variable			
	Cattle herd size	% households receiving Oportunidades	% households w/ vehicle	% households w/ cement floor
Gini coefficient of parcels	5.137	-22.370	-1.954	8.986
	(2.604)**	(7.890)***	(5.953)	(8.585)
Observations	346	274	346	345
R-squared	.201	.173	.407	.194

These are partial results. Other covariates include the size of the ejido, the proportion of households with members having completed secondary school, average private parcel size within the ejido, kilometers to the nearest town, and 4 regional dummy variables. Standard errors are heteroskedasticity robust.

Table 11: Correlation between parcel rank and receipt of production subsidies

	Dependent Variable		
	Cattle herd size	Receive Alianza	Receive Procampo
	(1)	(2)	(3)
Parcel rank	11.3	.166	.282
	(.69)***	(.021)***	(.014)***
Observations	11424	4079	10571
R-squared	.02	.016	.038

These regressions also include a fixed effect at the ejido level and a constant.

Table 12: Correlations between poverty measures and cattle holdings

	Dependent Variable = proportion households that					
	receive Oportunidades		own a vehicle		have a cement floor	
	Total	Average	Total	Average	Total	Average
Herd	-.031	-.95	.029	1.44	.026	.88
	(.01)**	(.36)**	(.008)**	(.24)***	(.01)***	(.28)***
Herd^2	.000016	.01	-.000012	-.012	-.000015	-.008
	(4.8 x 10^{-6})**	(.004)**	(4.8x10^{-6})**	(.003)***	(6.1x10^{-6})***	(.003)***
Turning point	969	48	1208	60	867	55
R-squared	.17	.17	.43	.48	.20	.21
Observations	275	275	346	346	346	346

Note columns (1) and (2) contain observations from only communities where at least one household receives Oportunidades. Standard errors are heteroskedasticity robust.