Deforestation in the Commons: A Village Level Approach

Jennifer Alix
ARE 298

Advisor: Elisabeth Sadoulet

Introduction

Over the past 20 years, Mexico's forest cover has decreased by over 50%, with rates of deforestation second in the world only to Brazil[1]. Although many countries have devastating deforestation rates, the Mexican forests are in the unique situation of being located almost entirely in common property lands. This paper proposes a model of deforestation appropriate for the common property situation and then tests it using a combination of survey, remote sensing and geophysical data.

Literature Review

Economic analysis of deforestation has experienced a boom in recent years. According to a review by Kaimowitz and Angelsen (1998), over 90 percent of the models available have been developed since 1990. Current models range from macro-level trade and commodity characterizations to household firm analyses. "First wave" models tended towards cross-country analyses, while those belonging to the "second wave" include more micro approaches (see Barbier, 2001). This paper finds itself within the latter group.

The micro approaches have been fruitful in pinning down the effect of distance, prices, and particular production processes on land use change. Walker (2000) applied a household modeling approach to look at the difference in land-clearing activity between small and large farmers, while Cropper et al (2001) used a cross-sectional pixel level analysis which showed the detrimental impact of road-building on forest loss in Thailand. Deininger and Minten's (2001) analysis of Mexican forests estimate the effect of municipal level variables on deforestation. They found that the presence of parks, rural extension, and highly sloped areas significantly decreased deforestation. Community data were not incorporated into these analyses.

---

[1] Market Report, April-May 2001, U.S. Forest Product Industry, Mexico Office.
http://www.afandpa.org/products/International/MR_Mexicomay01.pdf

The current study proposes to fill this gap. In particular, it intends to use the case of Mexican common property regimes (heretofore referred to as *ejidos*) to study the effects of cooperation and governance on land use change. *Ejidos* are a land tenure structure resulting from the distribution of land to groups of people for cooperative management in the wake of the Mexican Revolution. In effect, they are composed of two different kinds of land: private parcels and commons. Private land is mostly dedicated to agricultural activities and is subject to trade or sale between members of the community (*ejidatarios*). In some regions, particularly Chiapas and Oaxaca, parts of the commons are used in slash and burn agriculture. In general, however, they commons are dedicated to pastoral activities and frequently contain forest. In fact, they house over 70% of Mexico's remaining forest, and for this reason they are the focus of this study.

There is a vast theoretical and case study literature describing the role of groups in common property resource (CPR) management. The case of natural resource degradation and community management has been given a particularly careful treatment by Baland and Platteau (1996), who use both game theory and case studies to show how higher levels of cooperation in village communities may lead to less resource degradation. The general discussion indicates that incentives to overexploit CPR can be affected both by individuals' opportunity costs and socio-cultural community characteristics (see McCarthy, 1996, for insight into this case for pasture maintenance). Other authors have identified well-defined boundaries and membership (Ostrom, 1992), fewer members (Olson, 1965), trust capital (Seabright, 1994; Bardhan et al., 2001), outside opportunities (Bardhan, 1992) and enforcement as fundamental determinants of cooperation. Although much intuitively appealing theory has been developed in this area, rigorous empirical studies are difficult to come by, largely because of the lack of sufficiently large number of observations at the community level. The present study shares this problem.

The model

The majority of the economic modeling of deforestation uses a profit-maximizing individual who must make a decision between keeping the forest on a particular plot of land or cutting it down. We shift our perspective to the community level, where the socially optimal situation is one where the community maximizes profits given the characteristics of their land, input and output prices, as well as a cost function reflecting the payoffs that must be made to guarantee cooperation in the management of their land.

The cooperation cost function merits further discussion. We consider cooperation here to be an input to production. Cooperation in the ejidos might take the form of actively exploiting either forest or pasture resources in groups. While much of game theory models cooperation as an all or nothing endeavor. Cooperation here is a continuum, with the highest level being the optimal extraction or stocking rate for forest or pasture. The lowest level of cooperation results in a "tragedy of the commons" outcome, and *ejidos* can also be found at any point in between these two extremes.

The concept of costly cooperation is based upon McCarthy, de Janvry and Sadoulet's (2001) paper regarding pasture management in Mexican *ejidos*. The cost of cooperation in their case follows the game theoretic 'best deviation' framework, whereby a participant in the commons will cooperate if it is a best response to do so. The best deviation is what the individual would make given that everyone else in the community cooperates and he chooses to go it alone. Monitoring and enforcement of particular extraction schemes help decrease this incentive. To this end, the community determines their management (cooperation) choice by implementing particular punishment schemes.

In the case at hand we deviate in two ways from McCarthy, de Janvry and Sadoulet. First, we do not specify a function form, using instead a general cost function dependent on two main variables. The first variable represents our second modification; it is the sum over all community members of the "most costly" deviation. The logic behind this is the following: In ejidos, there is almost never a differentiated splitting rule for profits made in community activities. Because of this, we must be sure that the average share is greater than the highest possible deviation for the whole group. In the event that it is not, cooperation unravels, as that highest person will deviate, productivity will decrease and shares will decline, driving more members to deviate. According to this logic, group size would then raise the cost of cooperation. In addition, following the Olsonian line of thought, larger groups are more difficult to manage.

The second component of the cost function is a vector of "shifting variables" included in order to take into account community characteristics which might make cooperation more difficult, such as inequality, "trust capital", and other possibilities discussed above. Inequality in a community within this framework could work two ways. First, it might hinder cooperation as suggested by Bardhan et al (2001). The same paper, however, implies that in the case of certain public goods, there may exist an optimal amount of inequality. In this case, the wealthier group may take the responsibility of managing the commons resource. The latter hypothesis corresponds with Olson's theory.

On the basis of field observation, we posit that forest activities have a larger return to cooperation than pasture activities. At least part of this is because forestry activities are very difficult to undertake alone, but in collaboration they can prove to be profitable. In Mexico, pastures are mostly used for livestock production, an activity that is profitably engaged in by both groups and individuals. However, field evidence suggests that pasture management groups are difficult to keep together over time. We have also observed that families often have only one or two cows which serve more as a source of insurance than as a money-making venture.

Given the above discussion, we formalize the assumptions of the model as follows: The community must maximize profits from the two activities available given that the amount of land that they have to exploit is fixed. The production functions for forest and pasture activities are, respectively: $f^{p}(x^{f}, z, l^{f}, c^{f})$ and $f^{p}(x^{p}, z, l^{p}, c^{p})$. Where x^{p} and x^{f} are inputs for pasture and forest activities. Geophysical characteristics that make activities more profitable are represented by z. In the case of pasture activities, lower slope and altitude (in temperate zones) are characteristics that will positively affect livestock production. Forestry activities are difficult to undertake when slopes are quite steep, and we might hypothesize that where a larger percent of the land is highly sloped have more forest. L is the total amount of land and l_f is the amount of land in forest. The assumptions on these functions are:

1. $f_c^f > f_c^p$ Returns to cooperation in forestry are larger than returns to cooperation in pasture activities. .

2. $f_{cc}^f, f_{cc}^p < 0$. This is just the normal decreasing marginal returns assumption.

3. For the production functions in general, we assume that marginal productivity of all inputs increases at a decreasing rate.

Cooperation in either sector is denoted by c_i, and the cooperation cost function is given by $\delta^i\left(\sum_{m=1}^{M}\pi_m^i(c^i), q\right)$, where π^i is the highest outside option at a given level of cooperation summed over all (M) members of the *ejido* and q are characteristics which make cooperation more difficult. The maximization problem can be expressed as:

$$\max_{x^f, x^p, l^f, c^p, c^f} p^p f(x^p, z, L - l^f, c^p) - w^p x^p - \delta^p\left(\sum_M \pi_m^p(c^p), q\right) + p^f f(x^f, z, l^f, c^f)$$
$$- w^f x^f - \delta^f\left(\sum_M \pi_m^f(c^f), q\right)$$

The first order conditions are as follows:

$$(1) \quad p^f f^f_{x_f} - w^f = 0$$

$$(2) \quad p^p f^p_{x_p} - w^p = 0$$

$$(3) \quad p^f f^f_{l_f} - p^p f^p_{l_p} = 0$$

$$(4) \quad p^f f^f_{c_f} - \delta^f_\pi \pi^f_c = 0$$

$$(5) \quad p^p f^p_c - \delta^p_\pi \pi^p_c = 0$$

The first order conditions give fairly standard results; the value of marginal productivity of inputs must equal their price, marginal productivities across land uses must be equal, and, in the case of cooperation, its value must equal its marginal cost.

The comparative statics of the system are in some ways quite predictable; land in forest increases if price of forest outputs goes up, input prices decrease, pasture output prices go down or pasture input prices up, and if forest technology improves. These results, however, depend on having the marginal return to cooperation in a particular activity larger than the deviation option. If prices increase and the payoff to cooperation in forestry does not exceed the highest deviation, then land in forest will decrease. Similar outcomes occur with pasture resources.

More difficult is the prediction of how a decrease in q, qualities which discourage cooperation (i.e., make it more expensive) will affect land allocations. In this case, the price of cooperation decreases in both sectors, and cooperation will increase in both activities. However, the size of the increase depends on the rate at which marginal returns to cooperation are decreasing in either sector as well as the nature of substitutability between cooperation and land. Here we assume that increasing cooperation increases the productivity of land as well, i.e., the two inputs are complementary. If marginal returns decrease faster in pasture activities, then a decrease in cooperation price will increase land in forestry to the detriment of pasture activities. If, on the other hand, marginal returns decrease more quickly in the forestry sector, then we will see the opposite effect.

The solution to this model gives us two demand equations, one for land in pasture and the other for land in forest, which can be expressed as follows:

$$(6)\ L^f = L(p^f, p^p, w^f, w^p, z, \delta^f)$$
$$(7)\ L^p = 1 - L^f$$

These reduced forms will be the basis for our estimation.

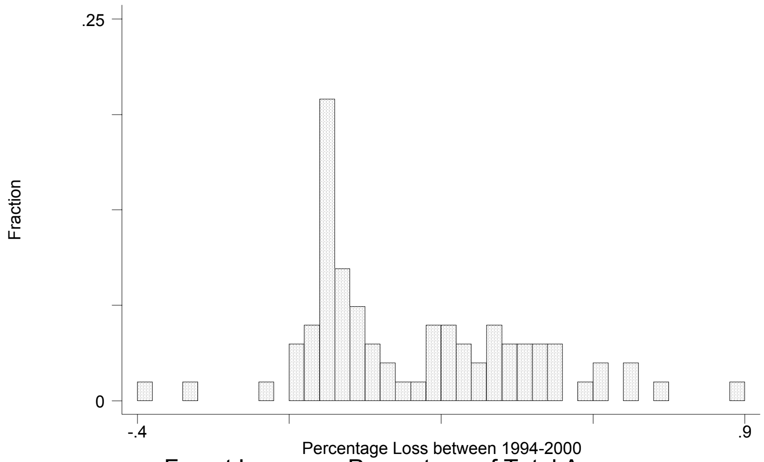
Data and Descriptive Statistics

The data for this project comes from many different sources, all of which will be described in this section. The focus, however, will be on the *ejido*-level variables unique to this study. A general table of summary statistics appears as an appendix.

In contrast to the majority of the deforestation studies, the unit of analysis for this project is not the pixel, but rather the entire ejido. 79 *ejidos* were selected out of a 1997 survey because they reported having forest. However, after calculating percentages of forest cover in both the initial and terminal years, there are 4 *ejidos* in the sample that were completely without forest in 1994 and 2000. They remain in the sample, however, since there are also 17 *ejidos* that showed an increase in forest cover, leaving 58 with deforestation.

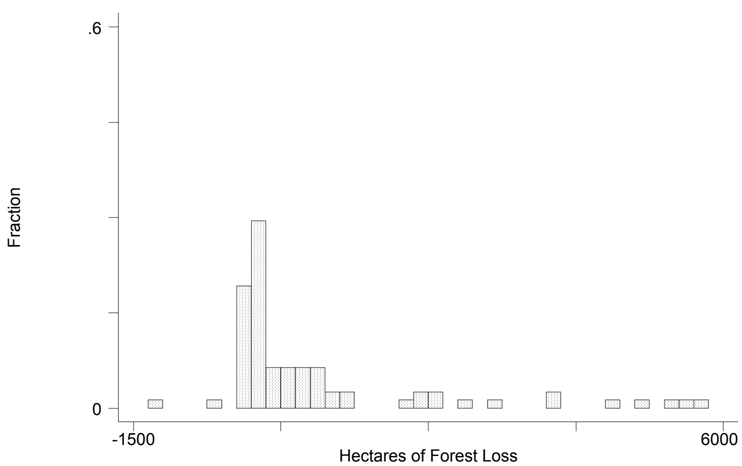
Descriptive statistics are given in some cases by using deforestation as measured by taking the change in forest cover as a percent of the whole *ejido* between 1994 and 2000 as well as putting the change in terms of total hectares lost. Estimations are made using both specifications. The images come from the Landsat TM (30 meter) satellite and were classified into 76 vegetation types for the National Forest Inventory of Mexico in 2000. The 1994 Forest Inventory, also from the Landsat, contains 45 categories. For the purposes of this study, the data has been reclassified into four categories: forest, pasture, agriculture, and other, from which percentages of land in each use have been calculated for each community.

The distribution of the deforestation as a percent of total area variable is shown in the following histogram:



Forest Loss as a Percentage of Total Area

The percentage forest loss ranges from -40 to 90 percent of total ejido area. The values of hectares lost range from -518 to 27,876 and is much more skewed than the percentages, as can be seen in the following figure, which has two outliers removed:



Distribution of Hectares Deforested 1994-2000

One must keep in mind that *ejidos* vary greatly in size - in our sample, from 17 to 53,000 hectares. Clearly, losing 90 percent of a forested area in a 17 hectare community is quite different from losing the same amount of a forested area in a 53,000 hectare community. Indeed, the 90% outlier comes from an 850 hectare *ejido*. For this reason, the estimation is done using the percent of forest loss out of the total area of the ejido. One might think that larger *ejidos* would have more forest in absolute size for two reasons; first, they simply have more resources to begin with. More interestingly, however, given that most forest exploitation is undertaken with relatively rudimentary technology, there are high transactions costs to extracting wood from distant corners of the commons. This latter story is supported by a brief analysis of the statistics at hand. The average size of *ejidos* with a percentage of primary forest above the mean in 2000 is over 6000 hectares, while those below the mean average around 2000. However, the relationship between per capita land availability in *ejidos* with more and less forest is the inverse; more forested *ejidos* in the sample have, on average, 22 hectares per capita, while the average for less forested *ejidos* is 27.

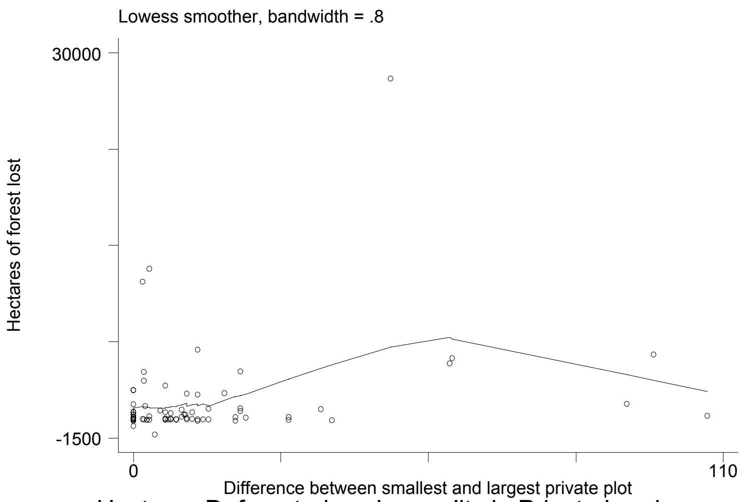
Given that a prolonged drought in the early 90's affected Northern states disproportionately, we have tried to control for this effect by introducing a dummy variable for the four states, Durango, Chihuahua, Coahuila and Nuevo Leon, which were declared "in a state of emergency" in 1995.[2]

Slope, another key geophysical variable, was calculated from Digital Elevations Models and then regrouped into the standard FAO categories: level (0-8%), hilly (8-30), and steep (>30) slope. Percentages of land in each category were then calculated for each unit using the Spatial Analyst component of Arcview. Field experience, along with findings from the studies cited above, has led to the hypothesis that very steep terrain may protect existing forest since it is more difficult to extract trees from extremely sloped areas. It is possible, however, that in Mexico most of the level areas have already been cleared for agricultural and pastoral purposes, in which case it might appear that that level areas are associated with lower deforestation.

The source for the variables regarding ejido size, total population and institutional variables comes from a combination of a 1994 and a 1997 survey of 286 randomly selected ejidos undertaken jointly by the Mexican Agrarian Reform and Berkeley. It is from the 1994 survey that the variables of total area and distance to nearest town are taken. Distance to the nearest large town is given as a total measure, although it might be useful to develop a weighting system in order to account for differences in travel cost over paved and gravel roads. Total population comes from the 1994 survey.

The 1994 survey also provides a source for "inequality" and "participation" variables suggested in the theoretical section. Since we do not have an income distribution to examine, we are forced to use some other proxy for inequality. As mentioned before, ejidos have both privately managed land and commons. Division of land in the commons is normally legally "equal" in the sense that each *ejidatario* has the right to the same percentage of land. Individual parcels, however, vary widely in size, and are subject to exchange between *ejiditarios*. From here we derive our crude proxy for inequality: the difference between the smallest and the largest parcel of land in the private plots. It is speculated that this disparity reflects differences in wealth and power within the communities, which may affect ability to distribute the costs of common resource management or come to agreement and enforce rules for its care. For example, if we only consider those that reforest (or didn't change) against those who deforested, we find that the former group has a mean difference of 6 hectares between largest and smallest holdings, while the latter have a mean of 14 hectares. Although this difference is not statistically significant, it is suggestive. If we further split the categories so as to compare those who reforested with *ejidos* that shows percentage forest losses of over 30, we find that the reforesters have an average difference in land holdings of 4 (sd 8) hectares, while those with high deforestation rates show an average 15 hectare differential (sd 25). The graph of hectares deforested on inequality shows an interesting, inverted-u relationship:

[2] Rural Migration News, January 1996, 2(1) http://migration.ucdavid.edu/rmn/Archive_RMN

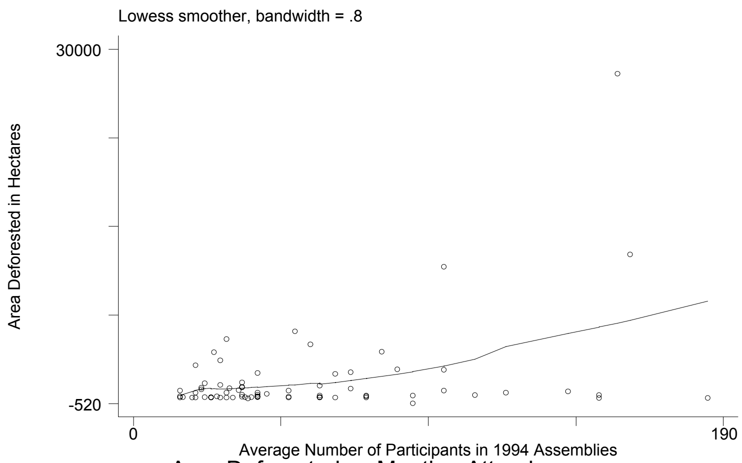


Hectares Deforested vs. Inequality in Private Land

Although this relationship appears to be driven by outliers, it is not inconsistent with the "optimal inequality" hypothesis suggested above and we will test for it in our estimations.

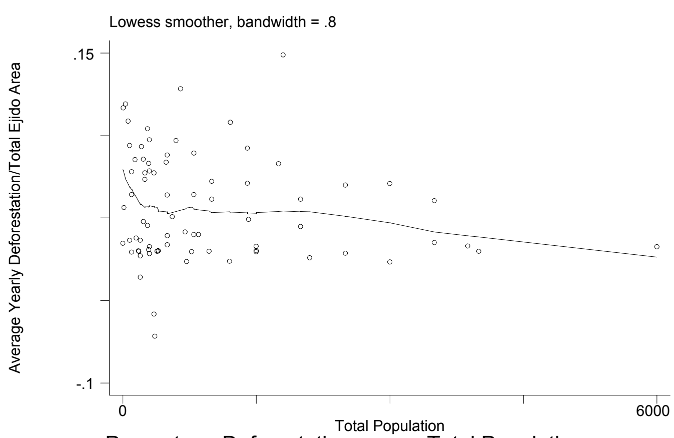
In addition to the land differences, the 1994 survey contains information regarding participation and governance. To frame it within the above discussion, good governance may include rules that make deviating from cooperation more costly and, following this logic, reduce deforestation. The proxies available to measure participation and governance are imperfect; there is little information regarding "real" participation, for example, in maintenance of community structures, and no detail of the types of rules recognized by the ejidos. We include instead whether or not rules written rules exist and the percentage participants in 1994 community assemblies.

While one might consider high participation in meetings a sign of good governance and cooperation, it is also entirely plausible that cooperation is harder to achieve with larger groups of people. Therefore, larger groups making decisions regarding resource use may find it more difficult. Indeed, if we consider the absolute amount of area deforested, we find that it is positively related to the number of participants in community meetings:



Area Deforested vs Meeting Attendance

Interestingly, the relationship between total population and percentage deforestation is exactly the opposite. Higher population seems to be negatively related to deforestation rates. This seems puzzling, with one possible explanation being that larger populations are generally located closer to cities where the majority of the forest loss took place long before the surveys were implemented. This location might also increase the opportunities for employment outside the community, thus decreasing dependence on natural resources. The graph below illustrates the relationship:



Percentage Deforestation versus Total Population

The variables for rule-making are limited to knowing if the community has written rules governing its activities. The presence of rule-making for particular activities is unknown. Obviously, this is a crude estimation of the formal governance structure of the community. When we consider its relationship to total hectares lost, however, it seems to be strongly related. The 32 e*jidos* without rules had, on average, 2335.86 (sd 5246.16) hectares of forest loss between 1994 and 2000. Those with rules had considerably less, 757.57 (sd 2037.171) hectares.

Finally, with regards to exogenous municipal and state variables, prices for corn and wood in 1995 and 1999 come from data compiled by the Centro de Investigación de Desarrollo Económico (CIDE) from various sources. Unfortunately, cattle and milk prices, which would have been more appropriate given the framework presented, were unavailable. The 1999 prices were collected by the Sistema Nacional de Información e Integración de Mercados (SNIIM), while the 1995 prices result from work done by SAGAR, Mexico's Ministry of Agriculture. Although it would be useful to have this information at a municipal level, we are unfortunately limited to more aggregated, state-level information, for which the sample selection process is unclear. Wood prices are not disaggregated into different types of wood, so we have to settle on a state-average. Hopefully this bias will be compensated for by the ecosystem-weighting mentioned above. Under the proposition that an increase in corn or wood price will change the incentives to clear forest, we report percent changes in prices between 1995 and 1999. Even in the absence of weighting, however, it is clear from the table below that higher deforestation is association with larger price changes, particularly for wood.

Ejido Category	***% change Corn (sd)***	***% change Wood (sd)***
> 30% forest loss (n=36)	46 (23.8)	193 (27.0)
<30% forest (n=22)	42 (26.3)	159 (112)
= 0 % forest loss (n=4)	26 (16.6)	135 (126)
reforestation (n=17)	36 (31.2)	96 (128)

Estimation

The small nature of the sample and its large outliers render OLS an imperfect choice of estimator. To address this issue, we followed Ruud's (2000) suggestion and use least absolute deviations, or LAD, estimator, the results of which will be compared to OLS with robust standard errors. The LAD estimator generalizes to a median regression in the situation at hand, and is the solution to the problem:

$$\min_{\beta} \sum_{n=1}^{N} \left| y_i - x_i ' \beta \right|$$

Choice of a LAD estimator is often motivated by its robustness even in the presence of heteroskedasticity (Joliffe, 1998), however, several other useful properties are outlined in Koenker and Bassett (1978). In particular, the authors note that when estimating the vector of parameters beta above, where the observations on the endogenous variable are distributed

$$P(Y_n < y) = F(y - x_n \beta)$$

and the shape of F is normal, then least squares is the minimum variance estimator of the class of unbiased estimators. When the shape of F is unknown, however, then even small outliers can contaminate the results, making it an inappropriate choice in "long-tailed situations." The 1978 paper contrasts the variance of mean and quantile estimators (of which the median is a special case) for a wide variety of distributions. With the exception of the standard normal distribution, the median estimator exhibits greater efficiency than the mean, even in cases of mixed Gaussian distributions.

To find the change in forest area as a percentage of the total land in the ejido, we can build from the demand equations (6) and (7) above. Because deforestation is inherently a dynamic process, we measuring the change in forest size rather than the levels at any given time. Assuming that there are also shocks that we may not observe or factors affecting cooperation that do not enter into the actual estimation, we can rewrite a simple reduced form:

$$\Delta l_f = \Delta p'\beta + z'\gamma + \delta'\alpha + \varepsilon$$

Here Δl_f refers to the change in forest as a percentage of area, Δp are percentage price changes, and δ is cooperation. In lieu of actual cooperation we use the variables discussed above, percent attendance at 1994 assemblies, the existence of bylaws and differences in private land-holdings. The following table details the relationship between the theoretical variables and those included in the estimation:

Theoretical Variable	***Estimation Variable (anticipated sign)***
Land in forest (l_f)	• Change in forest (hectares) from 1994 to 2000 • Change in forest (percent of total ejido) from 1994 to 2000
Output prices (p)	• Percent change in wood prices (1995-1999) (+) • Percent change in corn prices (1995-1999) (+)
Geophysical variables (z)	• % steep slope (-) • Distance to nearest city (km) (-) • Ecosystem class (dry, tropical, temperate) • Drought (dummy for Chihuahua, Coahuila, Nuevo Leon and Durango) (+) • Total size of commons area (+)
Factors affecting deviation (π)	• Population size (+)
Cooperation shifting factors (q)	• Percentage of population attending 1994 meetings (-) • Number of attendants at 1994 meetings (-) • Inequality in private land distribution (?) • Existence of written laws in 1994 (-)

While OLS requires the assumption of normality for the error, LAD has no such restriction. We will compare estimates from OLS and LAD to assess the impact of the variables of interest, all of which refer to the base year, 1994. Reduced form estimations were undertaken using both absolute forest loss and deforestation as a percentage of total *ejido* area as the dependent variable. The changes take place between 1994 and 2000. They are both included to get at different parts of the deforestation story. Given that ejidos vary so greatly in size, the latter specification is intended to normalize for this effect and give insight into the trade-offs made between land uses within the *ejido* boundaries. The former specification brings us closer to looking at what determines forest loss in absolute terms. Although *ejido* size is included in these estimations as a right hand side variable, these coefficients are more easily interpreted as impacts on deforestation in particular and not as within *ejido* trade-offs.

A core set of variables is maintained in all of the estimations. The percentage changes in prices, distance to nearest city, total population, percentage of land in level or steep areas, ecological zone, and a dummy for drought-affected states are included in all specifications. For those using absolute forest loss, the total commons area is also included as an explanatory variable. The importance of the majority of these variables has been established both in previous studies and in the variety of specifications attempted for the paper at hand.

Results and Discussion

Table 1 details the results of the estimates for hectares of forest lost. Here we run the estimations on the full sample. The appendix contains similar results for the group of *ejidos* experiencing only forest loss.

Table 1: Dependent variable: total hectares of forest lost between 1994 and 2000

Variable n=79	OLS[a] I.	II.	III.	IV.	Least Absolute Deviations[b] I.	II.	III.	IV.
Percent Change in Corn Price	-293.92	-388.11	-202.76	-303.40	34.82	63.05	184.02	171.98
	(453.65)	(481.01)	(435.81)	(455.91)	(93.82)	(83.79)	(84.40)*	(103.96)**
Percent Change in Wood Price	79.00	73.53	68.27	57.70	30.12	29.41	40.41	32.52
	(48.46)**	(49.26)	(50.09)	(52.15)	(12.86)*	(11.32)*	(11.55)*	(14.93)*
Ejido Commons Size (in hectares)	.5104	.5420	.5084	.5385	.5062	.5235	.5177	.5379
	(.0273)*	(.0284)*	(.0234)*	(.0247)*	(.0039)*	(.0041)*	(.0034)*	(.0039)*
Distance to Nearest City (km)	-5.43	-3.823	-5.359	-3.870	2.51	.9140	2.67	1.13
	(12.03)	(11.20)	(11.61)	(10.56)	(1.39)*	(1.20)	(1.23)*	(1.51)
Total Population	-.20859	-.0352	-.2077	-.0664	-.0288	.0083	.0046	.0352
	(.2003)	(.1274)	(.1971)	(.1304)	(.0250)	(.0198)	(.0201)	(.0306)
Drought (dummy)	652.68	504.47	493.20	382.62	355.94	149.47	66.80	58.49
	(466.00)	(398.66)	(469.94)	(391.01)	(67.16)*	(56.35)*	(61.98)	(76.66)
Percentage of Land with Steep Slope	2815.53	5861.98	1704.07	4825.25	-12376.86	862.85	-9016.14	-5800.71
	(11389.98)	(12014.79)	(10690.09)	(10897.62)	(1521.88)*	(1377.4)	(1360.3)*	(1764.53)*
Total Attendance in 1994 Meetings	-------	-10.99	--------	-10.89	-------	-3.10	--------	-3.42
		(4.84)*		(4.68)*		(.780)*		(.989)*
Percentage Attendance in 1994 Meetings	-906.45	--------	-481.99	--------	-375.47	-------	-55.79	-------
	(762.38)		(742.99)		(122.63)*		(120.43)	
Written Laws	182.06	333.37	235.66	402.47	265.91	267.93	293.75	302.16
	(267.17)	(272.41)	(263.14)	(265.25)	(53.39)*	(49.25)*	(49.15)*	(65.47)*
Inequality in Private Land	6.15	1.25	33.38	33.67	-3.38	-1.61	16.74	14.72
	(7.68)	(6.49)	(21.33)	(20.70)**	(1.22)*	(1.16)	(3.60)*	(4.33)*
Inequality Squared	----------	---------	-.3102	-.3587	--------	--------	-.1996	-.1797
			(.2046)	(.1950)**			(.0372)*	(.0420)*
Constant	-37.68	126.00	-280.14	-57.23	-317.37	-277.10	-588.26	-455.37
	(512.70)	(519.24)	(500.43)	(493.73)	(87.90)*	(75.71)*	(86.24)*	(99.88)*
Adjusted or Pseudo R^2	0.924	0.929	0.927	0.9318	0.606	0.6096	0.6162	0.6235

a. Robust standard errors in parentheses *Significant at a 5% level of confidence

.

Several results are consistent with the proposed hypotheses. Across all estimations, the larger commons areas are associated with more forest loss. This outcome is likely a combination of the two dynamics discussed earlier with reference to *ejido* size. First, larger commons simply have more forest to cut down in the first place, and second, they are harder to monitor. In our framework, the latter increases the cost of cooperation significantly. The distance effect is interesting; it is the opposite of what one might expect. However, it seems entirely possible that communities that are farther away from cities show a preference for forest-clearing because those nearer to the cities had already cleared their forest prior to 1994. In addition, perhaps more remote communities have fewer alternative employment options and less access to the technical information required for sustainable forest management.

Consistent with the hypothesis that better governance would result in less deforestation the coefficients on absolute and percentage participation in 1994 meetings are negative in the estimations where they are significant. It is interesting to note that the absolute participation has a smaller effect in the LAD estimations, suggesting that the outlying ejidos with very large populations (and hence large attendance), are strongly influencing the OLS coefficients. Percentage attendance is not very robust. This may be because what really matters are the absolute numbers of community members participating in meetings, not what part of the whole are helping make decisions.

Given that this study hopes to suggest something about institutional variables and commons management, a logical question to ask might be, "What would happen if participation were to increase by some fraction?" Using specification IV., a doubling in meeting attendance translates to an average increase in forest cover of 181 hectares, implying an overall decrease in deforestation of over 14,000 hectares for the entire sample.

The slope predictions, though not always significant, also correspond with field observation that steeply sloped land may serve a protective purpose for the forest. The evidence on prices supports the suggestion that the costs of cooperating in forest management do not outweigh individual incentives to deviate by cutting down additional trees. That is to say, in the LAD estimations, forest loss is strongly and positively related to increases in wood prices. Again using estimation IV, a doubling of wood prices would lead to an overall decrease in forest cover of over 4,000 hectares. While the geophysical characteristics , slope in particular, clearly dominate the institutional variables in terms of magnitude, these price and participation effects are not insignificant.

Finally, a puzzle is presented by the law and inequality variables. In the case of the former, one might expect that laws would proxy for stronger governance and ability to monitor community activities, however, the effect is strongly negative on forest cover. One could explain this phenomenon by speculating that the laws themselves were written in order to control a population which was previously behaving in an undesirable manner. Although the laws in question do not specifically pertain to commons resources, their existence may indicate prior problems in the *ejidos*. In this sense, written laws may indicate a governance problem the results of which we see in increased forest loss. While this discussion smacks of endogeneity, recall that these laws were written prior to the observation of the dependent variable, and therefore should be free of this problem.

The inequality predictions seem to correspond with the idea of an optimal level of inequality, where the highest levels of deforestation occur where the land holding disparity is around 35 hectares. At this point, increases in inequality reduce deforestation, suggesting that a particular interest group may form in order to manage the resource. Very low levels of inequality are also associated with low deforestation, lending support to the theory that very egalitarian groups may have less friction between members and be better able to come to agreement on management practices.

The second set of estimations regress forest loss as a percentage of the total *ejido* area as the dependent variable. The coefficients on the explanatory variables then represent their effect on the percentage of forest in the entire *ejido*. One way to interpret these results might be as the change in the portfolio of land uses within the *ejido* over the time period in question. The estimations present a combination of predictable and puzzling results, which are detailed in table 2 below.

Table 2: Dependent variable: Yearly Forest Loss as a Percentage of Total Ejido Area

Variable	**OLS**[a]			**Least Absolute Deviations**[b]		
n=79	**V.**	**VI.**	**VII.**	**V.**	**VI.**	**VII.**
Percentage Change Corn Prices	.0781 (.0768)	.0732 (.0794)	.0722 (.0752)	.0646 (.0292)*	.0868 (.0806)	.1054 (.0629)
Percentage Change Wood Prices	.0264 (.0096)*	.0273 (.0098)*	.0268 (.0092)*	.0206 (.0027)*	.0213 (.0075)*	.0198 (.0057)*
Total Population	-.0002 (.0004)	-.0002 (.0004)	.0002 (.0004)	-.0002 (.0002)	-5.05e-06 (.0004)	.0003 (.0002)
Distance to Nearest City (km)	.0028 (.0011)*	.0028 (.0011)*	.0027 (.0011)*	.0046 (.0004)*	.0042 (.0012)*	.0042 (.0009)*
Drought	.2324 (.0728)*	.2391 (.0723)*	.2028 (.0721)*	.1988 (.0206)*	.2119 (.0556)*	.2460 (.0446)*
Percentage Ejido in Steep Slope	-1.314 (1.340)	-1.261 (1.416)	-1.177 (1.233)	-.4299 (.0206)*	-.6908 (1.316)	-1.152 (.9958)*
Inequality in Private Land	.0005 (.0010)	-.0015 (.0033)	.0002 (.0012)	.0005 (.0004)	.0014 (.0031)	.0018 (.0008)*
Inequality Squared	---------	.00002 (.00004)	--------	---------	-7.48e-06 (.00003)	-------
Number of Ejidatarios Attending 1994 Meetings	.0009 (.0006)	.0010 (.0006)	--------	.0011 (.0003)*	.0009 (.0009)	--------
Percentage of Ejidatarios Attending 1994 Meetings	---------	---------	.1672 (.1693)	--------	--------	.0968 (.0951)
Written Laws	-.0183 (.0481)	-.0248 (.0492)	-.0155 (.0483)	-.0451 (.0179)*	-.0410 (.0484)	-.0255 (.0358)
Constant	-.0214 (.0636)	-.0081 (.0719)	-.0281 (.0721)	-.0757 (.0259)*	-.1013 (.0709)	-.1058 (.0547)*
Adjusted or Pseudo R^2	0.2801	0.2835	0.2870	0.3185	0.3191	0.3068

a. Standard errors in parentheses, robust standard errors in brackets.
b. Standard Errors in parentheses

* indicates significance at a 5% level
** indicates significance at a 10% level

Here the geographical variables clearly dominate, with distance and drought being major forces in increased deforestation. Slope again seems to be protective for forests, with *ejidos* having a large percentage of highly sloped land showing less deforestation. The largest effect of all the geographical variables is that of drought-affect regions. Clearly, the impact of this climatic extreme was severe for *ejidos* in the northern states. Here the distance effect is also significant and positive as it was for the first set of estimation, and wood prices are consistently and strongly associated with greater forest loss.

The results for the participation, inequality and bylaws variables are much weaker here, and where they are significant, they exhibit the opposite signs of those in the absolute deforestation regressions. Absolute participation has the effect predicted by the model, where the greater the number of participants the less forest there is relative to pasture. Inequality here does not exhibit the non-linearity of the first estimations. This is not unexpected, as preliminary inspection of the data showed the u-shape with respect to absolute forest lost, not to the percentage. It does, however, appear to increase the percentage of forest loss, suggesting that greater inequality results in land portfolios with less forest, perhaps because it is more difficult to manage than pasture. In contrast to the first estimations, the existence of written laws now corresponds to the predictions of the model by increasing the percentage of land in forest.

Although there is some evidence of the impact of community characteristics on the land portfolio choice, it would appear that the larger effects here are those of prices and geophysical variables.

Conclusion

The previous pages present the preliminary results of a deforestation model that moves beyond the standard geographical and price analysis of forest loss. It explains forest loss as a result of geographical, price, and community characteristics. Although our results verify some of those found in previous studies, we have found that community characteristics not present in other analyses have significant impacts on the management of forests in Mexican common property resources. This is a useful step towards understanding this situation; previous studies left the impression that near roads and in steeply sloped areas, the trees simply fell off the mountains without any human interference.

Under the proposition that OLS is particularly sensitive to outliers, least absolute deviations was also used to estimate the effects of participation, land inequality and laws on both absolute forest loss and forest loss as a percentage of *ejido* area. In the former case, participation was strongly associated with less deforestation. Liberally interpreted, this implies that cooperation is indeed important for resource management. Inequality exhibited a significant inverted-u effect on absolute forest loss, providing support for the claim of an optimal level of inequality for the management of common property resources. Finally, the presence of written laws was strongly associated with more loss in hectares of forest. One interpretation of this phenomenon is that written laws are actually a proxy for poor governance; in other words, communities write laws only when they have trouble controlling deviant behavior of their members. In the case at hand, poor governance translates to higher forest loss.

In the latter estimations, geophysical and price variables dominated, with higher wood prices strongly associated with less forested land in the *ejido* portfolio. Areas most affected by the drought in the early 90s had much lower percentages of forest, as did very remote communities. Inequality is associated with less forest land relative to other uses, and the same effect can be seen in the absolute numbers of participants in community meetings, two results which were predicted by the model. Finally, written laws have a weakly positive effect on the percentage of forested land.

In sum, we find that institutions matter. Although the proxies are crude and the sample size limited, this study presents new evidence to add to the previous case study and theoretical literature on cooperation and resource management.

Works Cited

Angelsen, A. (1999). "Agricultural expansion and deforestation: modeling the impact of population, market forces and property rights" *Journal of Development Economics* 58: 185-218.

Baland and Platteau (1996) *Halting Degradation of Natural Resources: Is There a Role for Rural Communities?* FAO and Claredon Press. Oxford, New York: Oxford University Press.

Barbier, E. (2001) "The Economics of Tropical Deforestation and Land Use: An Introduction to the Special Issue". *Land Economics* 77 (2): 155-171.

Bardhan, P., Ghatak, M., and Karaivanov, A. (2001) "Inequality and Collective Action". Working paper presented at the Development Seminar, University of California, Berkeley, Fall, 2001.

Cropper, M., J. Puri, and C. Griffiths. "Predicting the Location of Deforestation: The Role of Roads and Protected Areas in North Thailand." *Land Economics* 77 (2), (May, 2001): 172-186.

Deininger, K., Minten, B. "Poverty, Policies, and Deforestation: The Case of Mexico." *Economic Development and Cultural Change*, v47, no2 (January, 1999): 313-?

Joliffe, D. (1998) "Skills, Schooling, and Household Income in Ghana" World Bank Economic Review, Jan, 12(1): 81-104.

Kaimowitz and Angelsen (1998) *Economic Models of Tropical Deforestation: A Review.* Center for International Forestry Research (CIFOR): Bogor, Indonesia.

Koenker, R. and Bassett, G. (1978) "Regression Quantiles" *Econometrica* 46(1): 33-50.

McCarthy, N., de Janvry, A. and Sadoulet, B. (2001) "Common Pool Resource Appropriation under Costly Cooperation" Forthcoming in *Journal of Environmental Economics and Management.*

McCarthy, N. (1996) *Common Property and Cooperation in Rural Mexico*. Dissertation in Agricultural and Resource Economics at the University of California, Berkeley.

Olson, M. (1965) *The Logic of Collective Action: Public Goods and the Theory of Groups.* Harvard University Press, Cambridge, MA.

Ostrom, E. (1992) *Governing the Commons: The Evolution of Institutions for Collective Action.* Cambridge University Press, New York.

Ruud, P.(2000) *An Introduction to Classical Econometric Theory* Oxford University Press, Oxford.

Seabright, P. (1994) "Is Cooperation Habit Forming?" in *The Environment and Emerging Development Issues,* eds. P Dasgupta and K.G. Maler. Claredon Press, Oxford, UK.

Walker, R., Moran, E., and Anselin, L. (2000). "Deforestation and Cattle Ranching in the Brazilian Amazon: External Capital and Household Processes" *World Development* 28 (4): 683-699.

Appendix I.

The following table shows the average values for each of the above variables in the sample.

Average values of exogenous variables

Variable	Obs	Mean	St. Dev.	Min	Max
Ejido Variables:					
Number of Ejidatarios Attending Assemblies in 1994	79	54.75	38.48	15	185
Percentage of Ejidatarios Attending 1994 Assemblies	79	.1634	.202	.006	.909
Inequality of land	79	13.03	21.15	0	107
Total Distance to nearest city (kilometers)	79	26.86	21.63	0	80
Total land (hectares)	79	3936.104	7097.55	183	53000
Total commons land (hectares)	79	3072.86	7046.25	7	52738
State Variables:					
% change in corn price	79	.417	.260	.027	.955
% change in wood price	79	1.61	2.06	-.644	12.29
Geographic variables:					
Ejidos in temperate zone	27	---			
Ejidos in tropical zone	37	---			
Ejidos in dry zone	16	---			

Appendix II: Results for Ejidos with "Real" Deforestation:

Dependent Variable: Hectares of Forest Lost between 1994-2000

I.

Median regression Number of obs = 58
Raw sum of deviations 103411.8 (about 508.88635)
Min sum of deviations 31966.58 Pseudo R2 = 0.6909

Hec. Forest Lost	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
% change corn price	51.43037	132.6449	0.39	0.700	-215.4166	318.2774
% change wood price	15.8856	9.869531	1.61	0.114	-3.969331	35.74054
ejido size	.5310702	.0044481	119.39	0.000	.5221218	.5400185
total population	.0041578	.0285948	0.15	0.885	-.0533675	.0616832
distance	6.680822	1.8788	3.56	0.001	2.901163	10.46048
drought	177.4612	79.73682	2.23	0.031	17.05142	337.871
% land in steep slope	6746.089	2227.804	3.03	0.004	2264.326	11227.85
% attendance in 1994	-209.7595	142.2277	-1.47	0.147	-495.8848	76.36583
written laws	232.2636	65.49983	3.55	0.001	100.4949	364.0322
inequality	-5.390167	1.456405	-3.70	0.001	-8.320076	-2.460257
constant	-397.4841	121.8272	-3.26	0.002	-642.5687	-152.3995

II.

Median regression Number of obs = 58
Raw sum of deviations 103411.8 (about 508.88635)
Min sum of deviations 31380.9 Pseudo R2 = 0.6965

Hec. Forest Loss	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
% change corn price	39.11254	103.9143	0.38	0.708	-169.9361	248.1612
% change wood price	25.71109	8.937076	2.88	0.006	7.732013	43.69017
ejido size	.5421857	.004514	120.11	0.000	.5331047	.5512667
total population	.0101492	.0230635	0.44	0.662	-.0362486	.056547
distance	3.610849	1.62751	2.22	0.031	.3367211	6.884977
drought	149.6264	67.3816	2.22	0.031	14.07213	285.1807
% land in steep slope	6290.897	1924.452	3.27	0.002	2419.399	10162.4
# participants in 1994	-2.997744	.9058894	-3.31	0.002	-4.820158	-1.175329
written laws	251.9579	58.19752	4.33	0.000	134.8795	369.0362
inequality	-6.504686	1.147516	-5.67	0.000	-8.81319	-4.196182
constant	-279.9718	105.6479	-2.65	0.011	-492.508	-67.43559

III.

Median regression Number of obs = 58
Raw sum of deviations 103411.8 (about 508.88635)
Min sum of deviations 31129.22 Pseudo R2 = 0.6990

Hec. Forest Lost	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
% change corn price	255.6596	160.6243	1.59	0.118	-67.66041	578.9796
% change wood price	9.703169	14.24874	0.68	0.499	-18.97806	38.3844
ejido size	.5290642	.0040681	130.05	0.000	.5208757	.5372528
total population	.0150298	.0365606	0.41	0.683	-.0585628	.0886224
distance	2.582362	2.373123	1.09	0.282	-2.194486	7.359211
drought	23.31146	110.5612	0.21	0.834	-199.2367	245.8596
% land in steep slope	1061.693	3031.928	0.35	0.728	-5041.261	7164.647
% attendance in 1994	68.5741	227.2312	0.30	0.764	-388.8185	525.9667
written laws	380.058	86.53546	4.39	0.000	205.8711	554.2448
inequality	16.07554	7.274295	2.21	0.032	1.433141	30.71793
inequality squared	-.1995162	.0729944	-2.73	0.009	-.3464463	-.0525861
constant	-634.6218	158.6985	-4.00	0.000	-954.0653	-315.1783

IV.

Median regression Number of obs = 58
Raw sum of deviations 103411.8 (about 508.88635)
Min sum of deviations 30482.51 Pseudo R2 = 0.7052

Hec. Forest Lost	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
% change corn price	269.6219	204.4327	1.32	0.194	-141.8797	681.1235
% change wood price	3.052298	17.76295	0.17	0.864	-32.70266	38.80725
ejido size	.538516	.0069536	77.44	0.000	.524519	.552513
total population	.063149	.0531898	1.19	0.241	-.0439166	.1702146
distance	2.48945	3.225715	0.77	0.444	-4.003577	8.982477
drought	-13.79101	124.8544	-0.11	0.913	-265.1099	237.5279
% land in steep slope	1079.694	3926.011	0.28	0.785	-6822.957	8982.345
# participants in 1994	-4.841594	1.882694	-2.57	0.013	-8.631261	-1.051927
written laws	374.4303	112.2136	3.34	0.002	148.556	600.3046
inequality	16.43245	8.432376	1.95	0.057	-.5410373	33.40595
inequality squared	-.1917691	.0784833	-2.44	0.018	-.3497478	-.0337904
constant	-484.2815	196.9799	-2.46	0.018	-880.7814	-87.78149

V.

Median regression Number of obs = 62
Raw sum of deviations 11.24644 (about .23506673)
Min sum of deviations 8.058454 Pseudo R2 = 0.2835

pareadef	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ppmaiz	.0723878	.0499961	1.45	0.154	-.0279367	.1727122
ppmad	.0126884	.0065306	1.94	0.057	-.0004162	.0257931
totalej	.0000504	.00025	0.20	0.841	-.0004512	.000552
dist	.0054545	.0006189	8.81	0.000	.0042126	.0066964
drought	.1524679	.0312296	4.88	0.000	.0898012	.2151346
persteep	1.071354	.8690079	1.23	0.223	-.672438	2.815146
landif	-.0001391	.0005772	-0.24	0.810	-.0012974	.0010191
numatten	.0004848	.0004857	1.00	0.323	-.0004898	.0014593
bylaws	-.0314546	.0268763	-1.17	0.247	-.0853859	.0224766
_cons	-.0638167	.041064	-1.55	0.126	-.1462177	.0185843

VI.

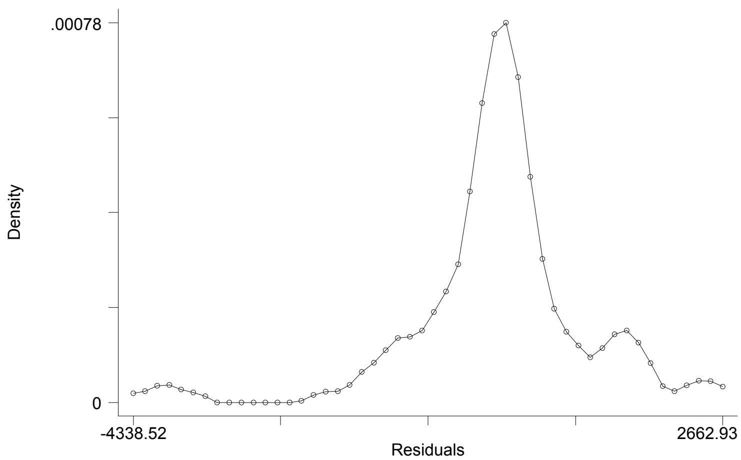
Median regression Number of obs = 62
Raw sum of deviations 11.24644 (about .23506673)
Min sum of deviations 8.054708 Pseudo R2 = 0.2838

pareadef	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ppmaiz	.0669357	.1014049	0.66	0.512	-.1366432	.2705146
ppmad	.0095347	.0130209	0.73	0.467	-.0166059	.0356753
totalej	.0000101	.0005272	0.02	0.985	-.0010482	.0010684
dist	.0052751	.0013638	3.87	0.000	.0025372	.0080131
drought	.1519275	.0644498	2.36	0.022	.0225392	.2813159
persteep	1.407395	1.751181	0.80	0.425	-2.108247	4.923036
landif	-.001229	.0041699	-0.29	0.769	-.0096004	.0071424
ineqsq	.000011	.0000422	0.26	0.795	-.0000737	.0000957
numatten	.0005405	.0010038	0.54	0.593	-.0014747	.0025557
bylaws	-.0382438	.0599214	-0.64	0.526	-.1585411	.0820535
_cons	-.0416269	.0899105	-0.46	0.645	-.2221298	.1388759

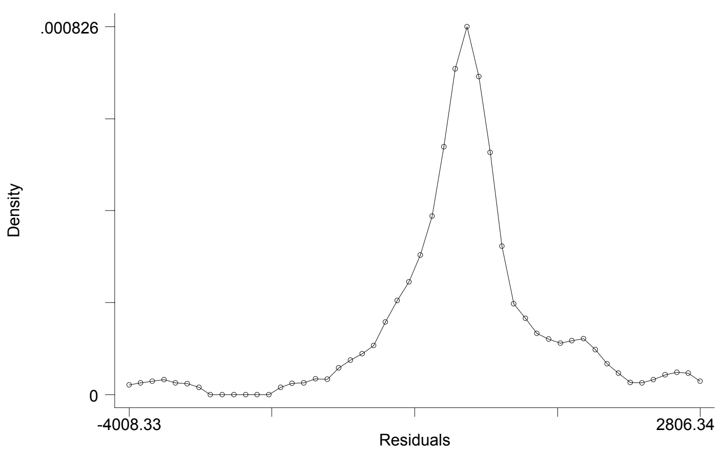
VII.

Median regression Number of obs = 62
Raw sum of deviations 11.24644 (about .23506673)
Min sum of deviations 8.099232 Pseudo R2 = 0.2798

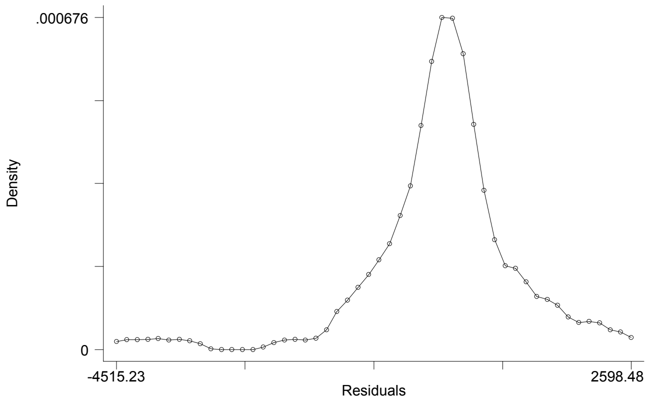
pareadef	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ppmaiz	.0787028	.0576906	1.36	0.178	-.0370618	.1944675
ppmad	.0094087	.0068774	1.37	0.177	-.0043919	.0232093
totalej	.0002628	.0001942	1.35	0.182	-.0001269	.0006524
dist	.00536	.0007698	6.96	0.000	.0038152	.0069048
drought	.1566495	.0373345	4.20	0.000	.0817323	.2315668
persteep	.9102833	.9219438	0.99	0.328	-.9397324	2.760299
landif	-.0001552	.0006575	-0.24	0.814	-.0014746	.0011642
patt94	.0645386	.0744194	0.87	0.390	-.0847947	.213872
bylaws	-.0264027	.0306869	-0.86	0.394	-.0879804	.0351751
_cons	-.0624506	.0482198	-1.30	0.201	-.1592107	.0343096



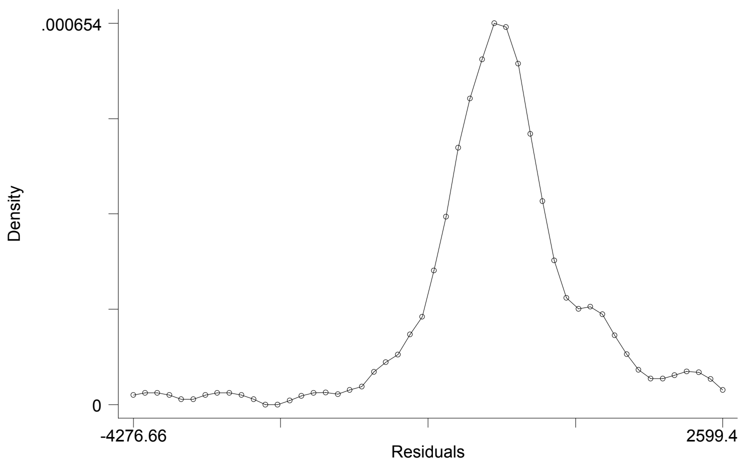
Density of Residuals for Estimation 1



Residuals of Estimation II



Residuals of Estimation III



Residuals of Estimation IV