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Community Forestry, Common Property, and Deforestation in Eight Mexican States

James Barsimantov[1] and Jake Kendall[1]

Abstract

Community management of forests for timber extraction has been widely implemented in Mexico. In this article, we investigate the relationship between property rights, community forestry, and deforestation over time. We conduct an econometric analysis of land use change at the municipality level in eight Mexican states that incorporates several variables commonly used in deforestation models plus variables on common property and community forestry. Our results show that both key explanatory variables, common property and community forestry, are related to lower deforestation. Coniferous forests, which have more marketable timber, show a stronger association, indicating that common property management may work by increasing the market value of the standing forest, thus building local consensus for timber management by distributing returns. The measured effects of common property and community forestry on deforestation rates are both statistically significant and large enough to confirm community forestry's usefulness as an environmental policy tool.

Keywords

community forestry, land use change, Mexico, deforestation, land tenure, Latin America, common property

Introduction and Background

In the past 50 years, Mexico has lost roughly half of its forest cover. Mexico has one of the highest levels of endemism and highest number of species of all countries

[1]University of California, Santa Cruz, CA, USA

Corresponding Author:
James Barsimantov, Department of Environmental Studies, University of California, 1156 High St., Santa Cruz, CA 95604, USA
Email: jbarsima@ucsc.edu

worldwide (McNeely, Miller, Reid, Mittermeier, & Werner, 1990), making forest conservation an issue of high importance for biodiversity conservation. About 10% of Mexico's population, many of the country's poorest citizens, live in forested regions (Segura, 2000). While deforestation rates have been declining in recent years, there is still cause for concern: Between 1993 and 2000, about 500,000 ha were deforested yearly, a rate of 1.0% for pine-oak forests and 2.1% for tropical forests (Velazquez et al., 2002), while between 2000 and 2005, Mexico lost 155,000 ha/year (Food and Agriculture Organization [FAO], 2010). This situation necessitates development programs that ensure maintenance of Mexico's forest cover and that create economically viable opportunities for the rural poor. Community forestry, which has been developing in Mexico for well over two decades, is a strategy that is claimed to achieve positive environmental and socioeconomic outcomes (Bray, Merino-Perez, & Barry, 2005). This study aims to determine whether community forestry in Mexico is related to lower rates of deforestation.

We test an econometric model of deforestation in eight states with large timber volumes of coniferous species, since this type of empirical analysis has not yet been conducted despite increasing efforts to develop community forestry. We find that common property forests are associated with statistically significant reductions in deforestation, and these reductions are large enough in magnitude to be policy relevant. We also find that even greater reductions in deforestation are associated with the percentage of common property forests with forestry permits.

Understanding whether and how common property forest management contributes to reduced deforestation is a key concern for development practitioners and policy makers. It is also crucial to provide a spatial and quantitative assessment of the theoretical and case-study-based relationship between common property management and forest cover change. As countries worldwide increasingly look to community forest management as a potential "win-win" situation for forests and rural citizens (White & Martin, 2002), this type of research on Mexico's established system of common property forest management is both timely and highly relevant. Therefore, this result is important as it demonstrates that development programs seeking economic improvements at the community level can also achieve conservation goals.

Common Property and Mexican Community Forestry

As a result of the Mexican Revolution of 1910, the large majority of Mexico's forests are under a common property regime,[1] creating a complex and unique situation for forest governance. The redistribution of land to peasants and indigenous people in the postrevolutionary period intended to undo the high level of land inequality that had been institutionalized since Spanish colonization (Bulmer-Thomas, 2003). Two types of commonly held land were created following the revolution: ejidos (lands granted by the postrevolution government) and comunidades agrarias (repatriated indigenous lands). We use the terms communities and *common property* landholdings to refer to both of these tenure arrangements, where *communities* refers to the group of people with common ownership of land, and *common property* referring to the tenure arrangement.

From the 1940's through the mid-1970s, although land was ostensibly governed by communities, the federal government retained control of forest governance, and granted timber concessions to private logging companies. Stumpage fees due to communities were often channeled through the Ministry of Agrarian Reform and did not reach the rural poor. By the mid-1970s the notion that communities should reap the benefits of timber extraction became popular, and several instances of public protests over the control of forest resources occurred. At the same time, many timber concessions were reaching their expiration, and the next two decades saw the rapid expansion of community forestry and the end of timber concessions (Klooster, 2003). Communities in Mexico can now choose if and how much of the common-use forest within their land holdings they wish to manage for timber production. This situation is unique even among countries with common property land tenure systems in terms of the relatively high level of local control over extraction of resources. Currently, roughly 2,000 federally issued permits for forestry in commonly property exist nationwide, most of which are in coniferous forests (Bray et al., 2005).

Community forestry is widely viewed by funding agencies and academics as an appropriate development model for Mexico's pine-oak forests (Bray et al., 2003). For the purposes of this article, we defined community forestry as the management of commonly property forests for sustainable resource extraction, regardless of the level of involvement of community members. Community forestry has become more popular as countries worldwide look to the decentralization of forest management as a means of increasing local benefits and conserving forests (Ribot, 2004; White & Martin, 2002). However, there have been few empirical studies that attempt to understand the relationship between community forestry, common property, and deforestation over a large geographic. To what extent does community forestry reduce deforestation in Mexico? How do the social and economic characteristics of forested regions influence the effectiveness of community forestry in reducing deforestation? Deforestation, defined here as a change from forest to nonforest land covers, is a major cause of species loss, deterioration of ecosystem services, and carbon emissions (Dirzo & Raven, 2003; Wright, 2005). Mexico, where common property land tenure and community forestry have been widespread for decades, offers a unique opportunity to explore this issue.

The importance of land tenure regimes, especially common property regimes, for forest governance has been extensively theorized and researched. Collective action theory (Olson, 1965), as applied to common pool resources (Ostrom, 1990), attempts to understand the conditions under which groups of people cooperate to manage these resources. Ostrom's theory rose in response to Hardin's (1968) claim that common pool resources will inevitably be ruined as individuals pursue personal benefit if not under a private or public property regime. Hardin's "Tragedy of the Commons" analysis failed to acknowledge that common property regimes are not identical to open access and can be effective in governing common pool resources. When local groups create effective rules to govern consumption of common pool resources, open access problems do not occur. In other words, Hardin's analysis assumes that the difficulty in regulating resource appropriation cannot be overcome by collective action.

In addition to the existence of effective rules created under common property regimes, there also may be additional benefits of common property over private property. Aggregating forested land for timber management can create economies of scale that may support collective action by reducing the cost of administering multiple small parcels. Managing larger forest areas can also reduce the uncertainty of variations in timber productivity within a forest (McKean & Ostrom, 1995). In addition, environmental externalities resulting from land use decisions may be less pronounced under a common property regime, since decisions will reflect the will of all local parties. There are also social equity benefits, such as broad access to locally available natural resources, as well as potentially lower enforcement costs (Runge, 1986). Extensive case study research has shown that certain social conditions lend to more successful rule making and therefore more successful common property management (Gibson, McKean, & Ostrom, 2000; Ostrom, 1990).

These principles have been applied in the study of community forestry in Mexico, which by now has an extensive literature. Community governance structure and the internal legitimacy of social institutions play a large role in determining whether forestry enterprises can deliver benefits to community members (Klooster, 2000; Tucker, 2004a), support from government agencies plays an important role in success (Richards, 1992, 1996), and the socioeconomic situation of a region may determine whether or not community forestry can develop successfully (Merino, 2000). Certain forestry communities have been found to provide socioeconomic and ecological benefits (Bray et al., 2005; Merino, 1997; Tucker, 2004b; Velazquez, Torres, & Bocco, 2003), although most of these studies were based on communities with an outstanding record of forest management, so selection bias may limit generalizability.

In fact, almost all studies have been based on one or two cases, and the few studies mentioned below are some of the only ones that have attempted to discern a general effect of common land tenure and community forestry on Mexico's forest cover. Antinori (2000) found that human capital expertise and community social capital increase the likelihood that a community in Oaxaca will attain a higher level of vertical integration of wood processing. However, spatial data were not included in this study. Bray, Ellis, Armijo-Canto, and Beck (2004) study the relationship between community forestry and land use change and found that one of the most significant factors in determining low deforestation in southern Quintana Roo was a high volume of legal timber extraction. Duran, Velazquez, and Mas (2005) showed that deforestation rates in communally managed pine-oak forests in Guerrero were roughly the same as those in protected areas. The relationship between community forestry and deforestation has also been explored in the Maya forests of Quintana Roo (Bray et al., 2008; DiGiano, 2011; Ellis & Porter-Bolland, 2008). These studies generally support the idea that community forestry can aid in forest conservation; yet, they focus on portions of individual states rather than a large percentage of the country. A recent meta-analysis of case studies shows that community managed forests are as effective at controlling deforestation as protected areas across the tropics (Porter-Bolland et al., in press), which suggests that the patterns found in Mexico also exist elsewhere.

In sum, the body of literature on community forestry in Mexico has provided some interesting insights, but many studies are not easily generalizable to the whole of Mexico or to other country contexts. Drawbacks include a limited geographic scope, omission of important control variables such as spatial data, and a focus on the micro (plot or community) level or case study data. While case studies are necessary to "ground-truth" results of econometric models, both micro and macro studies are essential for determining the advantages and disadvantages of community forestry, and this will lead to more profound knowledge of community forestry in Mexico. This study attempts to address these issues with a data set that covers a broad geographic area, contains a comprehensive set of control variables, and measures aggregate outcomes.

Drivers of Deforestation

While there has not been a sustained effort to understand the relationship between community forestry and deforestation in larger scale models, there has been extensive research on understanding other factors that affect deforestation. This body of literature has constructed theory and a set of empirical methodologies for this type of analysis, including cross-country, regional, and micro-level models (Kaimowitz & Angelsen, 1998), which we rely on to choose our specifications and control variables.

Work at the plot level may clarify mechanisms of deforestation that cannot be analyzed at more coarse scales of spatial aggregation. These studies are more capable of incorporating physical attributes of forests as well as decision-making parameters at a fine scale. Panayotou and Sungsuwan (1994) modeled population, price, and infrastructure in one of the earlier micro-level models on deforestation in Thailand, finding that population density was a key driver of increased deforestation. In Mexico, Alix-Garcia, De Janvry, and Sadoulet (2005) suggest that communities which develop forestry management programs versus those who simply hold the forest in common ownership have different incentive structures, and this explains varied processes in these communities. She concludes that communities with forestry permits deforest at higher rates than those without, a conclusion counter to the hypotheses of this article. Alix-Garcia (2007) also found that the amount of forest cleared is related to physical attributes of forested land as well as the ability of communities to affect the cost of land clearing through collective action. However, these plot-level studies are not capable of generalizing conclusions on a larger geographic scale because they do not adequately address ultimate causes of deforestation nor can they account for variations in these drivers over larger areas.

Although the actions of individual agents are obscured in coarse scale models due to aggregation, these models are nonetheless necessary to confirm qualitative conclusions and generalize processes observed at the plot level. A large number of econometric modeling studies have analyzed the underlying social and economic drivers of deforestation using satellite imagery and numerous independent variables to explain observed forest loss. Population is perhaps the most often used variable, and Cropper and Griffiths (1994), Allen and Barnes (1985), Rudel (1994), and Deacon (1994) and find some evidence for the effect of population on forests. Other variables, including poverty, access, geographic variables, and some trade variables have been used in other models (Geist & Lambin, 2001; Godoy et al., 1997; Kaimowitz & Angelsen, 1998; Mertens & Lambin, 1997; Palo & Mery, 1996; Pfaff, 1997; Southgate, Sierra, & Brown, 1991; Vosti, Witcover, & Carpentier, 2002). Conclusions often conflict depending on the structure of the model used; however, some consistent conclusions are that agents' decision parameters, including physical environment, agricultural prices, wage rates, and accessibility influence forest loss (Kaimowitz & Angelsen, 1998).

Drivers of deforestation have been explored in Mexico in coarse scale models as well. Population growth was shown to affect land devoted to both agriculture and pasture, whereas road density and per capita income did not (Barbier & Burgess, 1996). Poverty was also associated with higher levels of deforestation (Deininger & Minten, 1999). In addition, physiogeographic variables, such as slope, elevation, rainfall, and distance from infrastructure were highly significant, accounting for 71% of 1 km^2 plots that were deforested between 1980 and 1990 in the states of Oaxaca and Chiapas (Deininger & Minten, 2002). Bray et al. (2004) discussed above, use timber extraction from managed forests, one of our key variables, as a variable their model.

Another of our key variables, common property regime, has not been tested in any regional level studies that we are aware of, which is the scale of our study. The literature on property rights and deforestation has focused on deforestation for attaining property rights for land speculation (Mendelsohn, 1994), as well as the effect of secure versus insecure tenure (Kaimowitz, 1996; Pinchon, 1997; Southgate et al., 1991). But the context in Mexico, where the majority of forests are under a common property regime, provides the opportunity to test this parameter, which has broad implications for other countries with common property or those in the process of devolving rights to forest resources.

Data Set and Empirical Approach

To test the relationship between land use change, common property, and community forestry, we conducted an econometric analysis of land use change in all municipalities ($n = 733$) with at least 50 ha^2 of coniferous forests in the eight Mexican states with the most extensive coniferous timber resources: Chihuahua, Durango, Jalisco, Puebla, Oaxaca, Michoacan, Guerrero, and Chiapas. We use this universe because we seek to understand factors that affect the decision to deforest in areas where there is opportunity for timber management. Pine and fir species are the most widely harvested timber species in these states and are the most commercially viable, comprising 77.5% of authorized timber volumes within managed forests.[3] Oak represents roughly another 18.7% of authorized volumes, though only about 10% of this volume is actually harvested due to its low value and lack of processing facilities.[4] Broad-leaved tropical forests in these eight states have very low timber potential and comprise less than 4% of total extracted timber volume, and tropical forest timber potential in Mexico is concentrated outside of the study area in the Yucatan Peninsula. We exclude states where tropical broad-leaved forests are extensively managed for timber (Campeche and Quintana Roo for example) because land use and agricultural patterns are quite different and could confound results.

Our central hypothesis is that municipalities with higher percentages of common property forest and higher percentages of forest in community forestry programs will have lower rates of deforestation. In addition, we hypothesize that common property and community forestry will be most effective when the forest in question has economic value (i.e., is coniferous forest).

To create the dependant variables of gross deforestation (an annualized rate of change from forest to nonforest classifications), recovery (nonforest to forest cover), and net forest loss (gross deforestation minus recovery), polygons of land cover types from the 1993 and 2000 National Forest Inventory (NFI) were intersected to determine processes of forest cover change in each polygon, which were then summed within each municipality.

While we test models with all three dependent variables, our analysis and discussion focus on gross deforestation because understanding drivers of continued forest loss is the key to biodiversity conservation and maintenance of ecosystem services.

To create one of the main independent variables, percentage of total forest that is under a common property regime, 1993 NFI land cover polygons were intersected with a layer of polygons of all common property holding in Mexico from the National Agrarian Registry (RAN). The result was in a layer of all forest polygons located in common property landholdings, which was then summed by municipality. Using the NFI layer, we further disaggregated this variable into common property forest of coniferous and nonconiferous types.

To create the other main independent variable, percentage of common property forest in community forestry, we use a proxy variable, which is the existence of a forest management permit in a common property forest. It is debatable whether all forest management activities in common property forests can be considered community forestry, especially as the majority of these communities contract forest management to private timber companies. However, many communities lack the expertise to conduct forest management without the support of external actors (Barsimantov, 2010), and the decision to contract forestry services is still a community-based decision about forest management. In fact, determining whether contracted forest management in common property forests can maintain forest cover is an important question and is part of the goal of this study, although it is not analyzed separately from forest management in which community members take a more active role. Related research looks more closely at the effect of different levels of involvement in forest management in common property forests (Barsimantov, 2009). Therefore, for the purposes of this article, we use the existence of a forest management permit as a proxy for community forestry. These data were compiled using forestry permit data from a national survey

Table 1. Independent Variables Used in Multivariate Regression Model

Variable category	Variable name	Expected sign	Data source
Main independent	Percentage of forest common property	(–)	Created from spatial layers from 1993 NFI the National Agrarian Registry
	Percentage of common property forest in community forestry	(–)	Antinori et al., 2004—Phase 1 Survey Data
Control variables	Road density	(+)	Computed with GIS using INEGI data
	Topographic roughness	(+)	Computed with SRTM digital elevation models[b]
	Marginalization (poverty) Index	(+/–)	National Poverty Commission
	Percentage of speaking indigenous language	(–)	National Household Census—1990 and 2000 (INEGI)
	Percentage of employed in agricultural (1990)	(+)	
	Population growth (1990-2000)	(+)	
	Rural population density (1990)	(+)	
	Unemployment (1990)	(+/–)	
	Percentage of out-migration (1990)	(–)	
	Percentage of population illiterate (1990)	(+)	

[a]Data compiled from the National Survey of Community-Managed Forestry in Mexico (Phase 1), Antinori et al., 2004.
[b]This is a measure of rugosity created using 3-arc second Shuttle Radar Topography Mission (SRTM) digital elevation models and the ArcView plugin Benthic Terrain Modeler. Rugosity, as defined here, is the mean of ratios between the surface area and planar area over all cells in a region of interest. Two versions were explored, the first was mean rugosity over all cells in a municipality and the second was mean rugosity over all 1990 forested cells in the municipality. Spot checking the data in a large subsample, the correlation coefficient was .91 between the two versions, and we chose to use the first. Values from 1 to 5 are given to each cell, from 1 = *horizontal* to 5 = *vertical*. More information at http://www.csc.noaa.gov

of community forestry,[5] which were summed across municipalities and divided by total commonly owned 1993 forest area. Due to the structure of these data, we cannot disaggregate this variable by forest type, which limits our analysis. In addition, this survey only compiled data on forest management in common property forests, not in privately owned forests, which is another limitation.

Several other drivers of deforestation that have been found significant in other studies are included in the model. Their descriptions, sources and expected signs are detailed in Table 1. We include dummies in some regressions to control for state-level

Table 2. State-Level Means of Deforestation, Common Property, and Community Forestry Variables

		Coniferous forest cover change, % (1993-2000)				Forest common property, %		
	N	Deforestation	Recovery	Net change	Nonconiferous forest net change, %	Coniferous forest	All forest	Coniferous forest in community forestry, %
Chiapas	66	3.8	1.4	2.4	2.0	61.2	65.0	2.5
Chihuahua	44	1.4	0.5	1.0	1.6	53.1	50.8	9.9
Durango	25	1.8	0.4	1.6	2.0	65.4	65.3	9.4
Jalisco	51	1.5	1.0	0.8	1.9	78.6	81.7	1.9
Guerrero	72	1.5	0.3	1.2	1.7	27.0	29.2	15.4
Michoacan	82	2.3	1.2	1.0	0.6	46.7	49.0	17.9
Oaxaca	310	1.5	1.4	0.2	0.1	80.4	79.8	2.6
Puebla	83	1.4	1.9	–0.6	1.6	40.3	40.8	33.2
8 states (*M*)	733	1.8	1.2	0.6	0.9	62.8	63.5	9.6
8 states (*SD*)		0.046	0.032	0.050	0.075	0.355	0.326	0.464

effects, which may include different sociodemographic situations and varying histories of community forestry development, state-sponsored forest management and policy implementation, although the dummy variable has no way of capturing what causes any observed effect. According to the survey by Kaimowitz and Angelsen (1998), regional level models are more realistic when they include physiogeographic variables. In recognition of this, we have included a measure of road density (total length of paved and unpaved roads divided by total area) and topographic roughness among the control variables. The marginalization index, percentage of population living in rural areas, percentage of indigenous population, and percentage of employed in agriculture were not highly correlated, so all four variables were included in the model.

Summary Statistics and Preliminary Observations

The rate of net forest loss in coniferous forests is 0.6% for the entire sample, from a high of 2.4% in Chiapas to a low of –0.6% in Puebla (see Table 2).[6] Almost invariably, net forest loss rates in nonconiferous forests are higher than those in coniferous forests, which concurs with another analysis of the NFI (Velazquez et al., 2002) and more recent data (FAO, 2010). One obvious exception is Michoacan, with rates of coniferous and nonconiferous net forest loss at 1.0% and 0.6% respectively. An explanation for this, as well as Michoacan's high rate of gross deforestation (2.3%), may be rapid deforestation in certain regions of coniferous forest with suitable climatic conditions for avocado production. Michoacan's relatively high rate of recovery (1.2%) can be explained by abandonment of agriculture where climatic conditions are not suitable for avocado production (Barsimantov & Navia-Antezana, 2011).

Preliminary results of common property forest and community forestry variables show that Oaxaca has by far the highest percentage of common property forest (79.8%) but one of the lowest percentages of community forests with permits for forest management (2.6%). This is surprising given the state's nationwide fame for community forestry. The low rate of community forestry in common property forests may be due to the due to steep mountain ranges and lack of road access in many parts of state which inhibit commercial extraction. Oaxaca has the highest topographic roughness index value and lowest road density of any of the eight states, which may confirm this hypothesis. In fact, this result is not contradictory to popular opinion of community forestry in Oaxaca, since the state is known for the positive outcomes of community forestry, rather than the percentage of its forests with community forestry. These two examples, in Michoacan and Oaxaca, suggest that distinct political economic and geographic processes are occurring within regions of our sample, even though general trends are also evident.

Our data set also allowed us to compute the total percentage of common property forest in these 733 municipalities, which we found to be 64.2%. For years, it has been assumed that 80% of forests in Mexico are common property; however, this figure is not based on field calculations. While our calculation does not include all forests in Mexico, these eight states have a higher percentage of all land area under common property (58.2%) as compared to the remaining states in Mexico (51.6%).[7] Therefore, while a more complete calculation would be necessary to make a claim for all of Mexico, it is likely that a national-level calculation would yield a lower percentage than in the eight state sample.

Regression Results

We conducted three sets of regressions using gross deforestation, recovery, and net forest loss as the dependent variable (Tables 3-5). Results tables are organized in matrices with and without state-level dummies crossed with the forest types of coniferous, nonconiferous, and both forest types combined. For example, in Table 3, regressions (1) to (3) do not have state-level dummies as controls while (4) to (6) do. Furthermore, in each table, regressions (1) and (4) feature estimates for coniferous forests on the left hand side, (2) and (5) feature nonconiferous forests, while (3) and (6) show estimates for both forest categories combined. In addition, we conducted a second run of the gross deforestation variable dividing the sample into southern and northern states to test predictions described below (Table 6). Finally, our right hand side variables are either expressed in percentage terms or as the natural log of the quantity indicated. Our method of regression is the standard ordinary least squares (OLS) regression technique, as is common in these types of analyses (Kaimowitz & Angelsen, 1998), reported with heteroskedasticity-robust *t* statistics.[8] We begin by reviewing results of control variables commonly used in analyses of deforestation before turning to our main variables of interest, common property and community forestry.

The literature surveyed in the introduction leads us to certain predictions about the relationship that some of our control variables (detailed in Table 1) will have with deforestation outcomes. In particular, we would expect to find higher rates

Table 3. Coefficients for Six Regressions on Drivers of Gross Deforestation in Mexico

	Coniferous forest deforestation	Nonconiferous forest deforestation	All forest types deforestation	Coniferous forest deforestation	Nonconiferous forest deforestation	All forest types deforestation
	Without state-level dummies			With state-level dummies		
	(1)	(2)	(3)	(4)	(5)	(6)
1990, % coniferous area	0.013 (0.6)			0.011 (0.4)		
Common property, coniferous	−0.052*** (−3.1)			−0.042** (−2.2)		
1990, % nonconiferous area		0.068*** (3.0)			0.034 (1.4)	
Common property, nonconiferous		0.0055 (0.3)			0.022 (1.2)	
1990, % of area, all types			0.083*** (3.7)			0.037 (1.5)
Common property, all types			−0.055*** (−3.6)			−0.043** (−2.5)
% community forestry	−0.013** (−2.2)	0.016 (0.5)	−0.020*** (−4.3)	−0.0088 (−1.6)	0.017 (0.6)	−0.015*** (−3.8)
Population density 1990	0.014** (2.3)	−0.00083 (−0.1)	0.016*** (3.2)	0.023*** (2.8)	0.0038 (0.5)	0.018*** (2.7)
Population growth	−0.027 (−0.9)	−0.051 (−1.2)	−0.042 (−1.6)	−0.035 (−1.1)	−0.063 (−1.6)	−0.044* (−1.7)
All road density	0.066*** (3.8)	0.064*** (4.1)	0.071*** (5.1)	0.038** (2.0)	0.043** (2.5)	0.051*** (3.4)
Marginalization Index	−0.11 (−1.3)	−0.088 (−1.0)	0.010 (0.1)	−0.095 (−1.1)	−0.034 (−0.4)	0.018 (0.3)
% population rural	0.049** (2.1)	0.029 (1.0)	0.036* (1.9)	0.062** (2.5)	0.050* (1.8)	0.049** (2.4)
% population indigenous	0.013 (0.5)	−0.030 (−1.5)	−0.024 (−1.4)	0.023 (0.9)	−0.011 (−0.6)	−0.0095 (−0.6)
% employed in agriculture	0.00023*** (2.6)	0.00063*** (4.7)	0.00031*** (3.7)	−0.000027 (−0.2)	0.00053*** (3.8)	0.00016 (1.6)
1990 unemployment	0.047 (0.4)	0.19 (1.2)	0.12 (0.9)	0.040 (0.3)	0.14 (0.8)	0.091 (0.6)
% population out-migrated	−0.61** (−2.0)	−0.22 (−0.6)	−0.29 (−1.1)	−0.25 (−0.9)	−0.11 (−0.3)	−0.15 (−0.6)
Topology Roughness Index	0.87* (1.7)	0.063 (0.1)	−0.66 (−1.4)	1.14** (2.2)	0.42 (0.8)	−0.12 (−0.3)
Constant	−0.34 (−1.1)	0.13 (0.3)	0.45 (1.5)	−0.47 (−1.4)	−0.22 (−0.6)	0.13 (0.4)
Observations	733	733	733	733	733	733
R^2	0.09	0.11	0.16	0.15	0.16	0.21

Note: LHS variable is by coniferous forest, nonconiferous, and all forest in (1) to (3). Regressions (4) to (6) repeat (1) to (3) and include state-level fixed effects. State dummy coefficients not reported, robust *t* statistics in parentheses.
$^{*}p < .1$. $^{**}p < .05$. $^{***}p < .01$.

Table 4. Coefficients for Six Regressions on Drivers of Forest Recovery in Mexico

	Recovery, % coniferous	Recovery, % nonconiferous	Recovery, % all forest	Recovery, % coniferous	Recovery, % nonconiferous	Recovery, % all forest
	Without state-level dummies			With state-level dummies		
	(1)	(2)	(3)	(4)	(5)	(6)
1990, % agriculture area	0.081 (0.4)	1.58 (1.1)	0.18*** (4.3)	0.016 (0.08)	1.92 (1.1)	0.17*** (3.8)
Common property, coniferous	0.16** (2.3)			0.15* (1.9)		
Common property, nonconiferous		–0.87 (–1.0)			–1.78 (–1.0)	
Common property, all types			0.025* (1.7)			0.013 (0.8)
% community forestry	–0.035* (–1.7)	–0.48 (–1.0)	–0.010 (–1.3)	–0.037* (–1.9)	–0.36 (–1.0)	–0.011 (–1.3)
Population density 1990	0.046* (1.8)	0.058 (0.7)	0.0023 (0.3)	0.045 (1.4)	0.21 (0.9)	–0.0042 (–0.5)
Population growth	0.12 (0.5)	0.63 (0.9)	–0.00060 (–0.02)	0.095 (0.3)	1.55 (1.0)	0.0082 (0.3)
All road density	0.042 (0.8)	1.12 (1.0)	0.016 (1.1)	0.050 (1.0)	1.61 (1.0)	0.030** (2.0)
Marginalization Index	0.71 (1.5)	2.29 (0.9)	0.060 (0.8)	0.80 (1.4)	2.39 (0.9)	0.025 (0.3)
% population, rural	–0.067 (–0.6)	0.30 (0.7)	–0.0058 (–0.3)	–0.12 (–1.0)	0.26 (0.6)	–0.012 (–0.5)
% population, indigenous	–0.11 (–1.1)	–1.32 (–1.0)	–0.0098 (–0.4)	–0.16 (–1.4)	–2.15 (–1.0)	–0.016 (–0.6)
% employed in agriculture	–0.00044 (–1.4)	–0.0059 (–1.0)	–0.00019*** (–2.9)	–0.00041 (–1.3)	0.000037 (0.03)	–0.000056 (–0.9)
1990 unemployment	0.79 (0.6)	13.7 (0.9)	0.22 (1.1)	1.00 (0.8)	14.2 (0.9)	0.24 (1.2)
% population out-migrated	0.35 (0.2)	–22.9 (–1.0)	–0.035 (–0.10)	0.73 (0.4)	–30.8 (–1.0)	–0.26 (–0.7)
Topology Roughness Index	–0.85 (–0.4)	0.30 (0.08)	0.49 (1.2)	–1.29 (–0.5)	–5.87 (–0.8)	0.28 (0.6)
Constant	–0.94 (–0.5)	–6.18 (–0.9)	–0.49 (–1.6)	–0.68 (–0.3)	–3.04 (–0.6)	–0.29 (–0.9)
Observations	733	733	733	733	733	733
R^2	0.03	0.02	0.12	0.04	0.04	0.13

Note: LHS variable is recovery by coniferous forest, nonconiferous, and all forest in (1) to (3). Regressions (4) to (6) repeat (1) to (3) and include state-level fixed effects. State dummy coefficients not reported, robust *t* statistics in parentheses.
*$p < .1$. **$p < .05$. ***$p < .01$.

Table 5. Coefficients for Six Regressions on Drivers of Net Forest Cover Loss in Mexico

	Net deforestation, coniferous	Net deforestation, nonconiferous	Net deforestation, all forest	Net deforestation, coniferous	Net deforestation, nonconiferous	Net deforestation, all forest
	Without state-level dummies			With state-level dummies		
	(1)	(2)	(3)	(4)	(5)	(6)
1990, % coniferous area	0.022*** (2.8)			0.023*** (2.8)		
Common property, coniferous	–0.0099** (–2.4)			–0.0078* (–1.8)		
1990, % nonconiferous area		0.060* (1.9)			0.043 (1.2)	
Common property, nonconiferous		–0.053** (–2.4)			–0.036 (–1.6)	
1990, % area, all types			0.022*** (5.4)			0.019*** (4.3)
Common property, all types			–0.0083*** (–3.9)			–0.0060*** (–2.7)
% community forestry	–0.0011 (–1.3)	0.024 (1.1)	–0.0012* (–1.7)	–0.00012 (–0.1)	0.026 (1.1)	–0.00077 (–1.0)
Population density 1990	0.00017 (0.1)	–0.027*** (–2.6)	–0.0000079 (–0.010)	0.0031 (1.6)	–0.0041 (–0.3)	0.0016 (1.5)
Population growth	–0.012 (–1.3)	0.065 (0.9)	–0.0035 (–0.8)	–0.014 (–1.5)	0.047 (0.7)	–0.0049 (–1.2)
All road density	0.0010 (0.3)	0.039 (1.6)	0.0056*** (2.7)	–0.0040 (–1.2)	0.014 (0.5)	0.0020 (0.9)
Marginalization Index	–0.0056 (–0.2)	0.0095 (0.07)	–0.014 (–1.3)	0.0033 (0.09)	0.16 (1.0)	–0.0073 (–0.6)
% population, rural	0.0032 (0.7)	–0.013 (–0.3)	0.0034 (1.1)	0.0070 (1.5)	0.0076 (0.2)	0.0056* (1.8)
% population, indigenous	–0.0056 (–0.6)	–0.0051 (–0.1)	–0.000091 (–0.03)	–0.0042 (–0.4)	0.0026 (0.06)	0.0018 (0.6)
% employed in agriculture	0.000063*** (4.2)	0.00069*** (4.5)	0.000052*** (4.4)	0.000019 (1.1)	0.00048*** (3.1)	0.000020* (1.7)
1990 unemployment	0.011 (0.3)	0.026 (0.3)	–0.012 (–0.4)	0.0045 (0.1)	–0.046 (–0.4)	–0.018 (–0.6)
% population out-migrated	0.0085 (0.1)	–0.77 (–1.3)	–0.032 (–0.7)	0.081 (1.1)	–0.37 (–0.6)	0.013 (0.3)
Topology Roughness Index	0.018 (0.2)	0.42 (0.7)	–0.12* (–1.8)	0.051 (0.6)	0.63 (1.1)	–0.064 (–1.0)
Constant	2.30*** (35)	–0.38 (–0.9)	2.40*** (52)	2.27*** (31)	–0.82* (–1.8)	2.36*** (49)
Observations	733	726	733	733	726	733
R^2	0.04	0.06	0.12	0.07	0.09	0.17

Note: LHS variable is by net forest cover loss in coniferous forest, nonconiferous, and all forest in (1) to (3). Regressions (4) to (6) repeat (1) to (3) and include state-level fixed effects. State dummy coefficients not reported, robust *t* statistics in parentheses.
$^{*}p < .1$. $^{**}p < .05$. $^{***}p < .01$.

Table 6. Coefficients for Six Regressions on Drivers of Gross Deforestation in Mexico

	Coniferous deforestation		Nonconiferous deforestation		All deforestation	
	Southern	Northern	Southern	Northern	Southern	Northern
	(1)	(2)	(3)	(4)	(5)	(6)
1990, % coniferous area	0.014 (0.5)	0.012 (0.3)				
Common property, coniferous	–0.052** (–2.6)	–0.0093 (–0.2)				
1990, % nonconiferous area			0.058** (2.3)	0.019 (0.3)		
Common property, nonconiferous			0.023 (1.4)	–0.015 (–0.3)		
1990, % area, all types					0.088*** (3.1)	0.12** (2.5)
Common property, all types					–0.045*** (–2.6)	–0.029 (–1.0)
% community forestry	–0.015*** (–3.3)	–0.0016 (–0.1)	0.017 (0.5)	–0.0074 (–0.3)	–0.022*** (–4.4)	–0.021 (–1.2)
Population density 1990	0.015 (1.6)	0.019* (1.9)	0.0019 (0.2)	0.037*** (3.1)	0.019** (2.4)	0.024*** (3.2)
Population growth	–0.039 (–1.1)	0.036 (0.8)	–0.049 (–1.0)	–0.092 (–1.6)	–0.049 (–1.6)	–0.026 (–0.7)
All road density	0.077*** (3.4)	–0.017 (–0.7)	0.075*** (4.0)	–0.031 (–0.9)	0.085*** (4.8)	–0.017 (–0.7)
Marginalization Index	–0.046 (–0.4)	0.073 (0.4)	0.00057 (0.005)	0.48 (1.3)	0.069 (0.8)	0.38 (1.3)
% population, rural	0.043 (1.6)	0.022 (0.4)	0.0044 (0.1)	0.069 (1.2)	0.018 (0.8)	0.028 (0.6)
% population, indigenous	0.0065 (0.2)	0.043 (0.6)	–0.027 (–1.3)	–0.14 (–0.8)	–0.027 (–1.5)	–0.12 (–1.0)
% employed in agriculture	0.00020** (2.1)	0.00016 (0.6)	0.00065*** (4.4)	0.00023 (1.0)	0.00029*** (3.2)	0.00020 (1.0)
1990 unemployment	0.023 (0.2)	0.44 (1.3)	0.17 (1.0)	0.040 (0.08)	0.11 (0.7)	0.23 (0.6)
% population out-migrated	–0.40 (–1.1)	–1.32*** (–3.0)	–0.10 (–0.2)	–0.22 (–0.3)	–0.23 (–0.7)	–0.27 (–0.6)
Topology Roughness Index	1.13* (1.9)	–2.05** (–2.2)	0.44 (0.8)	–2.32 (–1.4)	–0.39 (–0.8)	–4.35*** (–3.1)
Constant	–0.70* (–1.7)	1.44*** (2.8)	–0.36 (–0.8)	0.79 (0.9)	0.11 (0.3)	2.36*** (3.4)
Observations	592	141	592	141	592	141
R^2	0.11	0.12	0.13	0.10	0.18	0.17

Note: LHS variable is by coniferous forest, nonconiferous, and all forest. Sample is restricted in each pair—Northern states (Chihuahua, Durango, Jalisco) versus Southern states (Chiapas, Oaxaca, Puebla, Guerrero, Michoacan). Robust *t* statistics in parentheses.
*$p < .1$. **$p < .05$. ***$p < .01$.

of deforestation in municipalities that have high population density, a high share of agricultural labor, greater road access, and a larger fraction of the population living in rural areas. This is what we find in Table 3, which presents the results of our most central regression specification, using gross deforestation rate as the dependent variable. Specifically, we can see that higher road density is associated with higher rates of deforestation in coniferous, nonconiferous, and combined forest categories, and this variable is significant in five of the six regressions in Table 3. Higher population density is related to higher gross deforestation in coniferous forests, a relationship that is also significant in the combined forest category but not in nonconiferous forests. A higher percentage of the population employed in agriculture is also associated with higher gross deforestation in all forest type categories when state-level dummies are included, but the impact of this variable is statistically significant only in coniferous forests when state-level dummies are dropped. Finally, the ratio of the population living in rural areas has a positive and significant relationship with gross deforestation in several regressions.

These results are expected by theory and are similar to previous studies cited above both in Mexico and in other regions. Tables 4 and 5 show the impact these variables have on the recovery margin and on net deforestation, respectively. Theory and prior literature have little to say about how these variables would affect the forest recovery rate and we find that they are not significant in many of the regressions. Where they are significant in the net deforestation regressions, they are of the same sign as in the gross deforestation regressions.

It is interesting to note results for certain variables that are not significant in our regressions but for which strong predictions have been made in the literature. The deforestation literature often predicts that higher income levels will results in more deforestation as more capital is available for investments in alternative land uses (see for example Barbier & Burgess, 1996; Capistrano, 1990; Krutilla, Hyde, & Barnes, 1995); however, the evidence is not consistent across studies (Angelsen & Kaimowitz, 2002). We do not find a significant effect for unemployment or for the marginalization index in any of our main specifications, although correlation with other independent variables may be responsible for this result.[9] We also do not find population growth to be significant in any regression except in (6) of Table 3 where it has the opposite of the expected sign and is significant only at the 10% level. As found in our analysis, population density is often found to be associated with deforestation (see for example Barbier & Burgess, 1996; Pfaff, 1997; Southgate et al., 1991); however, results for population growth are mixed in the literature (see for example Cropper & Griffiths, 1994; Inman, 1993; Palo & Mery, 1996; Rock, 1996). While migration variables have not been used extensively, anecdotal reports from managers and policy makers in Mexico suggest that areas with significant out-migration suffer less deforestation and greater recovery as agricultural lands are abandoned. We find out-migration to have the expected negative sign in all regressions, but it is only significant in (1) of Table 3. We also find that the terrain roughness index, a good measure of the land's accessibility and alternative agriculture value, has a negative sign and is significant in (3) of Table 5 (net deforestation) but is positive in (1) and (5) of Table 3 (gross deforestation).

This mixed result is in contrast with Deininger and Minten (2002) who find that physiogeographic variables are the best predictor of deforestation. One explanation for this result is that our data are aggregated at the municipality level, which may mask the importance of the relationship between topography and deforestation. Another explanation may be that low-lying areas well suited for agriculture may have been previously deforested, and thus steeper areas are now being converted. Therefore, a flat, deforested municipality may have a very low deforestation rate while a steeper, less deforested municipality may have a higher rate.

Finally, we turn to our main variables of interest: the proportion of forest that is common property and the proportion of common property forest that is in community forestry. Confirming one of our central hypotheses, in Table 3 the relationship between coniferous gross deforestation and percentage of forests under common property is negative and significant (regressions (1) and (4)); a higher proportion of common property forest is related to lower rates of deforestation. The same is true in the combined forest regressions, (3) and (6). However, with nonconiferous deforestation on the left hand side (regressions (2) and (5)) the relationship is not significant, suggesting that common property in nonconiferous forest is not associated with lower deforestation rates. Table 4 shows that the common property variable is also associated with increases in coniferous and combined forest recovery.

A similar pattern emerges in the percentage of common property forest in community forestry, our second variable of interest. Results for this variable show that a higher proportion of community forestry is significantly related to lower gross deforestation in regressions (1), (3), and (6) of Table 3. Perhaps surprisingly, the percentage of community forestry is negatively associated with coniferous forest recovery, suggesting that community forestry may not contribute to recovery. One potential explanation may be that both community forestry and agriculture occur in economically active areas, and thus agricultural fields are not being replaced with forests.

The fact that the results regarding the common property and forest management variables are robust to the inclusion of state-level dummies indicates that differences in state-level policies, management, enforcement, and outreach are not driving these results. These state-level factors would have been primary candidates to confound the causal interpretation of these results. This result is striking because it suggests that socioeconomic, demographic, and geographic factors may be more important drivers of deforestation than policy and governance variables. However, because Mexico has a strong central government, federal policies may in fact play an important role in land use patterns, while state-level policies may not be very important. Implementation of federal policies could have important impacts under different socioeconomic, demographic, and geographic situations at a substate level. The one exception is in Table 5, where community forestry ceases to be significantly related to reduced net deforestation in all forest types combined when state-level dummies are included.

Table 6 shows the results of regressions conducted in two subsamples created by taking the northern states of Chihuahua, Durango, and Jalisco as one subsample and the southern states of Oaxaca, Chiapas, Guerrero, Puebla, and Michoacan as the other subsample. We hypothesized that the relationships between forest cover change and

Table 7. Magnitude of Impact of Common Property and Community Forestry Variables

	% common property, coniferous	% common property, nonconiferous	% common property, all forest types	% community forestry
Interquartile range	67.28%	73.91%	59.20%	4.48%
Coefficient	–0.052	0	–0.055	–0.2
Impact (reduction in annual deforestation rate)	–0.50%	0.00%	–0.47%	–0.13%

Note: Variables expressed as the approximate reduction in annual rate of gross deforestation induced by changing the variable of interest by a value equivalent to its interquartile range within the sample. Coefficients are point estimates from regressions (1) to (3) in Table 1.

community forestry and common property may be more noticeable in southern states than in northern states. Field research conducted by the first author led to this hypothesis; conversations with policy makers and forestry specialists suggested that community forestry institutions are stronger in the Oaxaca and other southern states with relatively older community institutions that were less disrupted by the Spanish conquest and subsequent settlement. Our results confirm these anecdotal reports: the results presented with all states combined generally hold in southern states but not northern states.

In summary, these regressions indicate that common property and community forestry both reduce the gross and net rates of deforestation and increase the rate of forest recovery of coniferous forests. The evidence also indicates these institutions have little impact on deforestation or recovery of nonconiferous (mostly oak and tropical) forests in study municipalities. This conclusion is in line with our hypothesis that increased value of forests may lead to less deforestation. As nonconiferous forests in these states have little commercial timber value, it is not surprising that only coniferous forests have significant results.

Magnitude of the Measured Effects

The previous section shows statistically significant results indicating that higher percentages of forest under common property regimes and higher rates of community forestry are associated with reductions in deforestation and increases in forest recovery. Statistically significant results do not imply that the effect is large enough to be meaningful in a practical sense; however, Table 7 shows just how important these variables are. The impacts are assessed by calculating the implied reduction in the annual rate of deforestation that would occur in a municipality that increased its common property coverage or community forestry coverage by an amount equal to the interquartile range of these variables in the sample. Essentially, we compare the implied difference between a municipality at the 25th percentile to one at the 75th percentile in the distribution of the variable in question, with all other characteristics set equal. We find that the municipality at the 75th percentile of coniferous forest common ownership would reduce its rate of coniferous deforestation by approximately 0.51% per year relative to the 25th percentile, and that a municipality moving to the 75th percentile of common forest under a management plan would reduce its deforestation by a further 0.07% per year (taking as given the level of common property to be managed). Reductions of this magnitude imply very significant changes in outcomes given that the annualized gross rate of coniferous deforestation in these municipalities was 1.8% per year.

Conclusions

The evidence presented here indicates that common property and community forestry are significantly related to reduced rates of deforestation and increased rates of forest recovery of coniferous forests in Mexico. The evidence also indicates these institutions have little impact on deforestation or recovery of nonconiferous (mostly oak and tropical) forests. One lens through which to view our findings is that we assess the difference in deforestation outcomes in forests where policies intended to manage and protect forests are implemented only by the state versus in a nested system of local and state governance using common property institutions. Since our results indicate reduced deforestation in forests under a common property regime, we suggest that the nested system of governance is more effective in general in maintaining forest cover. This is the case in Mexico and many other developing countries where state-enforced environmental laws are insufficient to protect forests, and local governance plays a critical role. Recently, government figures show a decline in deforestation rates in Mexico, which have reduced overall rates in temperate forests to nearly zero (FAO, 2010). While many factors clearly play a role in this shift, and the research presented here is based on data prior to this decline, this article provides evidence that community forestry plays a role in reducing deforestation in Mexico.

Though there are different possible causal mechanisms to explain our findings, we favor our hypothesis that common property can lead to greater forest conservation when there is an economically valuable asset to protect (coniferous forests) and when there are management plans in place to formalize the extraction process and the revenue distribution. However, when the standing forest has little value and/or when institutions do not exist, increased deforestation may occur. As we found that common property and forest management are related to reduced deforestation only in coniferous forests, which have higher value than other forest type in these states, we suggest that in general common property institutions are playing a role in conserving forest cover.

In addition, it seems that community forestry programs may not have these effects in areas where common property institutions are known to be weaker due to historical factors and lack of government attention to community forestry development, such as in many parts of northern Mexico. This suggests that not all community forestry programs have desired conservation impacts, and that the outcome may depend critically on local social capital and other governance factors which our coarse-scale study cannot detect. Results from related research on eleven forest communities in Michoacan and Oaxaca explore these relationships further and confirm many of our interpretations (Barsimantov, 2009).

This finding coincides with a study of forest condition (measured through basal area and species diversity), which found that state harvesting bans do not sustain forest condition, while local use rights result do (Coleman, 2009). However, we conclude that a common property regime results in reduced deforestation, while Coleman finds the opposite for forest condition. Therefore, we note that simply maintaining forest cover may not be equivalent to maintaining the structure and function of those forests.

It should be recognized that our results are partial correlations and do not inevitably imply causality, as is often the case with OLS regressions. However, the fact that they are robust to the inclusion of many of the standard control variables as well as state-level dummies, and that the pattern of slopes fits our theoretical model of how community forestry will play out in high and low value forests, strengthens the case for interpreting the regression parameters as the causal impact of greater rates of common property and managed forest areas.

In addition, the use of NFI data in this study presents a potentially serious set of limitations. The inventories of 1993 and 2000 were conducted by different agencies using different categories of land cover types. As this study combines most forest types, the use of multiple categories is less of an issue. However, the coarse scale at which these data were created presents the potential for error especially in smaller municipalities, such as those in Oaxaca. In addition, different methods at the agencies may result in data that is not comparable. One way to determine whether our results reflect reality or are a product of a flawed dataset is to repeat this study using more accurate data. Related research by the first author classifies Landsat TM satellite images to answer similar questions to those posed here (Barsimantov, 2009), and finds similar results, although over a smaller geographic range.

A final weakness in our model is the potential for endogeneity of institutional choice. The percentage of forested land in any municipality is the result of past decisions made by communities. The choice to participate in community forestry is also based on the institutional strength of the community and forest quality. Both of these are related to deforestation rates, and thus present potential issues for interpreting results. We can conclude confidently that areas with high levels of common property and community forestry have performed well as compared to other areas. However, the issue described above prevents us from concluding that implementing common property regimes or community forestry in other areas will be as successful.

Deforestation continues at a high pace in Mexico's forests; however, it is clear that land cover change processes are impacted significantly by local economic, social, geographical, and institutional factors. In general, our results lend credence to the notion that common ownership of forests and a higher prevalence of community based forestry management plans both serve to reduce deforestation and promote forest recovery in forest types that have economic value. In addition, the measured impacts of these variables from our OLS regressions imply large and economically significant effects from common forest ownership and management.

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Notes

1. The figure 80% of all forests commonly owned is used widely in the literature; however, this figure has never been substantiated. More recent estimates, including one based on calculations in this study, suggest that roughly 60% to 65% of all forests are commonly owned.
2. Cutoffs of 100 ha and 200 ha were also used in initial analysis of the data, and results were unchanged.
3. Calculated from the National Survey of Community-Managed Forestry in Mexico database (Phase 1). Principal Investigators: Camille M. Antinori, Juan Manuel Torres-Rojo, Octavio Magaña, David B. Bray, 2006. Data collected from 2003 to 2005.
4. The statistic on the percentage of authorized oak actually harvested pertains only to the state of Michoacan; however, interview data suggest that this figure is probably similar throughout the country. Calculated from a database of forestry reports from all communities from 1993 to 2004 in the state of Michoacan, compiled by James Barsimantov and Jaime Navia Antezana.
5. National Survey of Community-Managed Forestry in Mexico (Phase 1), Antinori et al., 2004.
6. The table provides the mean values of all municipalities in each state, rather than the overall mean of each state. This also explains why the total percentage of forest commonly owned stated in the text differs from that in the table and why deforestation minus recovery does not exactly equal net change.
7. Calculated using 2001 Edijo Census from the National Institute of Statistics, Geography, and Information (INEGI).
8. Heteroskedasticity-robust *t* statistics are calculated using the standard Huber/White/sandwich method.
9. The only exception is that unemployment is significant at 10% level in one regression.

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Bios

James Barsimantov is a project scientist and lecturer at University of California, Santa Cruz, United States, as well as a cofounder and principal at EcoShift Consulting. He completed his dissertation in the Environmental Studies Department at UCSC in 2009 where his research focused on community forestry in Mexico and its potential to reduce deforestation and improve livelihoods.

Jake Kendall, a program officer at the Bill & Melinda Gates Foundation, holds a PhD in international economics from University of California. His dissertation focused on the economic importance of banking sector outreach in developing economies. He also served as an economist for the Analysis and Indicators Team at CGAP and as a World Bank intern.