Environment for Development

Discussion Paper Series August 2015 ■ EfD DP 15-19

Does Eco-certification Stem Tropical Deforestation?

Forest Stewardship Council Certification in Mexico

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Abstract

Since its creation more than two decades ago as a voluntary market-based approach to improving forest management, forest certification has proliferated rapidly in developing countries. Yet we know little about whether and under what conditions it affects deforestation. We use rich forest management unit-level panel data—including information on deforestation, certification, regulatory permitting, and geophysical and socioeconomic land characteristics—along with matched fixed effects models to identify the effect of Forest Stewardship Council (FSC) certification on deforestation in Mexico, the country with the third-highest number of FSC certifications in the developing world. We test for a variety of different temporal and subgroup effects but are unable to reject the null hypothesis that certification does not affect deforestation. Although these results do not indicate that FSC certification has no effect on forest management, they do suggest that its impact on deforestation may be limited.

Key Words: eco-label, certification, forest cover change, Mexico

JEL Classification Numbers: Q23, Q56, Q57

Contents

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1. Introduction

Since its creation more than two decades ago, forest certification has proliferated in developing countries. Forest Stewardship Council (FSC), the leading forest eco-labeling initiative in the tropics, now has certified more than 28 million hectares in 53 developing countries (FSC 2014a). Although FSC standards cover a wide range of issues and have evolved over time, environmental protection—and in particular stemming tropical deforestation—was an important motive for founding the initiative and has remained a central theme (FSC 2012; Cashore et al. 2006b; Humphreys 1996).

In principle, FSC and other types of forest certification can generate nonregulatory incentives for sustainable forest management, thereby sidestepping the problems of weak institutions and limited political will that often undermine conventional environmental policy initiatives in developing countries (Auld and Gulbrandsen 2013; Cashore et al. 2006a; Meidinger et al. 2003). According to advocates, the principal nonregulatory motivations are economic. Certification allows consumers and creditors to select "green" producers and boycott others. That selection, in turn, facilitates price premia and/or improved access to output and credit markets. And those private economic benefits motivate producers to either improve their environmental performance or—in the case of already-green producers—prevent it from slipping. In addition to these private economic incentives, certification may help disseminate technical information

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Acknowledgements: Funding for this project was provided by the Tinker Foundation, the National Space and Aeronautics Administration SERVIR Applied Sciences Team, and the Swedish Research Council, Formas, through the Human Cooperation to Manage Natural Resources program. We are grateful to Alfredo Cinsneros, Elizabeth Gallardo, Ana Malinosvskaya, Jimena Rico Staffon, Mavial Sarai Velazquez, and Juan Manuel Torres Rojo for help assembling our permit data; Jessica Chu for GIS assistance; William Crosse, David Hughell, Adolfo Lemus, Deanna Newsom, and Alicia Raimondi for assistance with certification data; Joyce Bond for editorial assistance; and Fred Cubbage, Jack Putz, Claudia Romero, Roger Sedjo, Laura Villalobos, and seminar participants at Centro de Investigación y Docencia Económias and the European Association of Environmental and Resources Economics annual meetings for helpful comments and suggestions. Remaining errors are our own.

about best management practices and mold private and public sector actors' environmental preferences and standards (Romero et al. 2013; Rickenbach and Overdevest 2006). On the basis of such arguments, national governments, bilateral donors, and leading multilateral agencies, such as the Global Environment Facility and World Bank, have devoted considerable resources to promoting forest certification in developing countries and increasingly are interested in using it for reducing greenhouse gas emissions from deforestation and forest degradation—that is, for REDD (Brotto et al. 2010; FSC 2011).

Despite the increasing use of forest certification in developing countries, we still know little about whether, under what conditions, and how it affects forest cover change (Romero et al. 2013; Milder et al. 2012; Miteva et al. 2012; Blackman and Rivera 2011). To help fill that gap, we use fine-scale panel data on forest cover change along with empirical methods aimed at controlling for self-selection bias (fixed effects and matching) to measure the effect of FSC certification on deforestation in Mexico. We focus on Mexico because it is a critical location for FSC certification. Historically, Mexico has had one of the highest deforestation rates in the world, and it currently has 48 FSC-certified forests, the third-highest number in the developing world (FAO 2011; FSC 2014a). As discussed below, to our knowledge, ours is among the first econometric analyses of the environmental benefits of forest certification to use panel data techniques to control for unobserved confounding factors and the first to focus on Mexico.

The remainder of the paper is organized as follows. The next section briefly reviews the literature evaluating the effects of FSC forest certification on forest management and environmental outcomes. The third section provides background on Mexico and FSC certification. The fourth section describes our empirical methods. The fifth section discusses our data. The sixth section presents our results. And the last section sums up and considers policy implications.

2. Literature

Although forest certification has attracted considerable attention in the literature, rigorous empirical evaluations are scarce (Romero et al. 2013; Miteva et al. 2012; Milder et al. 2012; Blackman and Rivera 2011). At least three approaches have been used to shed light on the environmental effects of forest certification: quantitative evaluations based on direct observation, interviews with forest managers, and analyses of corrective action requests (CARs). Below, we discuss each type in turn. In general, the literature is thin and findings are mixed. Studies that do not control for self-selection effects (discussed below) and those that focus on the United States generally reach more optimistic conclusions about certification's benefits.

Quantitative evaluations based on direct observation of environmental outcomes typically measure the effect of certification by comparing average outcomes for samples of certified and uncertified forest management units (FMUs). The main challenge is controlling for the tendency of FMUs that already manage their forests sustainably to disproportionately obtain certification because they need not make dramatic changes to production practices or on-the-ground conditions to meet certification criteria. Studies that fail to control for this self-selection typically generate overly optimistic conclusions: in effect, they attribute the superior average environmental performance of certified producers to certification when it actually reflects their preexisting characteristics.

To our knowledge, only six quantitative studies of the environmental effects of forest certification—two published and four unpublished—attempt to control for selection effects. However, all but one use cross-sectional data (along with regression or matching) and therefore only purport to control for observable confounding factors, not unobserved ones. The exception is Miteva et al. (2015). Using a matched difference-in-differences estimator along with three-period deforestation data derived from MODIS satellite images, they find that FSC certification in Kalimantan, Indonesia, reduces deforestation but increases forest perforation. As for the other studies, relying on cross-sectional regulatory inspection data, Nordén et al. (2015) find that neither FSC nor Programme for the Endorsement of Forest Certification (PEFEC) certification reduces noncompliance with regulations governing high conservation value areas in Sweden. Using matching along with cross-sectional deforestation derived from Landsat satellite images, two recent master's theses, by Rico Staffron (2015) and Panlasigui (2015), find that FSC certification in Peru and Cameroon does not stem deforestation. Relying on regression, Kukkonen et al. (2008) find that although FSC-certified forest plots in northern Honduras used more environmentally friendly practices, tree regeneration was actually lower on certified plots than on conventional ones. And finally, using matching, Barbosa de Lima et al. (2009) find that FSC certification in the Brazilian Amazon has minor effects on a range of environmental outcomes, which they attribute to the tendency of top-performing FMUs to obtain certification.

Not surprisingly, quantitative studies based on direct observation that do not control for self-selection generate more optimistic results. For example, Simpson et al. (2005) find that in the United States, implementation of best management practices was significantly higher when the timber was delivered to a mill certified by the Sustainable Forestry Initiative (SFI). And Hagan et al. (2005) find that landowners in the United States who were certified by either SFI or FSC had stronger biodiversity practices than uncertified landowners.

Interviews with forest managers and other stakeholders also have been used to assess the environmental effects of forest certification. Ebeling and Yasue (2009) examine FSC certification in Ecuador and Bolivia using semistructured interviews with certified and uncertified timber companies and landowners (among others). They conclude that certification is unlikely to have significant environmental benefits in developing countries that, like Ecuador, have limited governance capacity in the forestry sector. By contrast, Moore et al. (2012) examine FSC and SFI certification in the United States and Canada using email surveys of certified FMUs. They conclude that certification prompted substantial changes in forest management practices.

Finally, several papers have used CARs issued after third-party inspections of FSC-certified FMUs to shed light on the environmental effects of FSC certification. CARs detail the changes in procedures and on-the-ground conditions that land managers must make to either obtain a new certification or retain an existing one. Therefore, they provide insight into how FSC certification affects forest management. Nebel et al. (2005), Rametsteiner and Simula (2003), and Blackman et al. (2014) are most equivocal about these effects. For example, Nebel et al. (2005) find that most CARs issued to certified FMUs in Bolivia in the late 1990s and early 2000s focused on minor noncompliance that was easily corrected—likely because certified FMUs were top performers before certification—and as a result, certification probably generated "only small direct improvement in management." And Blackman et al. (2014) analyze more than 1,000 CARs issued to 35 Mexican FMUs. They find that most CARs addressed minor procedural issues and focused on social, economic, and legal issues rather than on-the-ground environmental changes.

Analyses of CARs by Newsom and Hewitt (2005), Newsom et al. (2006), and Peña-Claros et al. (2009) paint a more optimistic picture of certification's environmental effects. For example, Newsom and Hewitt (2005) examine CARs from 129 randomly selected FSC-certified FMUs in 21 countries in five regions (stratified by region) and find that most CARs required substantive on-the-ground changes. As a result, they conclude that certification does change behavior and is not simply a rubber stamp for already-green FMUs. And Peña-Claros et al. (2009) examine CARs issued to 123 FMUs in 10 tropical Latin American and Caribbean countries and find that the number of times a given issue was mentioned was lower in recertification reports than in certification reports, suggesting an improvement in forest management over time.

3. Background

3.1. Mexico's Forests

Mexico's forests, more than half of which are primary, comprise 65 million hectares, one-third of the national territory (FAO 2011). The majority are governed by more than 2,000 communal FMUs, a legacy of the agrarian reform that accompanied the Mexican revolution (FAO 2011; Madrid et al. 2010; Bray et al. 2006). The two principle types of communal FMUs are comunidades, which are indigenous communities with historical ties to land, and ejidos, which are composed of peasants granted land through the reform process. Most of these communal FMUs, particularly the smaller ones, lack the capacity for sustainable forest management (Anta Fonseca 2006).

Historically, deforestation and forest degradation have been severe problems in Mexico. Between 1990 and 2000, clearing of all types of forests averaged more than one-half of 1 percent per year and caused the seventh-highest net annual forest loss of any country in the world (FAO 2011). During the same period, clearing of primary forests averaged more than 1 percent per year (FAO 2011). Deforestation and forest degradation have contributed to a host of local and global environmental problems, including soil erosion, aquifer depletion, diminished biodiversity, and global warming (Cervigni and Brizzi 2001). Although deforestation at the national level has slowed significantly since 2000, rapid forest cover loss continues to plague some regions (Madrid et al. 2010).

As in many countries, Mexico's system of forest regulation emphasizes permits and management plans. To extract timber, FMUs, including comunidades and ejidos, are required to obtain permits from state offices of the National Environment Ministry (*Secretaría de Medio Ambiente y Recursos Naturales*, SEMARNAT). That, in turn, requires that they develop a forest management plan, typically with the assistance of a consulting forester. Among other things, permits specify the amount, type, and location of trees extracted each year, and the silvicultural system used to do so. State offices of the National Environmental Attorney General (*Procuraduía Federal de Protección Ambiente*, PROFEPA) have responsibility for monitoring compliance with SEMARNAT permits. However, during our 2001–2012 study period, particularly the early years, funding and manpower allocated to that task were insufficient (OECD 2003)

3.2. Forest Stewardship Council Certification

3.2.1. Forest Stewardship Council International

Founded in 1993, in the wake of the failure of participants in the 1992 Rio Earth Summit to agree on an international convention to stem tropical deforestation, FSC International was intended to provide a voluntary market-based approach to the problem (FSC 2014b). A nonprofit association with a diverse set of member organizations, FSC states that its mission is to "promote environmentally appropriate, socially beneficial, and economically viable management of the world's forests" (FSC 2014b).

At the heart of FSC initiative is a set of 10 International Principles along with dozens of more detailed Criteria, to which FMUs and other institutions must adhere in order to obtain certification (Appendix 1). FSC's International Principles and Criteria have evolved since they were first published in 1994. In its most recent incarnation, the 10 International Principles concern the following:

i. Compliance with laws

ii. Workers' rights and employment conditions

iii. Indigenous people's rights

iv. Community relations

v. Benefits from forests

vi. Environmental values and impacts

vii. Management planning

viii. Monitoring and assessment

ix. High conservation value forests

x. Implementation of management activities

More than two dozen countries, including Mexico (2009), have developed national FSC standards that provide locally appropriate indicators for each international criterion.

FSC does not accredit individual FMUs. Rather, independent certifying bodies do that. Certifying bodies are themselves accredited to ensure they follow FSC rules and operating procedures. Certifying bodies audit FMUs prior to certification to determine whether they conform with FSC criteria. Certification is valid for five years. During that period, certifying bodies inspect FMUs each year to ensure continued conformance. Failure to correct nonconformance expeditiously can result in revocation of certification.

FSC issues three main types of certification. Forest management certification is issued to FMUs; chain of custody certification to manufacturers, processors, and traders; and controlled wood certification to both sets of parties (to allow them to mix FSC-certified and certain types of uncertified wood). Our analysis focuses only on forest management certification.

3.2.2. Forest Stewardship Council in Mexico

This subsection is drawn from Anta Fonseca (2006), which reviews the history of FSC certification in Mexico. In Mexico, FSC certification began in the mid-1990s and was spearheaded by two nongovernmental organizations that operated as certifying bodies: the Mexican Civil Council for Sustainable Silviculture (*Consejo Civil Mexicano para la Silvicultura Sostenible*, CCMSS), which focused on community forestry, and Rainforest Alliance's SmartWood program. Early certification efforts received considerable external support, including from the World Bank, the Ford Foundation, the InterAmerican Foundation, and the Packard Foundation. Early efforts to promote FSC certification in Mexico focused on FMUs already exhibiting superior forest management and environmental performance, not those in which serious forest management issues, including deforestation, biodiversity loss, and illegal logging, were prevalent.

Two factors drove certification in the 1990s and early 2000s. One was a deliberate campaign by regulatory agencies, specifically the Environment Ministry and, within that ministry, the Forest Agency (*Comissión Nacional Forestal*, CONAFOR), which viewed FSC certification as a strategy for compensating for chronic gaps in resources and capacity for conventional command-and-control forest regulation. These institutions provided a variety of economic and regulatory incentives for FMUs to obtain FSC certification. The geographic focus of these efforts was southern Mexico, specifically Oaxaca and to a lesser extent Quintana Roo. The second driver of certification was market pressure. FMUs in northern Mexico, specifically Durango, were interested in FSC certification to access European markets. Since 1996 at least 100 Mexican FMUs obtained FSC forest management certifications. Most, however, have not been maintained. As noted above, today Mexico has 48 active forest management FSC certifications, the third-highest number in the developing world.

4. Empirical Approach

The principle challenge to identifying the effect of FSC certification on deforestation is controlling for the self-selection effects noted above. For example, as we shall see, compared with uncertified FMUs in our sample, certified ones are more likely to have lower population densities and to be farther from cities, observable characteristics typically negatively correlated with deforestation. More importantly, certified FMUs in our sample are likely to be disproportionately composed of those with unobserved features that affect deforestation, including management skill and environmental attitudes. Failure to control for selection on such observable and unobservable FMU characteristics risks conflating the causal effects of certification with the effects of FMUs' preexisting characteristics.

4.1. Naïve Model

To restate the identification challenge more formally, consider a naïve model of the effect of certification in which the percentage of an FMU deforested in a given year—hereafter, an "FMU-year"—depends on whether the FMU was certified in previous years and on a vector of control variables. That is,

$$Y_{it} = \alpha + D'_{it-z}\beta_1 + X'_{it-z}\beta_2 + W'\beta_3 + \varepsilon_{it} \quad (1)$$

where i indexes FMUs, t indexes years, z indexes temporal lags, Y is the percentage of the FMU deforested, D is a vector of contemporaneous and lagged dichotomous dummy variables indicating certification, X is a vector of time-varying control variables, W is a vector of time-invariant control variables, α and β are parameters or vectors of parameters to be estimated, and ε is an error term. The parameters in β_1 purport to measure certification's effect on forest cover change—formally, the average treatment effect on the treated (ATT). However, they will be biased if unobserved FMU characteristics affect both certification and deforestation.

We use three strategies to control for such endogeneity, some implemented simultaneously and some separately: fixed effects, matching, and restricting our sample to FMUs that at some point were FSC-certified. We discuss each strategy in more detail below. Section 6, which discusses our results, presents results of specification tests, including for using fixed effects.

4.2. Fixed Effects

The fixed effects model is specified as

$$Y_{it} = \gamma_i + \delta_t + D'_{it-z}\beta_1 + X'_{it-z}\beta_2 + \varepsilon_{it} \quad (2)$$

where γ are FMU-fixed effects and δ are year-fixed effects. The FMU-fixed effects control for unobserved time-invariant FMU heterogeneity, including that generated by self-selection into certification. The year-fixed effects control for unobserved temporal effects such as changes in forest policy and in the international prices of timber affecting all FMUs in the study area. We omit the time-invariant social and economic control variables because they are perfectly correlated with the FMU-fixed effects. We estimate Equation (2) using ordinary least squares (OLS) and cluster standard errors at the FMU level.

4.3. Matching

In addition to fixed effects, we control for self-selection by using matching to “preprocess” our data (Imbens and Wooldridge 2009; Ho et al. 2007). That is, we identify a matched control group of uncertified FMUs that are similar to the treatment group of certified FMUs in terms of observed characteristics that drive forest cover change, drop unmatched control FMUs from the regression sample, and then use OLS to estimate Equation (2). This strategy combining nonparametric matching (i.e., dropping from the study sample control observations that are dissimilar to the treatment observations) with standard parametric regression typically generates treatment effects estimates that are more robust to misspecification and omitted variables bias than does parametric regression alone (Imbens and Wooldridge 2009; Ho et al. 2007; Ferraro and Miranda 2012).

We use propensity scores for each FMU—the probability of certification predicted by a probit regression—to match certified and uncertified FMUs in four geographic regions within Mexico (Rosenbaum and Rubin 1983). That is, certified FMUs in each region are matched to uncertified FMUs in the same region. Propensity scores can be interpreted as weighted indices of the characteristics that drive the treatment, here certification. We implement propensity score matching as follows. First, we use a set of four cross-sectional probit models—one for each region—to estimate propensity scores for each FMU. The model is specified as

$$\Pr(D_{ij} = 1 | W_{ij}) = F(W'_{ij}\psi_j) \qquad (j = 1,2...4) \quad (3)$$

where j indexes regions, D is a binary variable indicating whether an FMU was certified in any year from 2001 to 2012 (“ever-certified”), F is the standard normal cumulative distribution function, and ψ_j is a vector of regression coefficients. Next, we create control groups of never-certified FMUs by matching certified FMUs with never-certified FMUs on the basis of propensity scores. We use nearest-neighbor 1-to-4 matching with replacement to identify the best matches for each FMU (Cochrane and Rubin 1973). Finally, we drop all unmatched control FMUs and then estimate Equation 2. We weight uncertified FMU-year observations in the control group based on the number of times they were included as matches (Abadie and Imbens 2006). Again, we cluster standard errors at the FMU level.

4.4. Treated-Only Sample

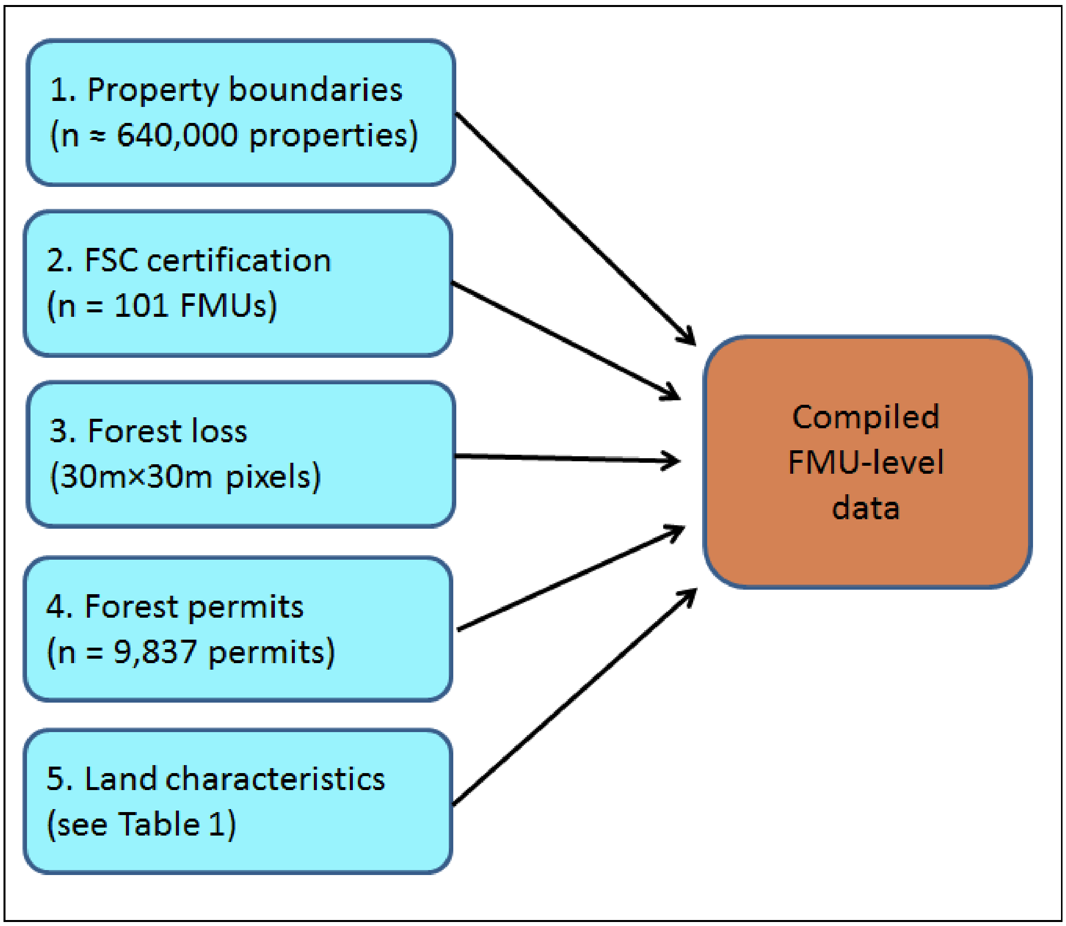
A potential weakness of the fixed effects models is that the control group includes FMU-year observations from never-certified FMUs as well as those from ever-certified ones. The latter set of FMU-years may differ from the former set in unobservable ways (e.g., the management capacity) that affect deforestation. To help control for such unobserved heterogeneity, we restrict the sample to ever-certified FMUs. In this smaller sample, treatment FMU-years are those that were FSC-certified in that year, and control FMU-years are those that were not yet certified or were previously certified. In this sample, cross-sectional matching (in which ever-certified FMUs are matched to never-certified FMUs) is obviously not feasible. Again, we cluster standard errors at the FMU level.

5. Data

5.1. Sources

Our data are drawn from five sources (Figure 1). The first is cadastral data for virtually all of Mexico, comprising more than 640,000 private and communal and state property polygons (RAN undated; ASERCA 2003). The second is a master list of all 101 Mexican FMUs that obtained FSC forest management certifications between 1996, when the first Mexican certification was awarded, and 2015 (i.e., the population of FMUs certified during this period). This list was compiled from registries maintained by FSC, Rainforest Alliance, and CCMSS. The third is annual 2000–2012 forest loss data derived from high resolution (30m×30m) Landsat satellite images for all of Mexico (Hansen et al. 2013). The fourth is a compendium of 9,837 forest permits issued by SEMARNAT state offices for 16 federal entities with significant forest area, including all 13 entities with a record of FSC certification (INECC 2013).[1] Comprising information on silivicultural practices, harvest areas, and permitted harvest volumes, these data were compiled by digitizing hard copies of permits housed in SEMARNAT regional offices. The final set of sources is a variety of datasets used to construct the FMU-level control variables described below.

Figure 1. Data Assembly



Although our compiled data and regression analysis are at the FMU level, in some cases FSC certification applies to only part of an FMU. SEMARNAT forest permits are supposed to

[1] The 16 entities are Campeche, Chiapas, Chihuahua, Distríto Federal, Durango, Estado de México, Guerrero, Jalisco, Michoacan, Morelos, Oaxaca, Puebla, Queretaro, Quintana Roo, Veracruz, and Yucatan.

contain geolocator information defining harvest zone polygons. However, most permits, particularly older ones, do not contain usable geolocator data. Hence, a harvest-zone-level analysis is not feasible. Our FMU-level analysis has advantages and disadvantages. The disadvantage is that we are not able to measure effects that only occur inside harvest zones. The advantage is that we control for spatial spillover effects that occur when forest management certification on one part of an FMU spurs deforestation on other parts.

5.2. Sample

Our regression samples of certified and uncertified FMUs were created as follows. To create our sample of certified FMUs, we manually associated FMUs on our certification master list with polygons in the cadastral data and records in the permit registry. We matched on FMU names, municipio names, and any geolocator information included in certification records. Of the 101 certified FMUs in our master list, we were dropped 37 either because matches were not found or because data on the start and end dates of the certification were missing, leaving the 64 FMUs in our regression sample (Table A1).

To create our sample of uncertified FMUs, we first dropped all FMUs in the cadastral data from states with no record of FSC certifications, with the exception of Campeche.[2] The purpose was to ensure that uncertified FMUs in our sample were as similar as possible to certified ones. Next, we associated the surviving FMUs in the permit registry with polygons in the cadastral data. To limit the sample of uncertified FMUs to a manageable size and to ensure permit records for uncertified FMUs were as complete as those for certified ones (complete permit records are required for FSC certification), we matched using geolocator information contained in permit records, which are included only in complete permit documents. This filter eliminated roughly two-thirds of the uncertified FMUs in the permit database. Finally, we dropped 9 observations with missing data.

Having undertaken these steps, our full regression sample—that is, our sample before using matching to select uncertified FMUs similar to certified ones—comprises 3,010 FMUs, 64 of which were ever-certified and 2,946 of which were never-certified (Figures 2A–2C). From these cross-sectional data, we created a 12-year unbalanced panel spanning 2001–2012, the years represented in our forest loss data (Hansen et al. 2013). The panel includes FMUs only during

[2] We retained FMUs in Campeche, which has no FSC certifications, because our sample of never-certified potential control FMUs in neighboring Quintana Roo was limited.

years for which their regulatory permits were valid and counts FMUs as certified only for years in which FSC certifications were valid. It comprises 18,103 FMU-year observations, of which 457 are FSC-certified and 17,646 are not certified. Again, this is the count of uncertified units prior to matching.

Figure 2A. Forest Management Units Constituting Regression Sample

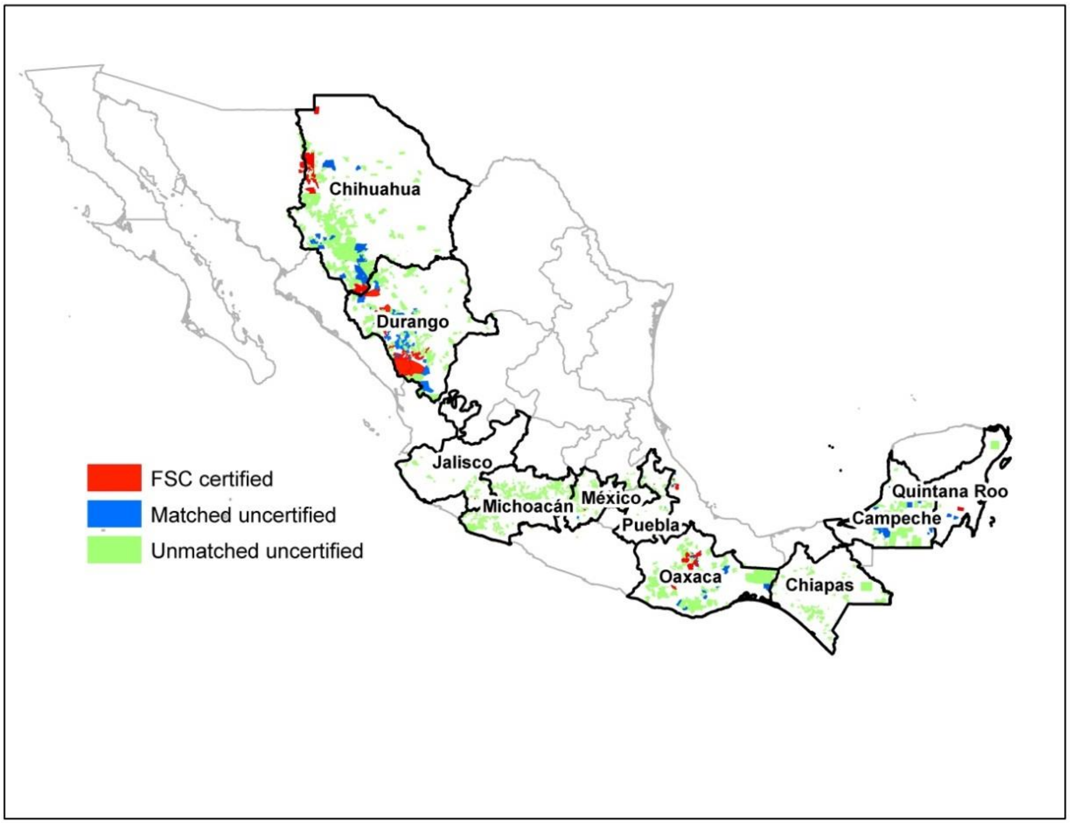


Figure 2B. Forest Management Units Constituting Regression Sample in Durango State

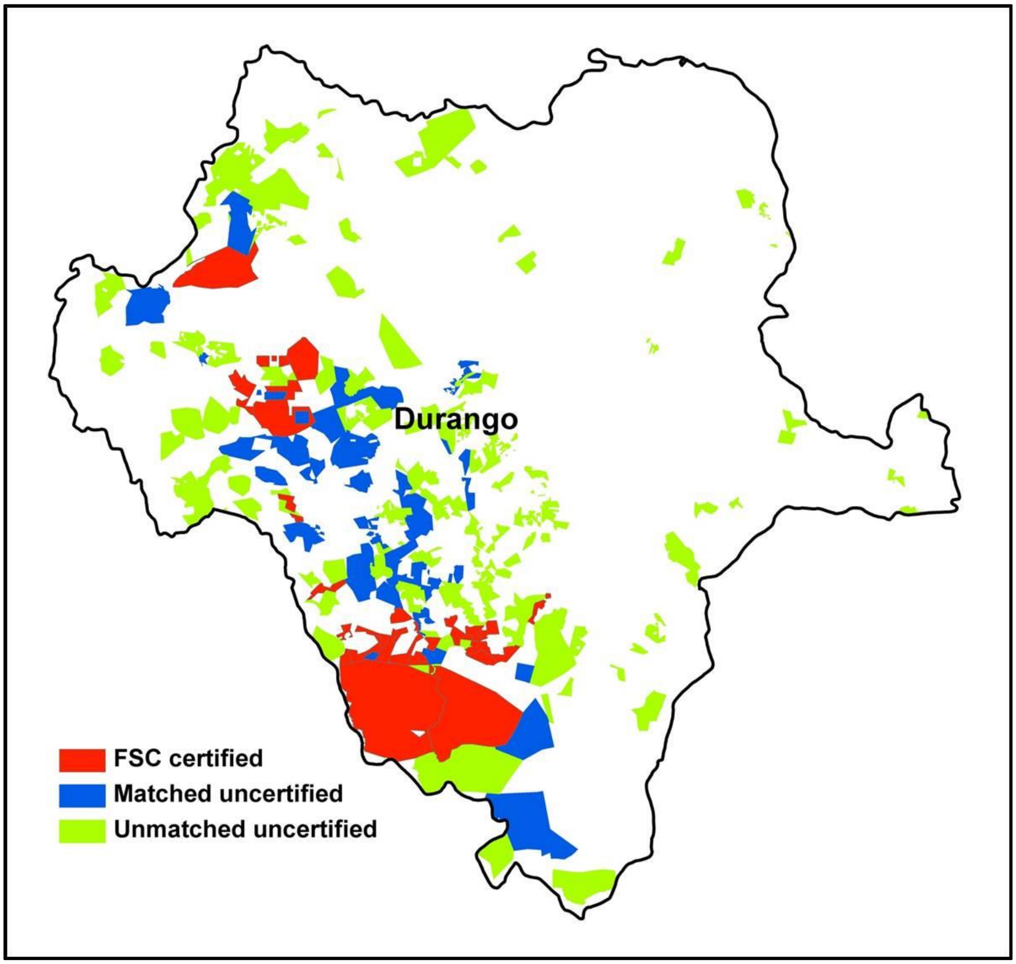
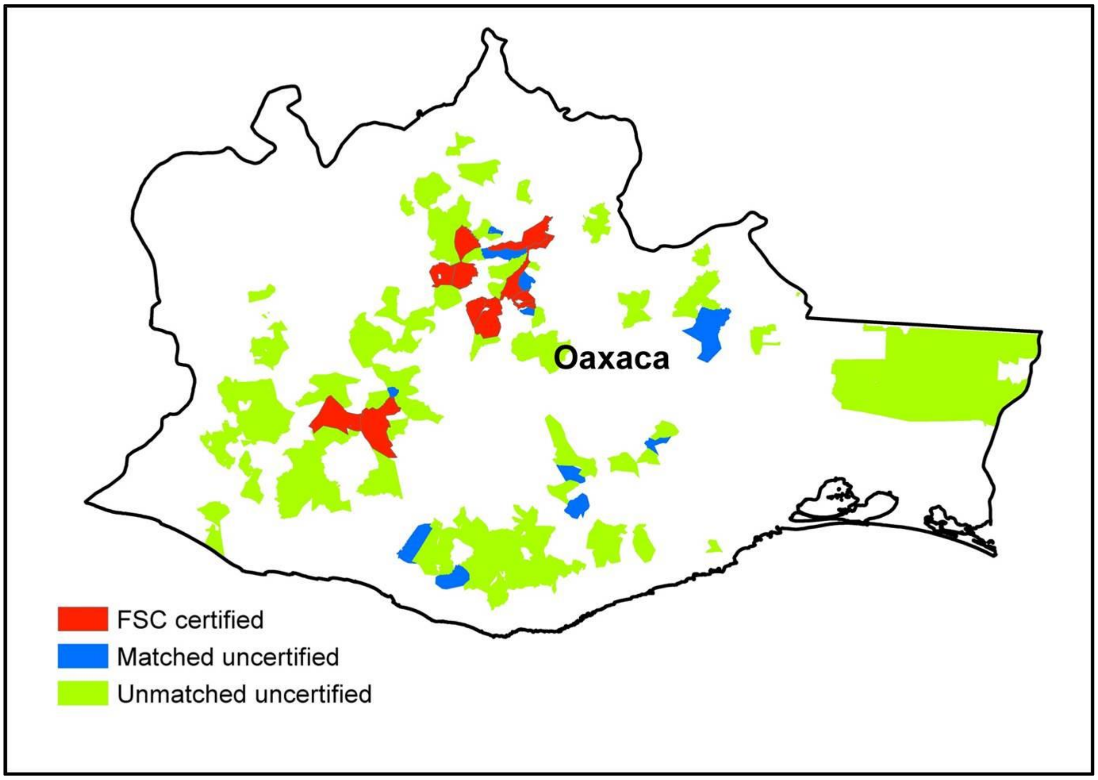


Figure 2C. Forest Management Units Constituting Regression Sample in Oaxaca State



5.3. Variables

Table 1 lists the variables in the regression analysis, including their names, definitions, units, sources, spatial scales, and years. An asterisk identifies variables that vary over time as well as across space, that is, variables that constitute the vector X in Equations 1 and 2.

Our dependent variable, *percentage cleared*, is the percentage of the total area of the FMU cleared each year from 2001 to 2012. It is derived from fine-scale Landsat images (Hansen et al. 2013).

Table 1. Variables (*time varying)

Variable	Description	Units	Source	Scale	Years
OUTCOME					
*percentage cleared**	Percentage of total surface area cleared in year t	0/1	Hansen et al. (2013)	30m	2001–2012
TREATMENT					
*fsc all years**	FSC certification in effect in year t?	0/1	CCMSS, FSC, RA	FMU	2001-2012
*fsc first certification**	FSC initial certification in effect in year t?	0/1	CCMSS, FSC, RA	FMU	2001-2012
*fsc anticipatory**	FSC initial certification awarded 1 or 2 years after t?	0/1	CCMSS, FSC, RA	FMU	2001-2012
*fsc year n**	FSC initial certification awarded in year t-n?	0/1	CCMSS, FSC, RA	FMU	2001-2012
fsc terminated	FSC certification terminated in year t?	0/1	CCMSS, FSC, RA	FMU	2001–2012
fsc suspended	FSC certification suspended in year t?	0/1	CCMSS, FSC, RA	FMU	2001–2012
fsc ever	FSC certification in any year?	0/1	CCMSS, FSC, RA	FMU	2001–2012
CONTROLS					
Forest management					
*total timber volume**	Total timber volume authorized for harvest in year t[a]	m^3	INECC	FMU	2001–2012
homogeneous management	Managed for phenotypic homogeneity?	0/1	INECC	FMU	2001–2012
nontimber forest product	Has nontimber forest product permit?	0/1	INECC	FMU	2001–2012
selection logging	Selection logging (vs. seed tree or clear-cut) silviculture?	0/1	INECC	FMU	2001–2012
percentage protected	Percentage overlap with national protected area	0/1	WDPA	1:50,000 to 1:1,000,000	1917–2010
FMU area	Total surface area of forest management unit	ha	INECC	FMU	2001–2012
Socioeconomic					
*population density**	Population density in year t-1	pers./ha	INEGI	municipio	2000–2010
opportunity cost	Gross annual agricultural revenue[b]	0/1	SAGARPA/INEGI	FMU	2010
communal tenure	Ejido, comunidad, or other type of communal (vs. private) tenure	0/1	INECC	FMU	2001–2012
Climatological					
*rainfall**	Mean total rainfall in year t	mm	Huffman et al. (2012)	25km	2001–2012
*temperature**	Mean temperature in year t	^oK	NASA (2001)	1km	2001–2012
Geophysical					
carbon	Total above-ground carbon stock	tons/ha	Cartus et al. (2014)	30m	circa 2006
elevation	Mean altitude above sea level	m	Farr et al. (2007)	90m	2006
slope variability	Standard deviation of slope	%	Farr et al. (2007)	90m	2006
aspect	Mean aspect	^{o}	Farr et al. (2007)	90m	2006
distance to city	Mean travel time to nearest city with 50K+ residents	min	Nelson (2008)	30 arc-sec	2000
distance clearing in 2000	Mean distance to nearest cleared plot in year = 2000	m	Hansen et al. (2013)	30m	2000

Table Notes:
CCMSS = Consejo Civil Mexicano para la Silvicultura Sostenible; FSC = Forest Stewardship Council; FMU = forest management unit; INEGI = Instituto Nacional de Estadística e Informática; RA = Rainforest Alliance; SAGARPA = Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación; WDPA = World Database on Protected Areas.
[a] Interpolated where values missing for one or more years, but available for both years bracketing the missing value.
[b] Computed from SAGARPA and INEGI data on hectares devoted to crops and pasture (comunidad level), average yields (muncipio level), and average crop prices (municipio level).

Our four principle treatment variables— *fsc all years, fsc first certification*, *fsc anticipatory*, and *fsc year n* —are binary dummy variables that aim to capture the deforestation effects of FSC certification. As discussed below, most are used in separate models. Each variable aims to capture a slightly different temporal effect. *fsc all years* is equal to one if certification was in effect in year t (the current year), and is zero otherwise. It aims to pick up the average annual effect on deforestation of certification during all years that certification was valid, including ‘recertification’ years that follow the initial five-year certification period. By contrast, *fsc first certification* is equal to one only during the first five-year certification period. Premised on the idea that the initial certification period is most likely to affect deforestation, it aims to pick up certification’s average annual effect over the course of the entire first five-year certification period. *fsc anticipatory* is equal to one if the initial certification was awarded in any of the two years after t. It is premised on the idea that FMUs improve forest management prior to their first certification in order to meet FSC criteria. It aims to pick up certification’s average annual anticipatory effects during the two years before the award of initial certification. Finally, *fsc year n* is equal to one if the initial certification was awarded n years before t and is zero otherwise. Unlike the first three treatment variables that purport to pick up average effects over a number of years, these variables aim to capture single-year effects of the initial certification. For example, *fsc year 3* is equal to one if the initial certification was awarded three years before t, and aims to capture only the effect in year t of that event.

In addition to these four main treatment variables, the variable *fsc terminated* identifies FMUs with terminated FSC certificates in year t and the variable *fsc suspended* identifies those with suspended, but not terminated, FSC certificates. Suspensions, which are rare in our sample, occurred one year prior to some cases of termination. We use these last two variables to help disentangle the effects of valid unsuspended FSC certifications. As noted above, our treatment variables are derived from certification records maintained by FSC and its certifying bodies in Mexico.

Among our control variables, four vary over time as well as across space: *total timber volume* is the volume of timber (in cubic meters) authorized by SEMARNAT for extraction in each year that a forestry permit was in force; *population density* is the average number of persons per square hectare lagged by one year; *rainfall* is average total rainfall each year; and *temperature* is average annual temperature in each year. *Total timber volume* is drawn from SEMARNAT permits (INECC 2013). Where values of this variable were missing for one or more years, but available for years bracketing the missing value, we interpolated the missing value(s) assuming a linear progression. In all, we interpolated 23 percent of the values of *total timber volume*. *Population density* in each year was imputed from 2000, 2005, and 2010 census data, again assuming a linear progression. *Rainfall* and *temperature* were derived from NASA satellite data (Huffman et al. 2012; NASA 2001).

Finally, we use 11 time-invariant variables in our propensity score matching model; that is, these variables constitute the vector W in Equation 3. To generate propensity scores, we use a single time-invariant dependent variable, *fsc ever*, which is a binary variable indicating whether the FMU was ever-certified in any year from 2001 to 2015. Control variables are forest management, socioeconomic, geophysical, and FMU characteristics.

Among the forest management characteristics, *homogeneous management* is a binary variable that identifies FMUs with forest management systems that aim to generate phenotypic homogeneity; *nontimber forest product* is binary variable that identifies FMUs authorized by SEMARNAT to harvest nontimber forest products such as palm fronds and mushrooms; *percentage protected* is the percentage of the FMU inside a national protected area; and *FMU area* is the total area of the FMU in hectares. Finally, *selection logging* is a binary variable that indicates whether the FMU uses a logging silvicultural system wherein trees meeting age and size criteria are selected for harvest. The other two silvicultural systems represented in our sample of FMUs—seed trees and clear-cutting—both entail clear-cutting regardless of such criteria. As discussed in the next subsection, we also use *selection logging* to test for subgroup effects. All of these variables except *percentage protected* and *FMU area* were derived from SEMARNAT permit data (INECC 2013).

Among the socioeconomic variables, *opportunity cost* is original FMU-level data on the opportunity cost of retaining land in forest instead of converting it to agriculture or pasture. It is the gross revenue from agriculture computed from secondary data on hectares planted in 365 crops (FMU level), average yields (municipio level), and average crop prices (municipio level). The second static socioeconomic variable, *communal tenure*, is a binary dummy variable that identifies FMUs with communal (versus private or state) tenure, including ejidos and comunidades.

Finally, among the geophysical variables, *carbon* is total above-ground carbon stock per hectare; *elevation* is average altitude; *slope variability* is the standard deviation of the slope;

aspect is average directional orientation; *distance to city* is mean travel time to the nearest city with more than 50,000 inhabitants; and *distance to clearing* is the mean Euclidian distance to the nearest cleared 30m×30m plot of land in 2000.

5.4. Summary Statistics

Table 2 lists the number of FSC certifications in our regression sample by year and state. Two-thirds of the 64 certifications are in two states—Durango (31) and Oaxaca (12) (Figures 2B and 2C). Two more states—Puebla (7) and Quintana Roo (6)—account for most of the rest. More than half of the certifications were awarded between 2001 and 2006, the first six years of our panel.

Table 2. Regression Sample FSC Certifications, by Year and State

Year	Chiapas	Chih.	Durango	E. Mexico	Jalisco	Mich.	Oaxaca	Puebla	Q. Roo	*Total*
1996	0	0	0	0	0	0	4	0	0	4
1998	0	0	2	0	0	0	0	0	0	2
1999	0	0	1	0	0	0	0	0	0	1
2000	0	0	1	0	0	0	0	0	0	1
2001	0	1	4	0	0	0	3	0	2	10
2002	0	1	6	0	0	0	0	0	0	7
2003	0	0	1	0	0	0	1	0	0	2
2004	0	0	6	0	0	0	0	0	0	6
2005	0	1	2	0	0	0	2	0	3	8
2006	0	0	1	0	0	1	2	0	1	5
2007	0	0	1	0	0	0	0	0	0	1
2008	1	0	0	0	0	0	0	0	0	1
2009	0	0	0	0	1	0	0	0	0	1
2010	0	0	1	0	0	0	0	0	0	1
2011	0	0	1	0	0	0	0	0	0	1
2012	0	0	2	0	0	0	0	2	0	4
2013	0	1	1	0	0	0	0	3	0	5
2014	0	0	0	1	0	0	0	1	0	2
2015	0	0	1	0	0	0	0	1	0	2
Total	1	4	31	1	1	1	12	7	6	64

Sources: Consejo Civil Mexicano para la Silvicultura Sostenible, Forest Stewardship Council, Rainforest Alliance.

Table 3 presents variable means for all 3,010 FMUs in our regression sample, and for subsamples of 64 ever-certified FMUs and 2,946 never-certified FMUs. It also presents results from difference-in-means tests for these subsamples.

Table 3. Summary Statistics: Means and Difference of Means Tests at FMU-Year Level (*denotes time varying variables)

Variable	All	Ever-certified	Never-certified	t-test
Number of FMU-years	18,103	457	17,646	
Number of FMUs	3,010	64	2,946	
OUTCOME				
*percentage cleared** (%/ψ)	0.001	0.001	0.001	
TREATMENT				
fsc all years (0/1)	0.012	0.488	0.000	***
CONTROLS				
Forest management				
*total timber volume** (m^3/ρ)	2.308	17.598	1.912	***
homogeneous management (0/1)	0.169	0.346	0.164	***
nontimber forest product (0/1)	0.040	0.168	0.037	***
selection logging (0/1)	0.831	0.538	0.839	***
percentage protected (%/ψ)	0.097	0.008	0.100	***
FMU area (ha/ρ)	3.645	19.203	3.242	***
Socioeconomic				
*lagged pop. density** (pop/ha)	0.603	0.339	0.609	***
opportunity cost (pesos/ha/μ)	3.304	3.404	3.301	
communal tenure (0/1)	0.403	0.939	0.389	***
Climatological				
*rainfall** (mm/ρ)	1.023	1.173	1.018	***
*temperature** (^{o}C/μ)	1.395	1.426	1.394	**
Geophysical				
carbon (tons/ha/μ)	2.956	3.169	2.951	***
elevation (m/ρ)	2.057	1.790	2.064	***
slope variability (s.d.)	0.796	2.362	0.755	***
aspect (^{o}/ψ)	1.771	1.749	1.771	
distance to city (min./ψ)	2.543	3.031	2.531	***
distance clearing in 2000 (m/ψ)	1.765	3.240	1.727	***

***, **, * = significant at 1, 5, 10% level; μ = 10, ψ = 100, ρ = 1,000; δ = 10,000.

Turning first to the outcome and treatment variables, for all FMUs in our sample, *percentage cleared* is 0.001, which indicates that on average, one-tenth of 1 percent of each FMU was cleared each year between 2001 and 2012. For an average-sized FMU in our sample (3,645 hectares) that implies a forest loss of 3.6 hectares per year. For all FMUs in our sample, *fsc all years* is 0.012, which indicates that on average, just over 1 percent of the FMUs in our sample were FSC-certified each year between 2001 and 2012.

The tests comparing means from the ever-certified and never-certified subsamples indicate statistically significant differences for every variable except *percentage cleared*, *opportunity cost*, and *aspect*. Hence, certified and uncertified FMUs have very different average observable characteristics (which we characterize below in our discussion of the results of the probit regressions used to generate propensity scores). The econometric models discussed in the next section aim to control for such differences.

Fixed effects models like ours identify treatment effects by exploiting within-group (here within-FMU) temporal variation and ignore between-group static variation. Therefore, to be estimable, they require significant within-group variation (Greene 2008). Table 4 presents statistics measuring overall, within-group, and between-group variation for our outcome and treatment variables: *percentage cleared* and *fsc all years*. For both variables, within-group variability is in fact significant.

Table 4. Overall, Within-Group, and Between-Group Variation for Outcome and Treatment Variables

Variable	Variation	Mean	s.d.	n
percentage cleared	overall	0.001	0.007	18,103
	between		0.006	3,010
	within		0.006	
fsc all years	overall	0.012	0.110	18,103
	between		0.093	3,010
	within		0.051	

Overall, between, and within variations are the variances of $(x_{it} - \bar{x})$, $(x_i - \bar{x})$, and $(x_{it} - \bar{x}_i + \bar{x})$, respectively, where $\bar{x}$ is the grand mean.

6. Results

We begin our discussion in this section with the probit regressions used to generate propensity scores used in matching certified and uncertified FMUs, then discuss the results of specification tests, and finally turn to our fixed effects OLS regression results.

6.1. Drivers of Certification

As noted above, we match certified FMUs to uncertified FMUs in the same geographic region to help control for unobserved heterogeneity. We define four geographic regions: North (Chihuahua, Durango, and Jalisco); Central (Estado de México and Puebla); South (Chiapas and Oaxaca); and Yucatan Peninsula (Campeche and Quintana Roo) (Figure 2A). We exclude regressors in some regions to avoid near-perfect predictors and/or nonconvergence.

Results from the four region-specific cross-sectional probit regressions (Equation 3) confirm what our summary statistics suggest: FSC certification is not randomly assigned across FMUs (Table 5). Rather, observable time-invariant forest management, socioeconomic and geophysical land characteristics are correlated with certification. For example, in the North region, certified FMUs tend to be larger, more carbon-rich, at lower altitudes, and closer to forest edges. And in the South, they tend to have homogeneous forest management, to have permits for harvesting nontimber forest products, and to be larger, less hilly, and farther from cities. Such characteristics affect forest cover change (Boucher et al. 2011; Chomitz 2007; Kaimowitz and Angelson 1998). Hence, these probit regression results underscore the importance of controlling for preexisting observable characteristics in estimating treatment effects.

Table 5. FMU-Level Cross-Sectional Propensity Score Probit Results: Dependent Variable is FSC Certification in Any Year; Marginal Effects (s.e.)

Variable	North (Chihuahua, Durango, Jalisco)	Central (Estado de México, Puebla)	South (Chiapas, Oaxaca)	Yucatan Penin. (Campeche, Quintana Roo)
Forest management				
homogeneous management	–0.0029	0.0034*	0.0017*	
	(0.0018)	(0.0019)	(0.0010)	
nontimber forest product			0.0003***	
			(0.0001)	
percentage protected	–0.0230	–0.0109	–0.0018	
	(0.0420)	(0.0124)	(0.0025)	
FMU area	0.0014***	0.0061	0.0007***	0.0035***
	(0.0003)	(0.0051)	(0.00023)	(0.0014)
Socioeconomic				
opportunity cost	0.0025	-0.0005	0.0005	–0.0136
	(0.0026)	(0.0010)	(0.0008)	(0.0117)
communal tenure			0.0008	
			(0.0012)	
Geophysical				
carbon	0.0637***	0.0120	0.0084	
	(0.0121)	(0.0104)	(0.0142)	
elevation	–0.0651***	–0.0196	0.0179	
	(0.0190)	(0.0149)	(0.0225)	
slope variability	0.0042	0.0031	–1.0867***	
	(0.0033)	(0.0025)	(0.4465)	
aspect	0.0529	0.0046	–0.0214	
	(0.0364)	(0.0159)	(0.02001)	
distance to city	0.0023	0.0056	0.0060***	–0.0296
	(0.0040)	(0.0065)	(0.00201)	(0.0218)
distance clearing in 2000	–0.0300**	–0.0058	0.0036***	–0.0025
	(0.0151)	(0.0095)	(0.0015)	(0.0032)
No. observations	874	415	593	74
Log likelihood	–99.4731	–29.7084	–23.2285	–15.2939
Pseudo R^2	0.3372	0.2481	0.6285	0.2656

***, **, * = significant at 1, 5, 10% level

6.2. Specification Tests

Before proceeding to the main regression results, we report results of formal hypothesis tests to support our fixed effects model specification. We focus on results for the full sample of 18,103 FMU-years. To check the intuition that a pooled OLS model is unlikely to generate unbiased estimates of treatment effects, we use Breusch and Pagan's (1980) Lagrange multiplier test, formally, a test of whether the variance of α_i (the intercept component of a composite error term $\alpha_i+\varepsilon_{it}$ derived from Equation 1) is zero, which is a necessary condition for OLS to be consistent. The test rejects the null hypothesis of zero variance at the 1 percent level, implying that an individual effects model, either random effects or fixed effects and not simple pooled OLS, is appropriate. To choose between a random effects and fixed effects model, we use a Hausman (1978) test of whether differences in coefficients from the two models are systematic. We reject the null of no systematic differences at the 1 percent level, implying that a fixed effects model, not a random effects model, is called for. Finally, we use a Chow (1960) test to determine whether year-fixed effects, in addition to FMU-fixed effects, are needed, formally, a test of whether year-fixed effects are jointly equal to zero. We reject the null hypothesis at the 1 percent level, a result that indicates year-fixed effects are indeed appropriate.

6.3. Certification Effects: Main Models

Given these specification test results, we use OLS to estimate Equation 2, which includes both FMU-fixed effects and year-fixed effects, for three different samples, each of which corresponds to a different model (Table 6). Model 1 uses the full unmatched regression sample, Model 2 uses the matched sample, and Model 3 uses the sample consisting only of ever-certified FMUs. We estimate two specifications of each model, which we refer to as A and B. Specification A includes *fsc all years*, which aims to pick up the average annual effect of certification over all years during which certification was valid, including recertification years. Specification B instead includes *fsc first certification*, which aims to pick up the average annual effects that occur only during the initial five-year certification period. All models also include: *fsc anticipatory*, which aims to pick up anticipatory effects that occur in the two years preceding the initial certification period; *fsc suspended*, a dummy variable that controls for suspensions; and *fsc terminated*, a dummy variable that controls for terminations. As noted above, in Model 2, observations are weighted based on the number of times they are used as matches and in all models, standard errors are clustered at the FMU level.

Table 6. FMU-Level Panel-Data OLS Regression Results; Dependent Variable is Percentage FMU Cleared in Year t = 2001–2012; Treatment is FSC certification (s.e.)

Model No.	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**
Sample	**Full**	**Full**	**Full**	**Full**	**Full**	**Full**
Control obs.	**unmatched**	**unmatched**	**matched**	**matched**	**FSC only**	**FSC only**
fsc all years	0.0002		0.0003		0.0004	
	(0.0003)		(0.0003)		(0.0004)	
fsc first certification		0.0002		0.0003		0.0004
		(0.0002)		(0.0002)		(0.0002)
fsc anticipatory	0.0000	0.0000	0.0001	0.0002	0.0002	0.0002
	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0005)	(0.0004)
fsc suspended	–0.0003		–0.0001		0.0001	
	(0.0008)		(0.0010)		(0.0013)	
fsc terminated	–0.0003		–0.0004		–0.0002	
	(0.0004)		(0.0004)		(0.0006)	
total timber volume	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
lagged pop. density	0.0003	0.0003	–0.0004	–0.0005	–0.0021	–0.0028
	(0.0004)	(0.0004)	(0.0014)	(0.0014)	(0.0038)	(0.0036)
rainfall	0.0003	0.0003	0.0009**	0.0009*	0.0010*	0.0010*
	(0.0006)	(0.0006)	(0.0005)	(0.0005)	(0.0006)	(0.0006)
temperature	0.0299**	0.0299**	0.0699**	0.0716**	0.0574	0.0596
	(0.0140)	(0.0140)	(0.0339)	(0.0339)	(0.0466)	(0.0463)
Average clearing	0.0011	0.0011	0.0011	0.0011	0.0012	0.0012
FMU-fixed effects?	yes	yes	yes	yes	yes	yes
Year-fixed effects?	yes	yes	yes	yes	yes	yes
Clustered s.e.s?	yes	yes	yes	yes	yes	yes
Prob. weights?	no	no	yes	yes	no	no
No. FMUs	3,010	3,010	205	205	64	64
No. observations	18,103	18,103	1,390	1,390	457	457
R^2	0.0000	0.0000	0.0032	0.0032	0.0025	0.0024
Prob > F	0.0000	0.0000	0.0098	0.0177	0.1169	0.1370

***, **, * = significant at 1, 5, 10% level

The results offer no evidence that FSC certification affects deforestation (Table 6). None of the contemporaneous or lagged treatment dummy variables are statistically significant in any of the six models.

It is interesting to note that, although insignificant, the point estimates of treatment effects for years when certification is active (i.e., the coefficients on *fsc all years* and *fsc first* *certification*) are positive and range from 0.0002 to 0.0004. Were these estimates statistically significant, the implication for the A models (which include *fsc all years*) would be that FSC certification in an average certification year *increases* the percentage of the FMU cleared by two to four one-hundredths of 1 percentage point. Using the average 2001–2012 rates of forest loss in the relevant regression samples as baseline deforestation rates (0.0011–0.0012; see Table 1), that translates into an 18–33 percent increase in deforestation. The B models (which include *fsc first certification*) also imply an 18–33 percent increase in deforestation. But again, none of these point estimates are statistically significant. Finally, note that we are not able to reject the null hypothesis that all the regressors in Model 3 are jointly insignificant, a result that likely stems from the relatively small sample size (n = 457).

6.4. Certification Effects: Robustness Checks

We estimated a variety of additional models to check the robustness of finding that FSC certification does not affect deforestation. These models essentially search for an effect of certification on deforestation occurring in subsamples of FMUs or with temporal lags not represented in our main models.

6.4.1. Forest Management Units Using Selection Silviculture

In principle, certification's effects on deforestation could depend on the FMU's choice of silvicultural system. For example, certification could have stronger effects in FMUs using selection logging than in those using seed trees and clear-cutting. If that were the case, the effects of FSC certification could be diluted in a pooled sample of FMUs using different systems. To control for such effects, we estimate models using subsamples that include only FMUs using selection logging. Insufficient degrees of freedom preclude testing subsamples using other silvicultural systems.

The results for these models are qualitatively quite similar to those for the main models. None of the certification treatment effects are statistically significant (Table 7). Although effects estimated using the matched sample (Model 5) and FSC-certified only sample (Model 6), appear to be slightly larger than those from analogous main models (Models 3 and 4), they are actually quite similar when expressed as percentage changes above a baseline deforestation rate. Note that using this subsample, we are able to reject at the 5 percent level the null hypothesis that all regressors in the certified only model (Model 6) are jointly insignificant.

Table 7. FMU-Level Panel-Data OLS Regression Results; Dependent Variable is Percentage FMU Cleared in Year t = 2001–2012; Treatment is FSC Certification; Sample Includes Only FMUs Using Selection Silviculture (s.e.)

Model No. *Sample* *Control obs.*	4A Selection Silv. unmatched	4B Selection Silv. unmatched	5A Selection Silv. matched	5B Selection Silv. matched	6A Selection Silv. FSC only	6B Selection Silv. FSC only
fsc all years	0.0002		0.0002		0.0006	
	(0.0005)		(0.0006)		(0.0008)	
fsc first certification		0.0004		0.0005		0.0006
		(0.0003)		(0.0004)		(0.0005)
fsc anticipatory	–0.0004	–0.0003	–0.0002	–0.0000	0.0002	0.0003
	(0.0006)	(0.0006)	(0.0008)	(0.0007)	(0.0012)	(0.0010)
fsc suspended	–0.0009		–0.0006		0.0001	
	(0.0011)		(0.0014)		(0.0020)	
fsc terminated	–0.0005		–0.0006		0.0001	
	(0.0006)		(0.0007)		(0.0011)	
Average clearing	0.0012	0.0012	0.0016	0.0016	0.0018	0.0018
Control variables	yes	yes	yes	yes	yes	yes
FMU-fixed effects?	yes	yes	yes	yes	yes	yes
Year-fixed effects?	yes	yes	yes	yes	yes	yes
Clustered s.e.s?	yes	yes	yes	yes	yes	yes
Prob. weights?	no	no	yes	yes	no	no
No. FMUs	2,539	2,539	131	131	246	246
No. observations	15,046	15,046	889	889	35	35
R^2	0.0000	0.0000	0.0020	0.0020	0.0028	0.0026

***, **, * = significant at 1, 5, 10% level

6.4.2. Forest Management Units in Various Geographic Regions

In principle, certification's effects on deforestation could depend on the unobserved factors that vary across regions in Mexico. For example, as discussed above, some evidence suggests that a particularly strong driver of certification in the north of Mexico has been forest managers' desire to access overseas markets, while a particularly strong driver in the south has been the provision of subsidies by government and international agencies (Anta Fonseca 2006). If certification, for some reason, had stronger effects when driven by some such factors than others, then here again the effects of FSC certification could be diluted in a pooled sample of FMUs. To control for variation across regions in unobservable confounders, we estimate separate models for southern Mexico and the Yucatan Peninsula (Chiapas, Oaxaca, Campeche, Quintana Roo) and northern Mexico (Chihuahua, Durango, Jalisco, Estado de Mexico, Puebla).

Again, we find that none of the treatment effects are statistically significant (Tables 8 and 9). Expressed as percentage changes above a baseline deforestation rate, the estimated effects for southern Mexico are similar in magnitude to those from the main models, ranging in all but one case from 10 to 38 percent. However, those for northern Mexico are noticeably smaller, ranging from –17 to 30 percent.

Table 8. FMU-Level Panel-Data OLS Regression Results; Dependent Variable is Percentage FMU Cleared in Year t = 2001–2012; Treatment is FSC Certification; Regional Sample = South and Yucatan (Chiapas, Oaxaca, Campeche, Quintana Roo) (s.e.)

Model No.	**7A**	**7B**	**8A**	**8B**	**9A**	**9B**
Sample	**S. & Yucatan**	**S. & Yucatan**	**S. & Yucatan**	**S. & Yucatan**	**S. & Yucatan**	**S. & Yucatan**
Control obs.	**full**	**full**	**matched**	**matched**	**FSC only**	**FSC only**
fsc all years	0.0003		0.0006		–0.0000	
	(0.0004)		(0.0006)		(0.0016)	
fsc first certification		0.0008		0.0011		0.0011
		(0.0007)		(0.0008)		(0.0011)
fsc anticipatory	–0.0005	–0.0001	0.0005	0.0010	–0.0003	0.0005
	(0.0004)	(0.0006)	(0.0005)	(0.0008)	(0.0013)	(0.0016)
fsc suspended	–0.0003		0.0006		0.0016	
	(0.0009)		(0.0020)		(0.0044)	
fsc terminated	–0.0012		–0.0013		–0.0017	
	(0.0009)		(0.0012)		(0.0030)	
Average clearing	0.0029	0.0029	0.0036	0.0036	0.0029	0.0029
Control variables	yes	yes	yes	yes	yes	yes
FMU-fixed effects?	yes	yes	yes	yes	yes	yes
Year-fixed effects?	yes	yes	yes	yes	yes	yes
Clustered s.e.s?	yes	yes	yes	yes	yes	yes
Prob. weights?	no	no	yes	yes	no	no
No. FMUs	666	666	51	51	19	19
No. observations	3,045	3,045	297	297	124	124
R^2	0.0324	0.0324	0.0139	0.0141	0.0291	0.0216

***, **, * = significant at 1, 5, 10% level

Table 9. FMU-Level Panel-Data OLS Regression Results; Dependent Variable is Percentage FMU Cleared in year t = 2001–2012; Treatment is FSC Certification; Regional Sample = North and Central (Chihuahua, Durango, Jalisco, Estado de Mexico, Puebla) (s.e.)

Model No.	**10A**	**710B**	**11A**	**11B**	**12A**	**12B**
Sample	**N. & Central**	**N. & Central**	**N. & Central**	**N. & Central**	**N. & Central**	**N. & Central**
Control obs.	**full**	**full**	**matched**	**matched**	**FSC only**	**FSC only**
fsc all years	0.0001		0.0000		–0.0001	
	(0.0003)		(0.0002)		(0.0002)	
fsc first certification		–0.0000		–0.0000		0.0000
		(0.0002)		(0.0002)		(0.0002)
fsc anticipatory	0.0000	–0.0000	0.0000	0.0000	0.0000	0.0001
	(0.0006)	(0.0005)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
fsc suspended	–0.0001		–0.0002		–0.0004	
	(0.0003)		(0.0002)		(0.0003)	
Average clearing	0.0003	0.0003	0.0005	0.0005	0.0006	0.0006
Control variables	yes	yes	yes	yes	yes	yes
FMU-fixed effects?	yes	yes	yes	yes	yes	yes
Year-fixed effects?	yes	yes	yes	yes	yes	yes
Clustered s.e.s?	yes	yes	yes	yes	yes	yes
Prob. weights?	no	no	yes	yes	no	no
No. FMUs	1,289	1,289	154	154	44	44
No. observations	9,161	9,161	1,093	1,093	327	327
R^2	0.0327	0.0328	0.0898	0.0901	0.1356	0.1352

***, **, * = significant at 1, 5, 10% level

6.4.3. Single-Year Lagged Effects

Finally, we estimate models to identify effects that may have occurred with lags not represented in our main models. The main models generate estimates of the average effect of certification over a span of years: the coefficient on *fsc all years* can be interpreted as the average annual effect over the entire duration of certification which, given repeated recertifications, may be upward of 15 years, while the coefficient on *fsc first certification* can be interpreted as the average annual effect during the initial five-year certification period. These estimates may miss effects that tend to occur only in certain years just before or just after certification.

To test for such effects, we estimate models with a vector of binary variables indicating that certification was awarded n years ago, that is, for *fsc year n* where n ranges from –2 to 10. In addition, we include *fsc year 11–15*, that indicates, for a given FMU-year, that certification began 11 to 15 years earlier. To control for the effects of the suspension and termination of FSC certification, we include interaction terms that identify the years in which these actions were applied. That is, we interact *fsc year n* with *fsc suspended* and *fsc terminated*. Similarly, we interact *fsc year 11–15* with *fsc suspended* and *fsc terminated*. Due to collinearity, we do not include the interaction between *fsc year n* and *fsc suspended* for all years. Rather, we include the most comprehensive set of interaction terms in which none of the binary variables are dropped due to collinearity.

Again, we find none of the treatment effects are statistically significant in any of the models, including those using the full sample (Figure 3), the matched sample (Figure 4), and the certified only sample (Figure 5). Although the temporal response function is not statistically significant, it is interesting to note that its shape is quite consistent across models: the point estimate of the effect is close to zero for most years, but spikes in year four and then drops precipitously in year five, which is the year preceding recertification. This shape hints at a tendency of forest managers to clear forest in anticipation of a recertification audit. Results for the subsample of FMUs practicing selection silviculture are qualitatively quite similar (Figures A1–A3).

Figure 3. Estimated Coefficients for Single-Year Lagged Certification Dummy Variables: Fixed Effects Model; Full Sample

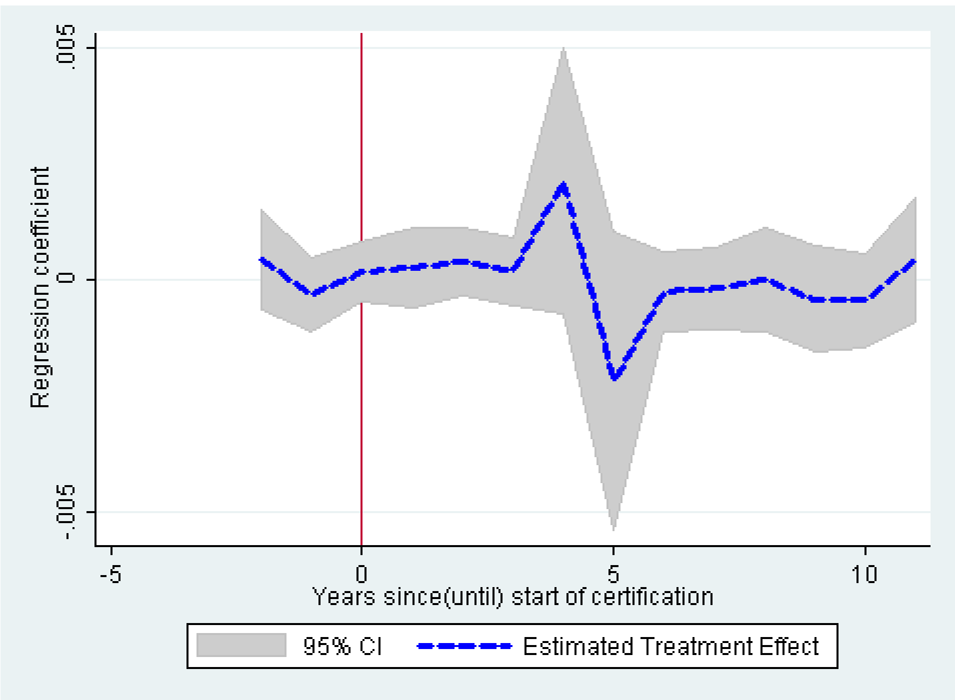


Figure 4. Estimated Coefficients for Single-Year Lagged Certification Dummy Variables: Fixed Effects Model; Matched Control FMUs; Full Sample

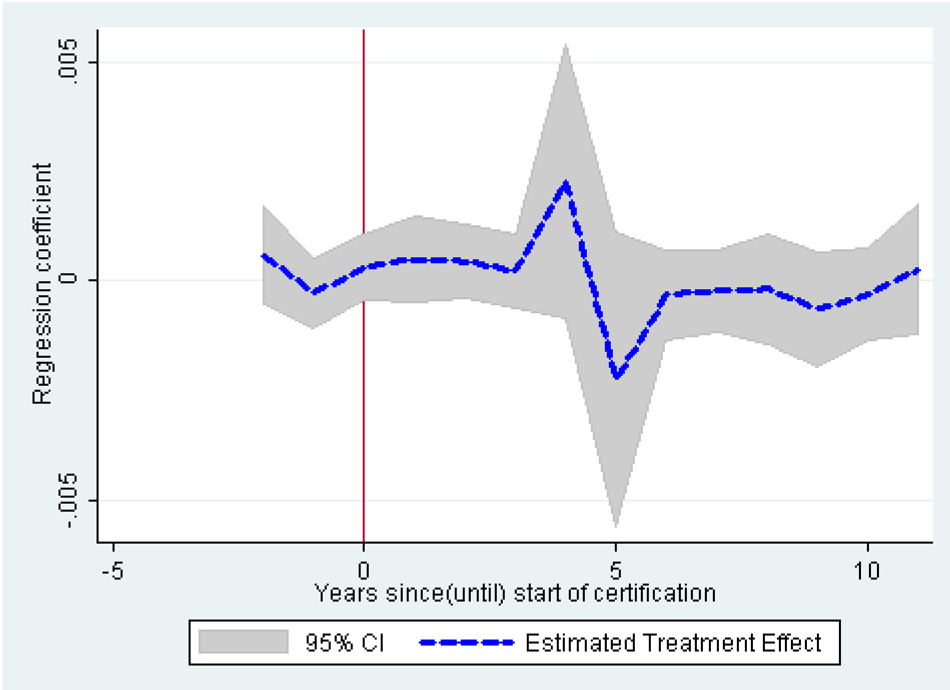
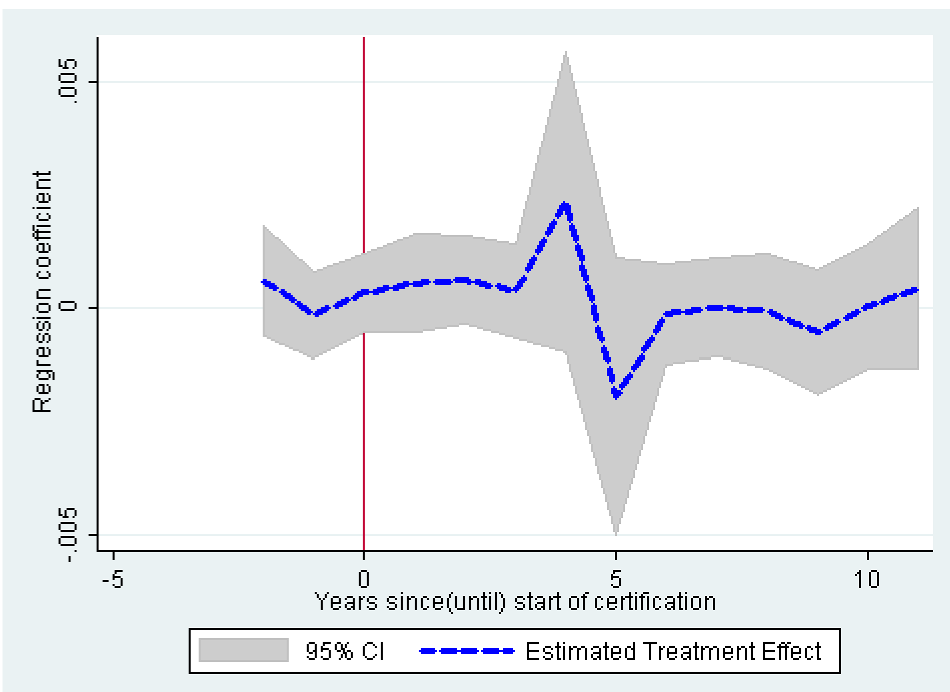


Figure 5. Estimated Coefficients for Single-Year Lagged Certification Dummy Variables: Fixed Effects Model; Certified FMUs Only



7. Discussion

We have used a rich FMU-level 2001–2012 panel data set—comprising information on forest loss, certification, regulatory permitting, and geophysical and socioeconomic land characteristics—along with econometric techniques that aim to control for both observed and unobserved confounding factors, to identify the effect of FSC certification on deforestation in Mexico, a country with both considerable FSC certification and deforestation. To our knowledge, ours is among the first such analyses to use panel data techniques that control for unobserved time-invariant heterogeneity. We find significant differences in the observed characteristics of FSC-certified FMUs. For example, in certain regions in Mexico, certified FMUs tend to be relatively large, carbon-rich, at high altitudes, and far from cities and previous clearing. Our econometric analysis aims at controlling for these and other confounders.

The results of this analysis offer no evidence that FSC certification affects deforestation. Because certification could in principle affect forests differently over time, we tested for a range of temporal effects, including anticipatory effects, contemporaneous effects, single-year lagged effects, and cumulative lagged effects. And because certification's effects could in principle differ across subgroups, we tested for effects among subsamples of FMUs using a specific silvicultural practice (selection logging) and in two geographic regions (North and South). None of these tests rejected the null hypothesis that certification does not affect deforestation. Moreover, in most of our models, point estimates of treatment effects were positive. Very few were negative.

Our analysis has at least three significant limitations. First, we are able to test for certification's effects only on deforestation. We are not able to test for effects on forest degradation. As discussed below, in principle, FSC certification's main environmental benefit could be to stem degradation. Second, lacking a valid instrumental variable, we are not able to control for time-varying confounding factors. Such factors could drive our findings if forest managers' decisions to seek certification were temporally correlated with spikes in forest loss due to unobserved factors—that is, if forest managers experiencing spikes in forest loss tended to seek certification. However, we are aware of no anecdotal or other type of evidence of such correlation. Finally, lacking reliable data on harvest zones, we have conducted our analysis at the FMU level, not at the harvest zone level. As discussed above, that has the advantage of controlling for intra-FMU spillovers. However, it also implies that we are not able to measure effects that occur only inside or outside of harvest zones.

That said, our findings comport with several studies on certification's effects on environmental outcomes. These include five of the six existing quantitative studies that purport to control for confounding factors (Nordén et al. 2015; Rico Staffron 2015; Panlasigui 2015; Barbosa de Lima et al. 2009; Kukkonen et al. 2008) and several studies of CARs (Blackman et al. 2014; Nebel et al. 2005; Rametsteiner and Simula 2003).

Identifying causal factors that might explain our results is beyond the scope of our analysis. However, at least two complementary hypotheses are possible, if not plausible. One is that in Mexico, FSC certification has not spurred *significant* improvements in forest management. Rather, the improvements that forest managers have made associated with certification have either been minor and/or focused on nonenvironmental factors. That is the conclusion of a recent study of more than 1,000 CARs issued to 35 Mexican FMUs in which the authors found that the vast majority addressed minor procedural issues and focused on social, economic, and legal issues rather than environmental ones (Blackman et al. 2014).

A second possibility is that even if FSC certification did spur significant changes in forest management, these changes had more substantial effects on forest degradation, which our outcome measure does not pick up, than on deforestation. An important implication is that our results do not necessarily imply that FSC certification does not have environmental benefits in Mexico, only that its effects on forest loss are not discernible.

What are the policy implications of our findings? As just noted, they do not imply that FSC certification has no environmental benefits, including stemming forest degradation. However, they do suggest that its effects on deforestation may be limited. This finding should at least give pause to policymakers using or considering using forest certification as a tool for addressing that particular problem.

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Appendix 1.

Forest Stewardship Council International Principles and Criteria (FSC-STD-01-001 V5-0 EN, 2012)

Principles (first level) and Criteria (second level) are abbreviated. For the full text, see https://ic.fsc.org/principles-and-criteria.34.htm.

1. Compliance with laws
    - 1.1. Legal status of organization to be certified ("organization")
    - 1.2. Legal status of management unit
    - 1.3. Legal rights to operate management unit
    - 1.4. Illegal resource use
    - 1.5. Compliance with laws, conventions, codes of practice
    - 1.6. Resolution of disputes over issues of law
    - 1.7. Corruption
    - 1.8. Commitment to FSC Principles and Criteria
2. Workers' rights and employment conditions
    - 2.1. Principles of International Labor Organization
    - 2.2. Gender equality
    - 2.3. Health and safety practices
    - 2.4. Living wages
    - 2.5. Job training
    - 2.6. Grievance resolution
3. Indigenous people's rights
    - 3.1. Identification of indigenous peoples
    - 3.2. Legal and customary rights
    - 3.3. Prior consent
    - 3.4. Rights, customs, and culture
    - 3.5. Sites of special significance
    - 3.6. Traditional knowledge
4. Community relations
    - 4.1. Identification of local communities
    - 4.2. Legal and customary rights
    - 4.3. Opportunities for employment and training
    - 4.4. Engagement with local communities
    - 4.5. Avoidance of negative impacts
    - 4.6. Grievance resolution
    - 4.7. Sites of special significance
    - 4.8. Traditional knowledge

5. Benefits from the forest
    - 5.1. Benefits from a range of ecosystem services
    - 5.2. Sustainable harvest levels
    - 5.3. Planning for positive and negative externalities
    - 5.4. Use of local value added services
    - 5.5. Commitment to long-term economic viability
6. Environmental values and impacts
    - 6.1. Assessment of environmental values
    - 6.2. Assessment of potential impacts on environmental values
    - 6.3. Actions to prevent and mitigate negative impacts
    - 6.4. Protection of rare and threatened species
    - 6.5. Protection/restoration of native ecosystems
    - 6.6. Maintenance of biological diversity
    - 6.7. Protection/restoration water resources
    - 6.8. Enhancing resilience
    - 6.9. Conversion of natural forests to plantations, and plantation to other uses
    - 6.10. Plantations
7. Management planning
    - 7.1. Management policies and objective
    - 7.2. Management plan
    - 7.3. Verifiable targets
    - 7.4. Revisions of plan
    - 7.5. Transparency
    - 7.6. Stakeholder engagement
8. Monitoring and assessment
    - 8.1. Implementation of management plan
    - 8.2. Environmental and social impacts
    - 8.3. Analysis of monitoring results
    - 8.4. Transparency
    - 8.5. Tracking and tracing system
9. High conservation values
    - 9.1. Assessment
    - 9.2. Maintenance and enhancement
    - 9.3. Precautionary approach
    - 9.4. Periodic monitoring
10. Implementation of management activities
    - 10.1. Regeneration
    - 10.2. Species used for regeneration
    - 10.3. Alien species
    - 10.4. Genetically modified organisms
    - 10.5. Silvicultural practices
    - 10.6. Fertilizers

10.7. Integrated pest management
10.8. Biological control agents
10.9. Natural hazards
10.10. Infrastructure development
10.11. Conservation of environmental values
10.12. Waste disposal

Appendix 2.

Table A1. 64 Certified Forest Management Units in Regression Sample

State	Municipio	Name	Tenure	First year certified	Last year certified	Size (ha)
Chiapas	Cintalapa	P.P. Los Ocotones	P	2008	2020	1,373
Chihuahua	Guadalupe y Calvo	Ejido El Tule y Portugal	E	2013	2018	8,843
Chihuahua	Guadalupe y Calvo	Ejido La Trinidad	E	2002	2019	43,722
Chihuahua	Guadalupe y Calvo	Ejido Redondeados	E	2005	2007	82,156
Chihuahua	Madera	Ejido El Largo y Anexos	E	2001	2017	261,460
Durango	Durango	Ejido Agustin Melgar	E	2002	2007	7,050
Durango	Durango	Ejido Centenario	E	1998	2010	4,353
Durango	Durango	Ejido Cienega de Caballos	E	2004	2017	6,318
Durango	Durango	Ejido Echeverria de la Sierra	E	1998	2008	5,484
Durango	Durango	Ejido el Encinal	E	1999	2005	7,073
Durango	Durango	Ejido el Nayar	E	2002	2012	4,975
Durango	Durango	Ejido Llano Grande	E	2012	2017	10,946
Durango	Durango	Ejido San Isidro	E	2002	2007	7,348
Durango	Pueblo Nuevo	Com. San B. de Milpillas Chico	C	2004	2017	153,202
Durango	Pueblo Nuevo	Ejido Adolfo Ruiz Cortinez	E	2010	2015	4,224
Durango	Pueblo Nuevo	Ejido Antonio Molina Deras	E	2011	2014	7,882
Durango	Pueblo Nuevo	Ejido Chavarria Nuevo	E	2005	2010	8,374
Durango	Pueblo Nuevo	Ejido Chavarria Viejo	E	2005	2017	9,788
Durango	Pueblo Nuevo	Ejido el Brillante	E	2004	2014	9,517
Durango	Pueblo Nuevo	Ejido la Campana	E	2004	2014	5,932
Durango	Pueblo Nuevo	Ejido la Ciudad	E	2002	2018	13,795
Durango	Pueblo Nuevo	Ejido la Victoria	E	2001	2020	10,761
Durango	Pueblo Nuevo	Ejido las Bayas	E	2013	2018	4,323
Durango	Pueblo Nuevo	Ejido los Bancos	E	2015	2020	3,652
Durango	Pueblo Nuevo	Ejido Pueblo Nuevo	E	2000	2016	166,755
Durango	Pueblo Nuevo	Ejido San Esteban y Anexos	E	2001	2018	9,685
Durango	San Dimas	Ejido Duraznitos y Picachos	E	2004	2014	3,410
Durango	San Dimas	Ejido La Manga y Anexos	E	2004	2014	6,305
Durango	San Dimas	Ejido San Jose de Causas	E	2006	2011	7,613
Durango	San Dimas	Ejido San Pedro	E	2007	2019	9,822
Durango	San Dimas	Ejido Vencedores	E	2002	2018	23,926
Durango	San Dimas	P.P. Lote 1 Fr. II de la Trinidad	P	2002	2007	300
Durango	Santiago Papasquiaro	Ejido Salto de Camellones	E	2001	2019	10,641
Durango	Santiago Papasquiaro	Ejido San Diego de Tenzaenz	E	2001	2018	60,468
Durango	Tepehuanes	Com. el Tarahumar y Bajios …	C	2003	2019	73,310
Durango	Tepehuanes	Comunidad Lobos y Pescaderos	C	2012	2017	30,115
Est. de Mex.	Coatepec Harinas	Ejido Agua Bendita	E	2014	2019	1,002
Jalisco	Pihuamo	Ejido Barranca del Calabozo	E	2009	2014	2,073
Michoacan	Nuevo Parangaricutiro	Com. Nuevo San Juan Parang.	C	2006	2011	18,138
Oaxaca	Capulalpam de Mendez	Com. Capulalpam de Mendez*	C	1996	2012	3,843
Oaxaca	Ixtlan de Juarez	Comunidad Ixtlan de Juarez	C	2001	2017	18,180

Oaxaca	Nuevo Zoquiapam	Comunidad Nuevo Zoquiapam	C	2005	2009	9,465
Oaxaca	S. Juan B. Jayacatlan	Com. S. Juan Bautista Jayacatlan	C	2003	2008	12,300
Oaxaca	San Juan Quiotepec	Com. S. Miguel Maninaltepec	C	2006	2009	13,743
Oaxaca	San Miguel Aloapam	Comunidad San Miguel Aloapam	C	2005	2008	13,518
Oaxaca	Santa Catarina Ixtepeji	Com. Santa Catarina Ixtepeji	C	2006	2017	21,059
Oaxaca	Santiago Comaltepec	Comunidad Santiago Comaltepec*	C	1996	2012	18,070
Oaxaca	Santiago Textitlan	Comunidad Santiago Textitlan	C	2001	2018	28,146
Oaxaca	Santiago Xiacui	Comunidad la Trinidad Ixtlan*	C	1996	2012	805
Oaxaca	Santiago Xiacui	Comunidad Santiago Xiacui*	C	1996	2012	1,681
Oaxaca	Zimatlan de Alvarez	Comunidad San Pedro el Alto	C	2001	2018	30,048
Puebla	Chignahuapan	C.P. Innominado … Chignahuapan	P	2015	2020	43
Puebla	Chignahuapan	Ejido Cruz Colorada	E	2013	2018	1,055
Puebla	Chignahuapan	Ejido el Manantial	E	2014	2019	395
Puebla	Chignahuapan	Ejido Llano Grande	E	2012	2017	2,446
Puebla	Chignahuapan	Ejido Llano Verde	E	2013	2018	814
Puebla	Chignahuapan	Ejido Piedra Ancha 2 Ampliacion	E	2012	2017	1,014
Puebla	Zacatlan	Ejido Rancho Nuevo Nanacamila	E	2013	2018	490
Quintana Roo	Felipe Carrillo Puerto	Ejido Laguna Kana	E	2001	2006	18,495
Quintana Roo	Felipe Carrillo Puerto	Ejido Naranjal Poniente	E	2001	2006	12,620
Quintana Roo	Felipe Carrillo Puerto	Ejido Petcacab	E	2005	2009	59,721
Quintana Roo	Othon P. Blanco	Ejido Caoba	E	2005	2018	67,781
Quintana Roo	Othon P. Blanco	Ejido Chac-Choben	E	2006	2009	18,654
Quintana Roo	Othon P. Blanco	Ejido Tres Garantias	E	2005	2009	43,678

*Certified jointly as Unión de Comunidades Productoras Forestales Zapotecas-Chinantecas de la Sierra de Juárez (UZACHI). **Tenure**: E = ejido; C = comunidad; P = private.
Sources: Rainforest Alliance, Consejo Civil Mexicano para la Silvicultura Sostenible.

Figure A1. Estimated Coefficients for Single-Year Lagged Certification Dummy Variables: Fixed Effects Model; FMUs Using Selection Silviculture Only

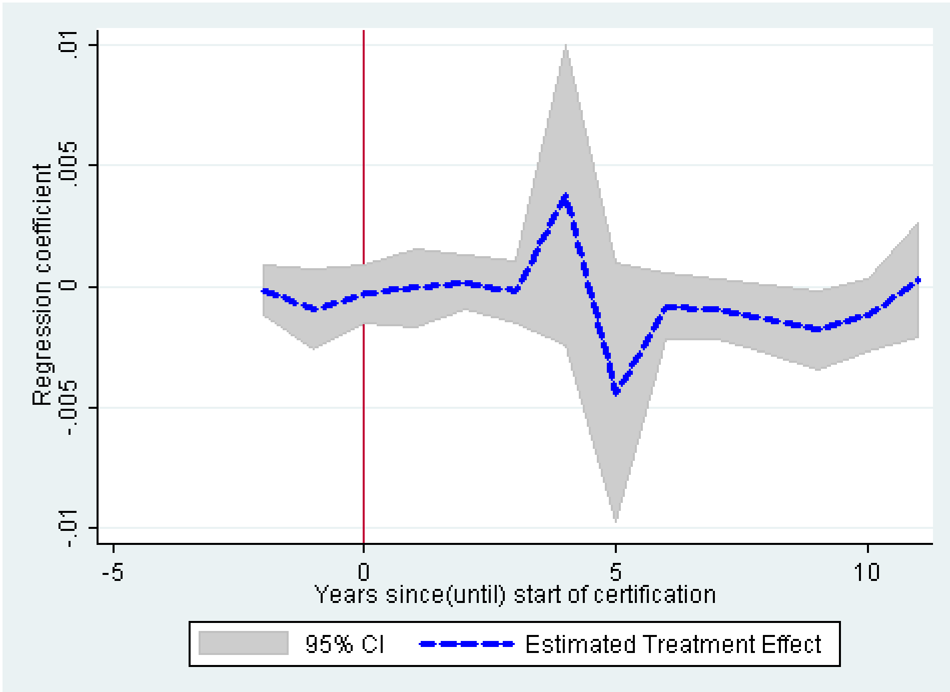

Figure A2. Estimated Coefficients for Single-Year Lagged Certification Dummy Variables: Fixed Effects Model; Matched Control FMUs; FMUs Using Selection Silviculture Only

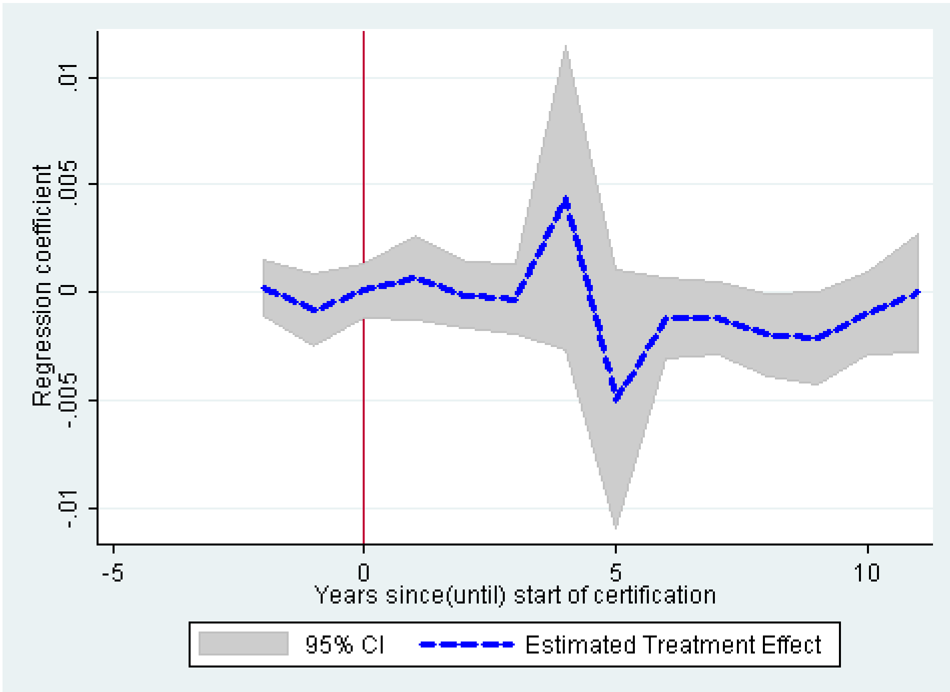

Figure A3. Estimated Coefficients for Single-Year Lagged Certification Dummy Variables: Fixed Effects Model; Certified FMUs Using Selection Silviculture Only