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The Effectiveness of Payments for Environmental Services in Mexican Community Forests

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Université d'Auvergne, Clermont-Ferrand 1
Ecole Doctorale des Sciences Economiques, Juridiques et de Gestion
Centre d'Etudes et de Recherches sur le Développement International (CERDI)

**THE EFFECTIVENESS OF
PAYMENTS FOR ENVIRONMENTAL SERVICES
IN MEXICAN COMMUNITY FORESTS**

Thèse Nouveau Régime
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Pour l'obtention du titre de Docteur *ès* Sciences Economiques

Par

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Sous la direction de:
Mme Catherine ARAUJO-BONJEAN

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L'université d'Auvergne n'entend donner aucune approbation ou improbation aux opinions émises dans cette thèse. Ces opinions doivent être considérées comme propres à leur auteur.

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Résumé

Durant ces dernières années, l'engouement suscité par les Paiements pour Services Environnementaux (PSE) n'a cessé de s'accroître et de nombreux programmes ont été mis en place à travers le monde. Néanmoins, malgré un nombre croissant d'études, l'efficacité de ces instruments pour la réduction de la déforestation reste contestée. Cette thèse contribue à cette littérature en se concentrant plus spécifiquement sur l'impact d'un programme fédéral mexicain de PSE: le PSA-H. Après une introduction générale retraçant l'émergence des PSE et les débats académiques autour de cet instrument, le second chapitre présente les spécificités du système foncier mexicain, les politiques environnementales et plus spécifiquement le PSA-H ainsi que les données utilisées dans l'analyse empirique. La thèse s'intéresse ensuite dans un troisième chapitre aux méthodes d'analyse d'impact et à leur application dans le contexte des instruments de conservation de la forêt. Ce chapitre montre que les PSE sont des traitements spécifiques et que de nombreux ajustements sont nécessaires pour pouvoir appliquer des méthodes d'analyse d'impact dans ce contexte. Par la suite, la thèse propose trois analyses empiriques s'appuyant sur des données d'enquêtes primaires et secondaires. Dans le quatrième chapitre, nous proposons une nouvelle méthode permettant d'estimer l'additionnalité et les effets de fuite du PSA-H dans notre zone d'étude. Les résultats montrent que les effets de fuite peuvent diminuer l'efficacité des PSE. Dans le cinquième chapitre, la thèse étudie comment l'usage de la terre peut influencer l'allocation des paiements au sein des communautés bénéficiaires. Les résultats de l'analyse empirique suggèrent que, en dépit de la volonté des autorités mexicaines de concevoir le PSA-H comme un instrument de compensation, la distribution suit une logique de récompense. Les agents qui déforêtent reçoivent moins de paiements, ce qui montre que la logique pollueur-payé à la base des PSE Coasiens n'est pas respectée. Le sixième chapitre étudie les interactions entre le PSA-H et la foresterie communautaire. Les entreprises de foresterie communautaire se sont largement développées au Mexique depuis les années 1980. Dans une optique de coordination des politiques économiques, il est crucial de savoir comment elles interagissent avec le PSA-H. Les résultats de l'analyse empirique montrent que le PSA-H peut aider ces entreprises à se stabiliser et se développer. Enfin, dans une conclusion générale, la thèse discute les implications des analyses empiriques pour la conception des PSE et les perspectives de recherche qui en découlent.

Mots clés: Analyse d'Impact; Conservation de la Forêt; Economie de l'Environnement; Mexique; Paiements pour Services Environnementaux

Summary

During recent years, Payments for Environmental Services (PES) have become a popular forest conservation instrument and numerous new schemes have emerged around the world, particularly in developing countries. Nevertheless, despite a growing body of academic literature on the topic, little remains known of the effectiveness of PES schemes in reducing deforestation. This dissertation contributes to the literature with a specific focus on the impact of a federal Mexican PES scheme: the PSA-H. We begin with a general introduction retracing the emergence of PES and the current academic debates surrounding the mechanism. Chapter 2 introduces the particularity of the land tenure system in Mexico, the country's environmental policies and the PSA-H scheme and presents the data used in our empirical analysis. Chapter 3 looks at impact evaluation methodologies and how they have been used in the context of forest conservation instruments. We show that PES schemes are very complex treatment and that evaluating their impact using classic impact evaluation techniques requires many adjustments. After discussing these challenges, we propose three empirical essays based on primary and secondary data. Chapter 4 presents a new methodology allowing us to estimate the additionality and leakages of the PSA-H in our study area. Our results provide evidence that leakages can undermine PES effectiveness. Chapter 5 studies how land use can influence the allocation of PES payments within the beneficiary community. Using original survey data, our results show that, despite the attempts of the Mexican authorities to design the PES scheme as compensation for avoiding deforestation, payments have been redistributed as a reward for existing conservation. The deforesting agents receive less remuneration than other recipients, which shows that the polluter-paid principle at the origin of the Coasean notion of PES has not been appropriated. Chapter 6 studies the interactions between the PSA-H and Mexico's Community forest enterprises (CFEs) which are run by the communities and implement sustainable extraction activities in community forests. In a search for a relevant policy mix, it seems crucial to know how they interact with the PSA-H. The results of our empirical analysis show that the PSA-H can help these enterprises to develop and stabilize over time. Finally, in the conclusion, we discuss the implications of the empirical essays for the design of PES schemes and future research.

Keywords: Environmental Economics; Forest conservation; Impact evaluation; Mexico; Payments for Environmental Services

List of Acronyms

AES	Agro-Environmental Schemes
AGEB	<i>Area Geostatística Básica</i>
ATE	Average Treatment Effect
ATT	Average Treatment Effect on the Treated
CCT	Conditional Cash-Transfers
CFE	Community Forest Enterprises
CONAFOR	<i>Comisión Nacional Forestales</i>
CONANP	<i>Comisión Nacional de Áreas Naturales Protegidas</i>
CONAPO	<i>Consejo Nacional de Población</i>
DID	Difference-In-Difference
ENNAF	<i>Encuesta Nacional a los Nucleos Agrarios Forestales</i>
ES	Environmental services
FAO	Food and Alimentation Organization
FE	Fixed Effects estimator
FSC	Forest Stewardship Council
GATT	General Agreement on Tariffs and Trade
GPS	Generalised Propensity Scores
IE	Impact evaluation
ICDP	Integrated Conservation and Development Project
IMR	Inverse-Mills Ratio
INECC	<i>Instituto Nacional de Ecología y Cambio Climático</i>
INEGI	<i>Instituto Nacional de Estadística Geografía e Informática</i>
IPCC	Intergovernmental Panel on Climate Change
ITT	Intention to Treat Effect
LATE	Local Average Treatment Effect
MP	Mexican pesos
NGO	Non-Governmental Organization
NPA	Natural Protected Areas
NAFTA	North American Free Trade Agreement
OC	Opportunity cost
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Square
PES	Payments for Environmental Services
PSA-CABSA	<i>Programa para el Desarrollo de los Mercados de Servicios Ambientales de Captura de Carbono y los Derivados de la Biodiversidad y para Fomentar el Establecimiento y Mejoramiento de los Sistemas Agroforestales</i>
PSA-H	<i>Pagos por Servicios Ambientales Hidrológicos</i>
PSM	Propensity Score Matching

PDFC	<i>Programa de Desarrollo Forestal Comunitario</i>
PMPM	<i>Programa de Mejores Prácticas de Manejo</i>
PROCEDE	<i>Programa de Certificación de Derechos Ejidales</i>
PROCOREF	<i>Programa de Conservación y Restauración de Ecosistemas Forestales</i>
PROCYMAF	<i>Proyecto de Conservación y Manejo Sostenible de Recursos Forestales</i>
PRODELAN	<i>Programa para el Desarrollo de Plantaciones Forestales Comerciales</i>
PRODEFOR	<i>Programa de Desarrollo Forestal</i>
RCT	Randomized Controlled Trials
RDD	Regression discontinuity design
RE	Random Effects estimator
SEMARNAT	Environment and Natural Resources Department
SUTVA	Stable Unit of Treatment Value Assumption
TSLS	Two-Stage Least Square
USD	United States Dollar
WLS	Weighted Least Squares

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General Introduction

“L’environnement est l’envers imaginaire de la Nature, parée de tous les attraits de l’harmonie, de l’équilibre. Dans l’imaginaire collectif, la nature est propre, l’environnement est sale: ne parle-t-on pas, dans le même temps, des équilibres de la nature et des déséquilibres environnementaux?”

Tout se passe comme si la nature était d’essence divine, l’environnement étant création des hommes.

Le millénaire touche à sa fin, engendrant des peurs.

Ce n’est plus, comme en l’An Mil, la comète qui nous tombera dessus, mais c’est encore la fin du monde qui nous est promise : cette fois, les hommes eux-mêmes seraient, nous dit-on, les artisans de leur propre perte.”

Jacques Weber (1995)¹

1.1 Ecosystem services: A redefinition of the interdependencies between human and natural capital

Social costs and internalization of externalities, pollution and abatement or compensation, natural capital and sustainability, tragedy of the commons and socio-ecological systems, prisoner’s dilemma and collective action... When it comes to environmental issues, one can not escape its own representation of how can human behavior impact nature and vice versa. In Weber’s words: “The way a management problem is posed is partially trapped in our representation of the context in which this problem arises or the way we make it emerge by formalizing it²”. In this regard, the emergence of the ecosystem services concept in the late 1990’s (Daily, 1997; Costanza et al., 1998) represents a crucial shift in the way States, non governmental organizations (NGOs), international institutions, academics or any actors directly or indirectly involved in environmental policies perceives environmental issues (Kull et al., 2015).

¹Source: Weber (2013). *Gestion des ressources renouvelables: fondements théoriques d’un programme de recherche*. Collection Indisciplines, Editions Quae

²Translation by the author: *La façon de poser un problème de gestion est en partie prisonnière de notre représentation du contexte dans lequel ce problème émerge, ou dont nous le faisons émerger en le formalisant.*

According to [Costanza et al. \(1998\)](#)'s definition, ecosystem services are *flows of materials, energy, and information from natural capital stocks which combine with manufactured and human capital services to produce human welfare*. The interdependencies between nature and human are at the core of this notion. Nature is here conceptualised as a stock: the natural capital. According to this definition, human behavior can degrade the natural capital, for instance by clearing forest, releasing CO₂ into the atmosphere or polluting rivers. As this stock of natural capital decreases, the flow of ecosystem services also decreases.

What are the services provided by this natural capital? The usual typology classifies them into four categories of ecological functions [De Groot et al. \(2002\)](#):

- Information to contribute to the maintenance of human health
- Regulation related to the capacity of the nature to regulate ecological processes
- Production of goods for human consumption
- Habitat for the conservation of biological and genetic diversity

Forest ecosystems are major providers of ecosystem services through various means such as carbon sequestration, flood or erosion mitigation bio-diversity conservation and improvement in water quality among many other things ([Daily, 1997](#); [Neary et al., 2009](#); [Fiquepron et al., 2013](#)). We will here focus primarily on forests but other types of ecosystems are important providers of ecosystem services such as wetlands, rivers, agricultural lands etc...

Following ecosystem services, environmental services (ES) subsequently appeared in the academic literature. Both terms are often used synonymously but slight differences may exist depending on the author. For instance, [Wunder \(2005\)](#) and others tend to consider that the notion of ecosystem services is implicitly larger than the ES notion. [Karsenty and Ezzine de Blas \(2014\)](#) propose an alternative distinction arguing that ecosystems services are provided by nature to human beings and are not appropriable while ES are provided by human beings to other human beings in order to increase the nature's provision of ecosystem services. Let's use the example of a landowner that is planting trees on his land located in the upper watershed which enhance water quality. The ES is provided by the landowner by planting trees and the water quality is the ecosystem services provided by the trees.

The use of these terms has widely spread during the last 15 years but their relevancy for the conceptualization of environmental issues is highly debated. Many authors emphasize that conceptualizing nature as a stock that provides flows of ES may underestimate the difficulty of governing the provision of ecosystem services ([Farley and Costanza, 2010](#); [Norgaard, 2010](#); [Muradian and Rival, 2012](#)). Reaching sustainable solutions requires major institutional changes. Moreover, a static project-by-project approach that aims at enhancing the provision of ES in one area may fail to account for the intrinsic complexity of ecosystem functioning.

A large debate that derives from a lack of clarification around the notion of ES and its application concerns ecosystem services valuation. Many authors tries

to estimate the value of services provided by nature in various places (Costanza et al., 1998; Farber et al., 2002; Costanza et al., 2006, among others). The debate about economic valuation of nature is a traditional point of disagreement between environmental economics and ecological economics (Gómez-Baggethun et al., 2010). As highlighted by Chevassus-au Louis et al. (2009) and Salles (2011), ecosystem services valuation is important in highlighting the biophysical values of nature that may not be directly perceived by humans, in improving decision making and in bringing political attention to these topics, among other reasons. Nevertheless, it may not be relevant to offer payments based on these valuations. In this regard, Karsenty and Ezzine de Blas (2014)'s distinction is important. If payments are for ES and not for ecosystem services, then the remuneration is no longer related to the value of the ecosystem services. In the above example, the landowners in the upper watershed is paid to plant trees on his land not to enhance water quality.

1.2 Payments for Environmental Services: A direct approach to conservation

Based on the assumption that environmental problems come from an under-provision of ES, Payments for Environmental Services (PES) schemes have emerged around the globe. PES are defined by Wunder (2005) as "voluntary transactions where a well-defined ES (or a land-use likely to secure that service) is being bought by a (minimum one) ES buyer from a (minimum one) ES provider if and only if the ES provider secures ES provision (conditionality)".

PES schemes have been implemented in various types of ecosystems but we will here again focus on forests. One can distinguish between use-restricting and asset-building PES. In the context of forest conservation, the former remunerates forest conservation while the latter proposes payments to restore the flow of ES through reforestation or agro-forestry, for instance. Four types of PES are usually acknowledged in the literature:

- Payments for carbon sequestration
- Payments for biodiversity protection
- Payments for watershed protection (or hydrological PES)
- Payments for landscape beauty

Compared to Natural Protected Areas (NPAs), PES schemes are voluntary instead of being based on command-and-control. As stated by Wunder (2005), PES use economic incentives while NPA rely on the regulatory framework. PES schemes are also more direct than Integrated Conservation and Development Projects (ICDP) that were not directly conditional on forest conservation and wanted to achieve "conservation by distraction" i.e. by providing alternative activities to land clearing. Hence, PES were supposed to be more effective than NPA or ICDP based

on the principle emphasized by Ferraro and Kiss (2002) that: “*the cheapest way to get something you want is to pay for what you want (e.g., protected rain forest), rather than pay for something indirectly related to it*”. Due to this apparent effectiveness and simplicity of implementation, PES schemes have largely developed during the last 15 years (Wunder et al., 2008; Pattanayak et al., 2010; Alix-Garcia and Wolff, 2014).

In line with Wunder (2005)’s definition, the concept of PES derive from the Coase theorem (Coase, 1960). If transaction costs are low and property-rights well defined, the buyers and sellers can find a monetary agreement over a land-use likely to secure an ES provision. As predicted by the Coase theorem, a PES scheme needs well defined property rights in order to function. Complete land titling is not necessary but PES schemes can not work without use and exclusion rights. It follows from the Coase theorem that PES schemes financed directly by the ES users will only emerge if transaction costs are not too high. In the context of PES, transaction costs include costs for search and information, negotiation or monitoring among others. According to Engel et al. (2008), high transaction costs justify the intermediation by the State or NGOs on behalf of the users.

Many authors contest the Coasean vision of PES which they consider as institutionally blind and counterproductive in the long-run (Muradian et al., 2010; Vatn, 2010; Muradian et al., 2013). Although, as in the famous Vittel case (Perrot-Maitre, 2006), Coasean PES emerged on small scales, this Coasean conceptualisation of the instrument does not seem appropriate for the schemes financed by States or NGOs. Many PES schemes are initiated, designed and financed by this type of intermediary. These PES schemes are shaped by local institutions and barely looks like Coasean agreement. In such cases, the intermediary is undeniably the main actor governing the scheme (Muradian et al., 2010; Vatn, 2010). As argued by Engel et al. (2008), the intermediaries may act on behalf of ES beneficiaries but it seems exaggerated to state that those beneficiaries are voluntarily contributing to the scheme as they are required to pay taxes (Vatn, 2015). For this reason, Muradian (2013) refers to PES as incentives for better resource management more than Coasean agreement. The main innovation of PES is the conditionality (Wunder, 2015), therefore, by many characteristics, PES can be analyzed as an environmental conditional-cash-transfer (CCT) (Martin Persson and Alpizar, 2012). Finally, when designing PES programs, many stakeholder interact in the policy making process and environmental schemes often tend to be hybridized into programs with multiple objectives including poverty reduction (Jack et al., 2008; Le Coq et al., 2013; Shapiro-Garza, 2013; Kolinjivadi et al., 2015). This hybridization also tends to drive the program away from a Coasean environmental program.

A related debate concerns the supposed market-based nature of the instrument. The perception of PES as market based instruments ideologically attracted decision makers who associate market with efficiency as much as it has repulsed others that accuse PES of selling nature as a commodity (Lapeyre and Pirard, 2013). The perception of nature as a stock providing services tends to give utilitarian values to nature and simplify complex ecosystems into commodities (Gómez-Baggethun et al.,

2010; Kosoy and Corbera, 2010). Nevertheless, as highlighted by Pirard (2012), the term “market-based” refers to a wide variety of arrangements and most of them are not directly related to a market. In the case of PES, the term “market-based” may be used to distinguish the instrument from command-and-control initiatives but PES does not result in any transfer of land property rights (Karsenty and Ezzine de Blas, 2014; Gómez-Baggethun and Muradian, 2015). In most cases, the existence of a PES scheme does not mean that a market for ES has been created (Corbera et al., 2007). National PES schemes are often financed through compulsory taxes, most buyers do not even know they are contributing to a PES scheme. In that case, PES programs do not rely on a market mechanism at least on the demand-side (Vatn, 2015).

1.3 PES: An effective instrument?

The effectiveness of PES for forest conservation relies on three criteria (Wunder, 2005; Engel et al., 2008):

- Additionality, defined as the avoided deforestation on protected parcels attributable to the PES
- Leakages, defined as the indirect impact of the PES on land-use in another area
- Permanence, defined as the ability of the PES to achieve a sustainable increase of ES provision over time

In the influential “*Money for Nothing?*”, Ferraro and Pattanayak (2006) highlight that evaluating additionality goes beyond monitoring the number of hectares in a given PES program. Additionality is the PES’s schemes capacity to make a difference compared to a counterfactual situation in the absence of the program. As highlighted by Martin Persson and Alpizar (2012), if payments are conditional to a type of land-use, the extent of additionality depends on the percentage of area enrolled that would not have met the conditionality in the absence of the scheme. In the case of PES for conservation, effectiveness is measured by the avoided deforestation i.e. the decrease in deforestation attributable to the program.

Much attention has been given to leakages of conservation projects (Wu, 2000; Wu et al., 2001; Chomitz, 2002). In the context of forest conservation, leakages emerge when conservation in one area leads to more deforestation in another area. Various mechanisms can lead to leakages. The most cited is activity shifting if the activity responsible for clearing is displaced to another area. Leakages can also occur because of market effects. If by reducing available land, the PES scheme impacts the price of timber or agricultural commodities, this can increase deforestation in another area. In the context of PES programs for forest conservation, direct leakages are very likely to occur if land is easily available (Aukland et al., 2003).

In the literature, permanence has been given less attention than additionality and leakages. This may be due to the fact that most PES schemes are too recent

to empirically explore their effects over the long run. We can distinguish two approaches to PES permanence. In his study of a Costa Rican national PES, [Pagiola \(2008\)](#) acknowledges that the positive impacts of PES are likely to be temporary if the payments stop. The PES must continue as long as necessary and permanence depends on the capacity to sustain and secure funding for the scheme over time. Alternatively, one can think about PES schemes as temporary instruments likely to initiate a transition toward more sustainable use of the forest cover through agroforestry for example ([Wunder, 2005](#)). As highlighted by [Pirard et al. \(2010\)](#) and [Karsenty \(2011\)](#), to have a sustainable impact on deforestation, PES schemes must be combined with investment in order to relax dependence on degrading activities. Otherwise, PES programs may only have a short-term impact and are likely to generate leakages.

All authors agree that with scarce resources PES must make a difference according to a business-as-usual situation and generate avoided deforestation. However, uncertainties remain about how to achieve effectiveness, especially in the case of schemes funded by States or NGOs. In line with a polluter-paid Coasean approach, to be additional, PES must target threatened forests that would be deforested without the payments and compensate the owners for the foregone income due to PES implementation: the opportunity cost (OC) ([Alix-Garcia et al., 2008](#); [Engel et al., 2008](#); [Wunder, 2008](#); [Martin Persson and Alpizar, 2012](#)). Yet, as highlighted by [Ferraro \(2008\)](#) and [Anthon et al. \(2010\)](#), PES schemes are subject to adverse selection because of asymmetric information. The OC and the willingness to deforest are known only by forest owners so targeting credible threats of deforestation is not an easy task.

Moreover, targeting credible threats of deforestation may not be the most effective solution. As emphasized by many authors ([Muradian et al., 2013](#)), the polluter-paid logic of Coasean PES disregards many other issues that determine the long-run impact of the schemes. How the scheme considers the existing institutions that rule the use of the forest cover as well as the local perception of justice and fairness may be a crucial determinant of PES effectiveness ([Corbera et al., 2007](#); [Swallow et al., 2009](#); [Pascual et al., 2010](#)). Moreover, following a polluter-paid approach, PES must prioritize environmental benefits over social goals and focus solely on OC compensation. By contrast, the approach of PES as incentives proposed by [Muradian \(2013\)](#), acknowledges that PES may have multiple goals and may reward greener behavior even though they are not additional. Yet, it is often feared that directing payments to the agents that deforest in a polluter-paid approach may crowd-out any intrinsic motivation to conserve ([Rode et al., 2014](#)).

1.4 Studying the Mexican PSA-H

Many authors recently have emphasized the need for more impact evaluation (IE) of PES and of conservation instruments in general ([Ferraro and Pattanayak, 2006](#); [Pattanayak et al., 2010](#); [Miteva et al., 2012](#)). Until recently, IE has focused mainly on

additionality and leakages. A growing body of literature has emerged during the last five years that looks at the impact of PES on deforestation in Costa Rica (Arriagada et al., 2012; Robalino and Pfaff, 2013), Mexico (Honey-roses et al., 2011; Alix-Garcia et al., 2012), Bolivia (Canavire-Bacarreza and Hanauer, 2013) and Thailand (Sims, 2010; Ferraro et al., 2011) among others. This literature is mainly based on the application to environmental issues of IE methodologies developed in other fields of development economics such as microfinance, education and health economics (Ravallion, 2007).

In line with this literature, this dissertation proposes an empirical analysis of the implementation and the impact of a Mexican PES scheme: The PSA-H. The PSA-H is a federal PES program that has offered payments for forest conservation since 2003. It is a hydrological PES partially financed by a water use tax and managed by the federal forest commission: CONAFOR (Muñoz-Piña et al., 2008). The particularity of Mexican forest relates to the Mexican land tenure system. As a result of one century of agrarian reforms in the rural sector, more than 80% of the forest cover is constituted of community forests (Bray et al., 2003b). While these forests are ultimately state-property, they are managed by communities called *ejidos* through traditional governance institutions including a community assembly of *ejidatarios*.

While, most of the PSA-H payments are made to *ejidos*, as highlighted by Corbera et al. (2009), the ultimate beneficiaries are not clearly identifiable. Through the assembly, *ejidatarios* can choose to redistribute the payments according to their own rules or invest it into common goods. Enrollment in the scheme is voluntary but all applying *ejidos* are not necessarily accepted into the scheme as CONAFOR ranks application according to predefined objectives (Rolon et al., 2011). Since 2003, the program has gained political attention and financial support but has been progressively hybridized into a multi-objectives program targeting both threatened forests and marginal areas (Muñoz Piña et al., 2011; Shapiro-Garza, 2013; Sims et al., 2014). Once enrolled in the program, beneficiaries commit themselves avoiding land-use change in a defined forested area and receive yearly payments proportional to the amount of forest enrolled.

Chapter 2 summarizes the evolution of the land tenure system in Mexico until the second agrarian reform in 1992 and presents Mexican environmental policies, with a strong emphasis on the PSA-H. In addition, this chapter presents the data used in the empirical analysis including the surveys realized through the ANR-funded project PESMIX. It also proposes useful descriptive statistics in order to introduce the empirical analysis.

Chapter 3 discusses the implementation of IE methodologies in the context of PES. As emphasized above, a growing body of literature has emerged on this topic in the last ten years. In Chapter 3, the main methodologies used to evaluate the impact of PES are introduced. This chapter emphasizes the main assumptions of the estimators and illustrates their uses based on examples from the literature. In a final section, we discuss the relevance of these methodologies in the context of PES. Many methodological choices and trade-offs arise in the IES of PES schemes. We

discuss the methodological trade-offs, propose guidelines and identify new area of investigation for future research for IE.

Building on these conclusions, Chapter 4 proposes a new methodological approach to estimate PES additionality. This approach explicitly considers forest ownership and simultaneously estimates impact on protected land and leakages. Moreover, it takes into consideration heterogeneity of exposure to the treatment regarding time spent in the scheme. First, we use a unit of observation that combines land tenure, land cover, gridding and PSA-H protection. We build on spatial econometrics tools to conjointly estimate direct impacts of PSA-H and potential leakage effects. Rather than using a dummy variable, we introduce the time spent in the program in our estimation and take into account contract renewal. We pre-process our data using matching to account for the selection bias and propose a regression framework to estimate the impact of the program. Our analysis provides evidence that, in our study area, leakage effects undermined the additionality of the PSA-H.

Chapter 5 looks at the distribution of payments within the *ejidos* and how it is linked to *ejidatarios'* land use. As highlighted above, while PES instruments must be additional, a debate remains about which types of forest should be targeted. One viewpoint is that PES schemes should focus on threatened areas and compensate landowners for lost land opportunity costs. Another viewpoint is that PES schemes should constitute incentives for conservation and may reward greener behavior rather than compensate opportunity costs. During the last decade, CONAFOR has developed a complex targeting system in order to focus the PSA-H on threatened forests and overcome adverse selection. Through its targeting system, the program is clearly oriented toward compensation. However, since most forests are managed by *ejidos*, PSA-H payments are given, not to individual landowners, but to a board representing the assembly of *ejidatarios*, which decides how to share the payments in accordance with the assembly. We first investigate, at the *ejido*-level, how land-use heterogeneity within the *ejidos* impacts inequality in the distribution of payments. Second, we analyze how the land-use of each *ejidatario* within the *ejidos* influences the amount of payment received in the distribution. Our analysis shows that the way the PSA-H is being distributed by *ejidatarios* bypasses the initial compensation objective, and has transformed it into a reward for not using the forest.

Increasing attention has recently been given in the literature to the interactions between policy instruments at the landscape-level. In a search for a relevant policy-mix, Chapter 6 looks at the interaction between the PSA-H and Community Forestry. Community Forest Enterprises (CFEs) have developed since the early 1980's in Mexico and become a prominent actor in Mexico's timber value chain. These CFEs implement extraction activities in community forests and sometimes valorize the timber through a transformation process. They are regulated by a federal forestry management plan that ensures sustainability of extraction activities. Does paying for conservation discourage investment in CFEs? Or by contrast, can the PES scheme help *ejidos* create and stabilize CFEs? In this chapter, we argue that the PSA-H can have a positive impact on CFEs. First, because developing a CFE requires heavy investment and the PSA-H can relax credit constraints.

Second, because PES enhances *ejidos*' access to valuable information about CFEs. Finally, because following PSA-H enrollment, the *ejidatarios* must organize themselves to implement various tasks in the forest which creates the forest management institutions within the *ejidos* that are necessary for the development of CFEs. We explore the interactions between Mexican CFEs and the PSA-H using a sample of 223 *ejidos* composed of PSA-H beneficiaries and non beneficiaries surveyed both in 2003 and 2010. Our empirical results suggest that the PSA-H can contribute to the development and stabilization of CFEs.

In a final section of this dissertation, we draw the conclusions from the empirical essays for the design of PES and for future research.

Studying the impact of a PES in community forests: Context and methodology

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2.1 Land tenure in Mexico

In Mexico, around 80% of the forest cover is owned as commons by communities called *ejidos* (Bray et al., 2003b; Kaimowitz, 2005) as a result of a century of reforms in Mexico's rural communities. This section summarizes the evolution of land tenure system in Mexico based on De Janvry et al. (1997), Gordillo de Anda et al. (1998), Dutilly (2001) and Assies (2008).

2.1.1 Colonial time and the Mexican revolution

The origin of the Mexican land tenure system can be traced back to the Spanish colonial era. Upon their arrival in 1519, the Spanish colonists were allocated land and assigned indigenous workers through the *encomienda* system. The term "*encomienda*" literally suggests that the colonists were entrusted indigenous workers with the mission to evangelize them in return for their labor. During the period of the *encomienda* system, the Spanish colonists appropriated large areas of the best farming land. Progressively, the land passed from many small indigenous landowners into the hands of a few large landowners. The *encomienda* system led to many abuses by the colonists and the Spanish Crown eventually decided to promote the New Laws of the Indies in 1542 to regulate and eliminate the *encomienda* system and replace it with a new one. This new system, called *repartimiento*, obliged the indigenous workers to provide a certain amount of labor hours to the Spaniards but for a given wage. It also created pueblos de *indios* or villages where the indigenous were allowed to cultivate their own crops and breed livestock. Within these villages, the common land for livestock breeding was called an *ejido*.

Over the following centuries, the Spanish Crown continued allocating land to indigenous communities. However, most of the land was appropriated by the colonizers through various means, which led to the emergence of haciendas: large properties specialized in mining or crop cultivation. Their expansion continued after Mexican independence in the beginning of the 19th century. The main preoccupation for successive governments was to cultivate more land and increase agricultural productivity, and many parcels owned by the church or by *ejidos* were considered by officials to be inefficiently managed. In 1856, the Lerdo Law authorized the expropriation of land held by civil entities or the church at the profit of a private agent. In 1857, *ejido*-land was included in the Lerdo Law consolidating the movement of land concentration into the hands of larger landowners.

This trend was reinforced during the rule of General Porfirio Diaz. Mexican economic growth at the end of the 19th century was mostly driven by the exports of the haciendas. In order to identify land without owners, around 50 companies (mostly based in the United States) were given concessions in exchange for running a demarcation process. These companies received one third of the area demarcated (around 20 million hectares) and the remaining 40 million hectares became public land before being widely sold to private owners such as the haciendas. At the beginning of the 20th century, 87% of Mexico's rural land was owned by 0.2% of the

landowners

In 1910, General Diaz's reelection gave rise to the first protests announcing a decade of civil war. As emphasized by the southern revolutionary slogan "*tierra y libertad*", claims for land redistribution were at the heart of the Mexican revolution. In 1913, Francisco Villa promoted an expropriation decree in the northern states while in the south, Emiliano Zapata called for an immediate return of lost lands to the communities and a redistribution of hacienda land among landless peasants. These propositions were gathered in the Plan de Ayala and constitute the basis of Article 27 of the new Mexican Constitution of 1917, which concerned land tenure and the first agrarian reform.

2.1.2 The first agrarian reform

Article 27 stated that all land and waters ultimately belong to the nation but may be transmitted to private parties under certain conditions. With the new constitution began the first agrarian reform allowing groups of former hacienda workers or indigenous communities to ask for restitution, dotation or amplification of their common land endowment. This land remains owned in commons: it is ultimately the property of the state and can not be sold, rent or mortgaged. The land commonly owned by a group of peasants is called an *ejido*. In the aftermath of the revolution, redistribution remained modest under the rules of Alvaro Obregon and Plutarco Elias Calles as priority was given to reconstruction and the stabilization of the country.

The main redistribution process happened during the rule of Lazaro Cardenas between 1934 and 1940. The Wall Street Crash of 1929 directly impacted Mexican growth through a decrease in agricultural exports and the expulsion of about one million Mexican immigrants from the United States. Facing more claims for land redistribution, President Cardenas began a vast land redistribution process. More than 20 million hectares were redistributed during this period to nearly 800,000 peasants. Nevertheless, although haciendas were dismantled by the reform, the effect on land concentration remains unclear. The land may just have been redistributed among family members and other *prestanombres*. Moreover, new industrial groups may have appropriated the most profitable lands while poorer households received small parcels of poor quality land. This land redistribution was complemented with the creation of farm credit institutions. However, given land profitability and the poor education of farmers, the credits remained inaccessible for small peasants. President Cardenas also created corporatist structures such as the *Confederacion Nacional Campesino* that would eventually serve to ensure the dominance of the revolutionary party in rural communities.

In subsequent years, Mexican industry grew at a remarkable rate. As a consequence, redistribution slowed down and priority was given to large-scale agriculture boosted by green revolution technologies. Between 1940 and 1970, *ejidatarios* constituted a large pool of cheap labor for the commercial agriculture industry. While economic growth slowed down in the 1970's, many protests took place in some

Table 2.1: Land redistribution by presidential term

Period	Hectares redistributed	Number of beneficiaries
1934-1940: Lazaro Cardenas del Rio	18,786,131	728,847
1940-1946: Manuel Avila Camacho	7,287,697	157,816
1946-1952: Miguel Aleman Valdes	4,633,321	80,161
1952-1958: Adolfo Ruiz Cortines	6,056,773	68,317
1958-1964: Adolfo Lopez Mateos	8,870,430	148,238
1964-1970: Gustavo Diaz Ordaz	24,738,199	278,214
1970-1976: Luis Echevaria Alvarez	12,773,888	205,999
1976-1982: Jose Lopez Portillo	6,397,595	243,35
1982-1988: Miguel de la Madrid Hurtado	5,626,227	248,486
1988-1992: Carlos Salinas de Gortari	551,869	80,692

Source: Assies (2008) based on Bizberg (2003)

states of Mexico including Michoacan, Guerrero and Oaxaca, which obliged the governments to get back to land redistribution. By the 1980's, over half of Mexican farmland was owned by *ejidos* or *comunidades*. There is a slight difference between *ejidos* and *comunidades* in terms of property rights (Brown, 2004). *Ejidos* have three land classifications: parcelized arable land, common land, and land for human settlement. Access to common land is regulated by the assembly. *Comunidades* have just two land classifications: human settlement and common land. Within *comunidades*, each member is supposed to have equal access to the commons but there can be de facto repartition among the different members.

Para-state institutions were also created providing services paid by a federal institution such as agricultural credit, distribution of inputs or a guaranteed price for many commodities. However, following the Mexican crisis of 1981, state support to the rural world began to decline. *Ejidos* began illegally renting land to commercial farms and looking for off-farm opportunities through massive migration to the urban areas and to the United States.

2.1.3 PROCEDE: Second agrarian reform

During the seventy-five years of the first agrarian reform, more than half of rural Mexican land was reallocated to peasants under the form of *ejidos* and *comunidades* (Dutilly, 2001). In the late 1980's, Mexico joined the GATT (1986) and began negotiating NAFTA (North American Free Trade Agreement) and their entry into the OECD. It became crucial for the Mexican government led by Salinas de Gortari to improve productivity in the agricultural sector through reform of the land tenure system (De Janvry et al., 1997; Deininger et al., 2003).

As highlighted by Heath (1992), following the implementation of the first agrarian reforms, large landowners still faced the threat having lands expropriated above an uncertain size of holdings and it was de jure impossible to cultivate crops on

lands labeled as pasture. Lots of land was abandoned as a consequence of rural migration but leasing was supposed to be prohibited which limited access to land to landowners willing to cultivate more. Access to credit was also limited since rural public banks mainly offered in-kind payments, such as inputs, and because the land was state-property, it could not be mortgaged. The government, considering the system insecure and leading to under-investment in agriculture, undertook a massive agrarian reform called PROCEDE (*Programa de Certificacion de Derechos Ejidales*).

The second agrarian reforms included many changes in government institutions or regarding access to credits among others (De Janvry et al., 1997) but we here focus on the Article 27 reform regarding land property. This reform involved a recognition of the *ejido*'s governance institutions and allowed it to choose its property regime. The reform also eliminated land rental restrictions (Deininger and Bresciani, 2001).

PROCEDE was a voluntary land regularization run by federal institutions. For an *ejido*, implementing Procede involved two steps (De Janvry et al., 2001; Brown, 2004)

1. An external assessment determined boundaries of *ejidos* and *comunidades* and informed the assembly. If the assembly chose to go forward (simple majority vote) with this first step of PROCEDE, these boundaries were officially recognized by the *Instituto Nacional de Estadística Geografía y Informática* (INEGI) who created a map that demarcated the different classification of lands and individual parcels.
2. Considering the map produced, the assembly could choose to obtain full titling over the land plots. Implementing this step required a two-thirds majority at the assembly. The assembly could choose full or partial privatization. In the case, of partial privatization it allowed individual *ejidatarios* who wished to privatize to obtain complete property rights but these did not apply to the entire community.

The assembly could also choose to dissolve the *ejido* as a political and economic organization. PROCEDE granted individual land title to the *ejidatarios*. Note that, once the *ejido* completed PROCEDE, the title of *ejidatario* could only be transmitted to one heir and the *ejido* was no longer allowed to integrate new *ejidatarios*. Three types of property rights were allocated:

- *Certificado parcelios*: Property right over an individual parcel
- *Certificado de derechos de uso comun*: Rights to use of a percentage of the common land of the *ejido*
- *Titulos de propiedad de solares urbanos*: Residential property titles

Certificado parcelios gave *ejidatarios* the right to legally rent and sell their land. Nevertheless, this did not amount to complete property rights as the landholder was

not allowed to sell his land to non members of the *ejido* without community agreement (Key et al., 1998). *Certificado parcelios* could be converted to full property titles (*Certificados de dominio pleno*) upon the request of the *ejidatarios* (De Janvry et al., 2014).

According to the federal statistics of the *Registro Agrario Nacional* reported by Assies (2008), 76.2 million hectares were certified or titled during PROCEDE, which benefited approximately 3.8 million people or more than 95% of the *ejidos*. Among the 76.2 million hectares, 23 million were certified as parcels and 52 million as commons.

The consequences of the reform are highly debated. Before the reform, Heath (1992) noted that, apart from the rural public bank, other non institutional sources of credit existed before PROCEDE (family, money lenders, merchants...). Using the private sector and *ejidos* that did not complete PROCEDE as a control group, Deininger and Bresciani (2001) highlight that the reform had a small impact on land sales but a significant positive impact on the rental market. Nevertheless, as emphasized by Bouquet (2009), rental and land markets existed informally before PROCEDE. For instance, to make a land transaction appear legal, *ejidatarios* often disguised it as an inheritance or as a sanction against the landowners. Nevertheless, a commonly acknowledged positive impact of the reform is that the land titles are perceived today by the *ejidatarios* as more secure.

During the reform, most *ejidos* chose to keep the forests owned as commons. This is the reason why 80% of the Mexican forest cover is formed by community forests (Bray et al., 2003b; Kaimowitz, 2005).

2.1.4 The *ejidos* today

Nowadays, governance of the *ejidos*, including management of the common forests, is still based on the traditional institutions that endure as a result of the different agrarian reforms (Haenn, 2006). Following PROCEDE, three types of households are acknowledged within the *ejidos*:

- *Ejidatarios* which have the right of access to the common land, an urban plot (*solar*), an arable parcel of land, and voting rights at the assembly
- *Poseisionarios* who have the right of access to the common land, a *solar*, and an arable land parcel but do not have voting rights
- *Avecindados*: Right to a *solar*

The title of *ejidatario* is transmitted by inheritance to the first heir. Therefore, buying land from an *ejidatario* does not give vote right at the assembly. *Poseisionarios* often are sons of *ejidatarios* that did not inherit from the title. *Avecindados* may only live in the *ejido*, have off-farm activities or, since PROCEDE, rent land within the *ejidos*.

Four types of authorities (*autoridades*) are in charge of *ejido*'s governance. They are usually non-remunerated, serving once for one of these authorities is considered as part of an *ejidatarios*' duty toward the *ejido* (Antinori, 2000; Dutilly, 2001):

- *El consejo del comisariado de bienes comunales*: The council is constituted of the president (*el comisariado*), a secretary (*el secretario*) and a treasurer (*tesorero*). They administer the communal property and represent it in all the activities related to the territory of the *ejido*. They are elected for three years. Being part of this council, and especially being elected president, is often perceived as a burden by the *ejidatarios*. It takes them away from their productive activities and they usually do not perceive any compensation.
- *El consejo de vigilancia*: This is also constituted of three elected members. Its role is to monitor the *consejo del comisariado*. It ensures that authorities fulfil their missions and that funds are not diverted.
- *La municipal*: Two members of the *ejido* in charge of law enforcement
- *La asamblea general*: The assembly gathers all the *ejidatarios*. Important issues concerning the *ejido* are debated and voted by the assembly.

Decisions regarding commons management, land access, federal schemes and conflict resolution, and other issues, are debated at the assembly. Enrolling commons in an environmental program, such as a PES, requires an agreement at the assembly. *Posesionarios* may have the right to attend and speak at the assembly but voting rights are normally reserved for the *ejidatarios*. Even after the reforms, the rules of the *ejido* concerning land access and sales often coexist with federal law (Haenn, 2006; Bouquet, 2009). Therefore, selling or leasing land often requires agreement of the assembly.

2.2 Mexican forests

2.2.1 Deforestation in Mexico

Deforestation is a crucial matter of concern in Mexico. The FAO (2011) estimates that on average 195 thousands of hectares were deforested yearly between 2000 and 2010, which corresponded to an annual average rate of 0.3 percent. Nevertheless, deforestation has sharply decreased since the 1990's. Between 1990 and 2000, 354 thousands hectares were deforested annually (0.5% per year). The greatest deforestation pressure comes from cattle-ranching, cropping and logging in some specific areas.

Before PROCEDE implementation, Deininger and Minten (1999) studied the deforestation rate in the 1980's using national land-use change maps at the scale of 1:250 000. Their results suggest that agricultural subsidies and poverty were important determinants of deforestation rates. The same authors later highlighted the

importance of transaction costs proxied by distances to the markets and agroecological characteristics such as slopes (Deininger and Minten, 2002). Similar results were found by Muñoz-Piña et al. (2004) between 1993 and 2000.

After the implementation of PROCEDE, 80% of Mexican forests remained owned as commons by the *ejidatarios* (Bray et al., 2003b; Kaimowitz, 2005). In Brazil, land tenure insecurity has been a strong determinant of deforestation according to Araujo et al. (2009). The impact of the land tenure system on deforestation is widely debated in Mexico. Deininger and Minten (1999), Deininger and Minten (2002), and Muñoz-Piña et al. (2004)'s results provide no evidence that *ejidos*' tenure arrangements have led to a higher level of deforestation. Using data from 350 *ejidos*, Alix-García (2008) showed that a higher level of inequality within *ejidos* decreased deforestation rates. The underlying hypothesis that could explain this fact is that while inequality increases the use of the commons by wealthier households to a lesser extent than it decreases the use of the commons by poorer households. One important issue raised by Alix-García (2007) regarding deforestation in Mexico is related to the localization of deforestation. As a matter of fact, to understand deforestation in Mexico, one must not only take into account the absolute land quality but also the relative land quality within the *ejido*. Indeed, decisions to deforest depend first, on the demand by some *ejidatarios* for pasture or agricultural land and second, on the relative value of the land within the *ejido*.

Since the entry into force of the General Law of Sustainable Forestry Development of 2006 (*Ley General de Desarrollo Forestal Sustentable*), deforestation is *de jure* prohibited by law unless the landowners comply with a Management Plan insuring that extraction activities take place at a sustainable rate. Slash-and-burn (*Roza Tumba Quema* in Spanish) is explicitly prohibited by the law but tolerated *de facto* as the traditional form of agriculture.

2.2.2 Environmental policies in Mexico

Two main federal commissions are in charge of forest management policy : the CONAFOR (National Forest Commission) and CONANP (Natural Protected Areas Commission).

NPA emerged in Mexico during the Cardenas administration in the late 1930's and subsequently developed during the second part of the 20th century. NPA's are defined at the federal, state or municipal level with a certain degree of overlap. In 2014, federal NPA covered approximately 12% of the Mexican territories (Sims and Alix-García, 2014). As presented in table 2.2, they are classified into 6 categories with decreasing levels of protection that slightly overlap with ICUN classification (Dudley, 2008):

At the beginning of the 21st century, Mexico, like many countries, took a step toward incentive- based approaches such as PES. The CONAFOR, created in 2001, is in charge of Mexican forest policy. Its two main objectives are conservation and forest restoration and development. CONAFOR manages many public policies that were merged into a single programme called Pro Arbol in 2006 (Guevara-Sanginés

Table 2.2: Natural Protected Areas in Mexico in 2014

	Categorie	Number	Size (km2)
	<i>Reservas de la Biosfera</i>	41	12,751,149
	<i>Parques Nacionales</i>	66	1,411,319
	<i>Monumentos Naturales</i>	5	16,269
	<i>Areas de Proteccion de Recursos Naturales</i>	8	4,503,345
	<i>Areas de Proteccion de Fauna y Flora</i>	38	6,786,837
	<i>Santuarios</i>	18	148,332
	Total	176	25,617,251

Source: CONANP (2015)

and Lara-Pulido, 2012). This program proposes among others:

- PES: Hydrological (the PSA-H) and Carbon and Biodiversity (the PSA-CABSA)
- Reforestation subsidies (PROCOREF)
- Subsidies for sustainable forestry and training program (PRODEFOR) and forest plantation (PRODEPLAN)
- Fire prevention
- Community forest development planning

In the first ten years of CONAFOR, PROCOREF is the program that received the largest share of CONAFOR's funding (25%). The PSA-H received 18% while the other PES, the PSA-CABSA, captured only 6% of CONAFOR's resources.

2.3 The PSA-H

2.3.1 Design and payments

The PSA-H was created in 2003 as a response to high deforestation pressures in Mexico and overexploitation of about 15% of the country's aquifers (Rolon et al., 2011). The program was originally designed by researchers from INE¹ (Instituto Nacional de Ecología) and part of SEMARNAT (Environment and Natural Resources Department), Universidad Iberoamericana, Centro de Investigacion y Docencia Economica and the University of California at Berkeley between 2001 and 2003 with the support of the World Bank (Muñoz-Piña et al., 2008). The PSA-H aims at enhancing the provision of hydrological services in overexploited aquifers.

¹Now called INECC (*Instituto Nacional de Ecología y Cambio Climático*)

Table 2.3: Payments areas by vegetation types and deforestation risk

	Type of forests	Deforestation risk	Payment
Area 1	Bosque Mesofilo	Very high	1.100 Pesos per Ha
Area 2	Bosque Mesofilo	Low to high	700 Pesos per Ha
Area 3	Bosque de coniferas, selva subcaducifolia and bosque de encino	Very low to very high	550 Pesos per Ha
Area 4	Selva alta perennifolias	Very low to very high	382 Pesos per Ha

Source:(CONAFOR, 2009)

Budget allocated to the program increased since 2003 from 200 millions pesos to 965 millions pesos in 2009. The scheme is supposed to enhance water quality. Therefore, the program is partly financed by a fee on water users. In accordance with the General Law of Sustainable Forestry Development, 200 millions of water fees are earmarked for the PSA-H. It represented about 20% of the program's budget in 2009, the rest is financed by federal funds allocated to CONAFOR.

Additional funding allowed CONAFOR to remunerate more service providers with higher payments. According to CONAFOR, the program covered only 127 millions of hectares in 2003 and 486 millions of hectares in 2010. Cumulating contracts over time between 2003 and 2010, the program had been granted to 4,893 beneficiaries covering more than 2 billions of hectares of forests.

The PSA-H remunerates only conservation and should not be confounded with the PSA-CABSA which also remunerates sustainable forest management and reforestation (Corbera et al., 2009). Note that in order to apply collectively for the PSA-H, *ejidos* have to enroll at least 200 Ha of forests into the scheme. For individual owners of forests, it is also possible to apply individually with a minimum of 20 Ha.

Payments were originally set to 200 pesos per hectare and were later increased and differentiated according to the type of forests and the deforestation risk. Mesophyll forests (cloud forests), for instance, are expected to provide more hydrological services. Since 2010, payments are set as shown in Table 2.3.

The deforestation risk index is computed by INECC in order to measure deforestation pressure. It is based on an econometric model developed by Muñoz-Piña et al. (2008) that determines the probability of deforestation. Using satellite images, the authors computed the probability for a pixel to be deforested between 1993 and 2000 according to variables reflecting agro-ecological characteristics, transaction costs, socioeconomic variables and regulation. They used their results to compute a map of deforestation risk covering all of the Mexican territory that is now used to target the PSA-H. The authors also found that most of the payments were allocated to low deforestation risk area. This finding justified the inclusion of deforestation risk in the criteria of the PSA-H in order to enhance additionality of the scheme.

2.3.2 From application to approval

CONAFOR does not have a staff dedicated to the promotion, assistance and monitoring of the PSA-H in the *ejido*. If an *ejido* is accepted into the program, he receives extra money to contract with a technical advisor who will help him to comply with PSA-H rules. These CONAFOR-accredited advisors play the role of intermediary between CONAFOR and the *ejidos*. In order to get new contracts, advisors promote the PSA-H by inviting *ejidos* to apply for the program, helping them to fill-in their applications and gathering the necessary administrative documentation. The role of the technical advisor is crucial and the probability that an *ejido* will be accepted into the program is influenced by the dynamism and capabilities of the advisors.

Applying for the program requires an agreement at the assembly. Nevertheless, this does not necessarily mean that all *ejidatarios* agree to enroll commons in the program. The *ejidatarios* can decide that only a specific part of the commons will be enrolled in the program and that some *ejidatarios* and *poseesionarios* will not be concerned by the PSA-H. It is common, especially in large *ejidos*, that a substantial number of the *ejidatarios* decides not to enroll their share of commons and remain outside of the program. These *ejidatarios* will not receive payments from the PSA-H.

Note that the *ejidos* can fill-in different applications for PSA-H contracts over time on different parcels of forest. For instance, they can enroll 200 hectares in 2007 and 400 additional hectares three years later. In larger *ejidos*, the *ejidatarios* and *poseesionarios* concerned by each application may even be different. An *ejido* can also apply to renew the PSA-H on enrolled land after the five-year contract. On this occasion, *ejidatarios* often increase or reduce the size of the forest enrolled in the program.

Not all *ejidos* who apply receive the payments. CONAFOR have defined eligibility zones for each ProArbol programme, including the PSA-H, and only the *ejidos* located in these areas are eligible for the program. Moreover, because the PSA-H is underfunded in comparison to the number of applications received, CONAFOR has developed a scoring system in order to rank the applications.

2.3.2.1 Eligibility zones

In 2003, for the first year of allocation, there were no scoring systems or eligibility zones planned. CONAFOR received too many applications for the funds available. Payments were allocated to the first applicants until there were no more funds available. To avoid the recurrence of this problem, CONAFOR began to define eligibility zones and developed a scoring system in order to rank the applications.

Since 2004, *ejidos* must belong to these eligibility zones in order to receive the PSA-H. Eligibility zones have been regularly modified. The eligible area has increased significantly over the years as PSA-H's budget has simultaneously increased. In 2004, eligibility zones represented only 2% of Mexican territory while they covered about a quarter of the territory by 2012, according to our calculations².

²Calculations have been made with GIS software using CONAFOR's data. Eligibility zones

Figure 2.1: Evolution of eligible areas



Source: Authors

Since the beginning of the program, NPA have been de facto eligible. In 2010, eligible zones for PSA-H and CABSA have been determined using a scoring system based on priority areas (CONAFOR, 2009) such as:

- Zone of importance for birds conservation
- Areas under RAMSAR convention (Wetlands of International Importance)
- Priority mountains
- Terrestrial priority regions
- Hydrological priority regions

2.3.2.2 The scoring system

Each application inside the eligible zones receives a score. Since the PSA-H has been incorporated into ProArbol, we can distinguish the criteria that are commons to every ProArbol programme and those that are specific to the PSA-H.

All applications to ProArbol programs receive points if the *ejido* never received any support from CONAFOR, complies with a forestry management plan or is located in a marginal area or a zone with a majority of indigenous population among other things.

A second scoring system applies specifically for the PSA-H. Points are added to those obtained for ProArbol. In 2010, there were 18 criteria in the scoring system: 11 of them are common with PSA-CABSA, the other national PES scheme. Other criteria deal with, for instance, location inside priority zones for the environment and water accessibility. Details about the scoring system can be found in the Appendix.

The scoring system has evolved considerably since 2003. As highlighted by Shapiro-Garza (2013), the targeting of the PSA-H is the result of the interaction

measured 38 805 km^2 in 2004 and 486 640 km^2 in 2012.

of many stakeholders such as CONAFOR, other federal ministries and commissions and civil society organizations. The program has taken a hybrid form combining environmental and social objectives. Looking at only four criteria (overexploited aquifers, INE risk of deforestation, water scarcity zones and marginalization), Rolon et al. (2011) show that the allocation of the PSA-H has been strongly influenced by the constant evolution of the scoring system. Nevertheless, Sims et al. (2014) note that the targeting of the PSA-H evolved over time in order to combine environmental and social priorities and has succeeded in enrolling land on the basis of both.

2.3.3 The PSA-H in the ejidos

2.3.3.1 Commitment

In order to receive payments, *ejidos* must comply with certain rules (CONAFOR, 2009). The technical advisor accredited by CONAFOR is in charge of establishing a Program of Better Management Practices (PMPM in Spanish: *Programa de Mejores Practicas de Manejo*).

This PMPM defines the activities that will have to be undertaken for forest conservation. The *ejidos* must provide this program to CONAFOR in order to receive the first payment³ The advisor is also in charge of providing beneficiaries a workshop twice a year to teach about environmental issues.

During the five years of the reception of the payment, the *ejido* commits itself to complying with the following rules in the area enrolled in the PSA-H. The advisor must provide assistance to the *ejido* in order to comply with these commitments.

- Avoid land-use change
- Conserve the forest cover and avoid degradation
- Set at least two notices (signs) announcing the implementation of the scheme in the *ejido* that will remain during the five years.
- Avoid overgrazing
- Implement the activities planned by the PMPM
- Realize monitoring and prevention activities against fires including the formation of at least one brigade.

This last commitment includes the necessity of patrolling in the forest (*hacer las rondas* in Spanish) or building firebreaks. As highlighted by Yanez-Pagans (2013), the *ejidatarios* must provide a certain amount of labour hours to receive payments. Therefore, the scheme tends to increase cooperation within the *ejidos* but not only in forest conservation activities. Since the *ejidatarios* are exposed to sanctions for

³The PMPM should not be confounded with the Forestry Management Plan which allows the *ejidos* to extract and sell timber.

not participating to the *ejidos*' collective work, it also increases participation to collective activities that are not required by the PSA-H.

If the *ejido* does not comply with these rules, sanctions can vary from simple notification to an exclusion from the program and a ban from any future CONAFOR scheme.

2.3.3.2 Payment repartition

The *ejidos* receive payments every year for five years. ProArbol's rules state that a share of these payments must be used to remunerate the technical assistant (CONAFOR, 2009). In 2010, this amount varied from 22,000 to 60,000 Mexican pesos (1,700 to 4,600 USD⁴). According to our surveys in *Cono Sur* (see Section 2.4.1), it represents on average 10% of the total amount received. The fact that the funds dedicated to technical assistants were transmitted to the *ejidos* led to some abuses either from technical assistants or from a collusion between *ejidos*' elite and the technical assistants. Therefore, to avoid misappropriation, CONAFOR has decided in recent years to remunerate the technical assistants directly.

Once the technical assistant has been remunerated, the remainder of the payments is left at the discretionary power of the *ejidos*' authorities. The use of payments is usually discussed during the assembly or between the *ejidos* that chose enter into the program. As emphasized by Corbera et al. (2009), a particularity of PES in commons is that the beneficiary is not clearly identifiable.

We distinguish three types of use for PSA-H payments. The first is collective investment. A certain share of payments can be used for investment in public goods (roads, school...) but also in new income generation activities at *ejido*-level (community forest enterprises, palm oil plantation...). A second possibility is to use a certain share of payments to remunerate the collective work required to receive the PSA-H, including the days spent patrolling or building firebreaks. PSA-H payments can be used to remunerate these activities at a fixed daily wage. A third use is to redistribute payments within *ejidatarios* and *posesionarios* as collective owners of the forests. The rule of distribution can vary from one *ejido* to another and *ejidatarios* do not systematically receive the same amount of payments. If no funds are specifically allocated to the remuneration of firebreak building and patrolling, it is usually mandatory for PSA-H beneficiaries to participate in these activities or, if unable to do so, to pay someone to do so in their place.

Note that the choice between these different types of payment use may be influenced by the perceptions of PSA-H's objectives by regional offices and technical assistants. The use of payments as remuneration has never been found in our surveys in Yucatan while it has been frequently found in Chiapas.

⁴During all the dissertation, we use exchange rate on the 1st January 2010: 1USD is approximately equal to 13MP

2.3.4 Impact of the PSA-H

Alix-Garcia et al. (2012) studied the impact of the program on avoided deforestation based on a sample of early beneficiaries in 2003 and rejected applicants as a control group. They use pre-matching to control for the selection bias. Their estimate suggests a low additionality of the scheme and the existence of leakage effects in neighboring parcels. The low additionality can be attributed to the weak capacity of CONAFOR to target threatened forests. This hypothesis is confirmed by earlier work by Muñoz-Piña et al. (2008) that showed that the scheme failed to focus on the areas with the highest deforestation risk.

The lack of the PSA-H focus on endangered forest can be explained by its multiple objectives. If CONAFOR's position was to target threatened forests, interactions with civil society and other governmental organizations hybridized the program into a reward for conservation within the NPA and a poverty alleviation tool (Muñoz Piña et al., 2011; Shapiro-Garza, 2013). Combining multiple objectives drove the scheme away from its original environmental objective. On the same sample of early beneficiaries and rejected applicants described above, Alix-Garcia et al. (2014) showed that the program had a limited impact on poverty. Combining both objectives might be difficult because higher impact on poverty have been achieved in areas of low deforestation risk and vice versa. Nevertheless, according to Sims et al. (2014), CONAFOR have succeeded over time in improving the focus of the program on threatened forests and marginal areas through adaptive management of the targeting criteria.

2.4 Databases

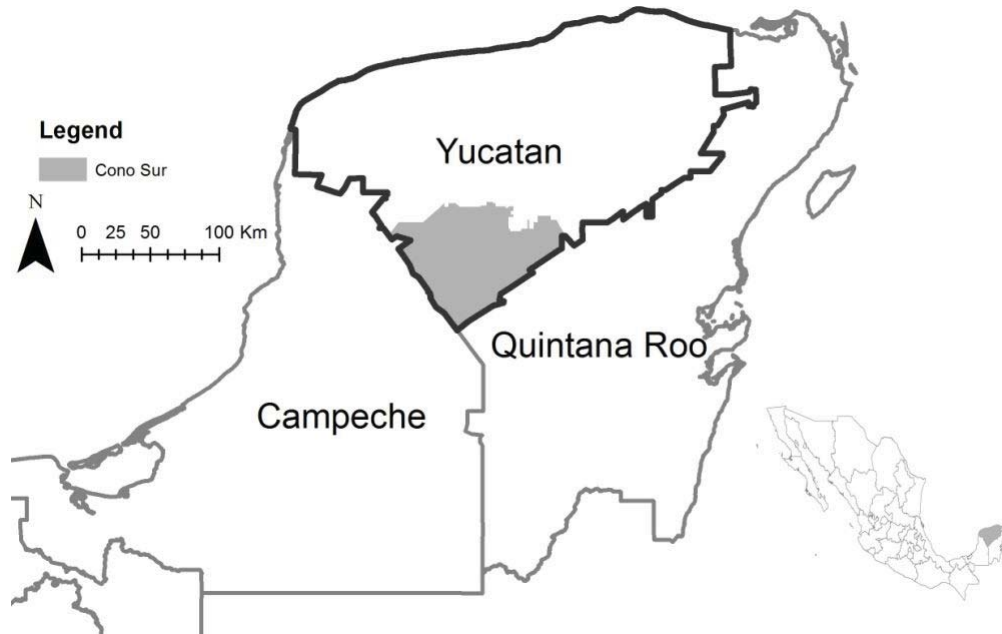
2.4.1 PESMIX surveys

2.4.1.1 Study area: the Cono Sur of Yucatan

The Yucatan Peninsula (formed by the states of Campeche, Quintana Roo and Yucatan) covers around 140 thousand Km², of which 62,229 thousand of hectares are protected areas. It has a population of about 4 million inhabitants of whom more than 800 thousand rely on agricultural production.

Agriculture generally consists of 2 to 4 hectares of land reserved for (*milpa*) agriculture. *Milpa* is a traditional Mayan production process which includes maize, beans and squash. *Milpa* goes hand in hand with the *roza-tumba-quema* method: a form of slash-and-burn agriculture. The latter consists in working the land according to precise periods; trimming and weeding (*roza*), cutting and clearing (*tumba*) and, finally burning the wastes (*quema*). It is based on a rotating principal. Bovine production takes an extensive form in the Yucatan Peninsula implicating deforestation in order to create pastures. Finally, the area also relies on beekeeping and honey production.

Figure 2.2: *Peninsula de Yucatan and Cono Sur*

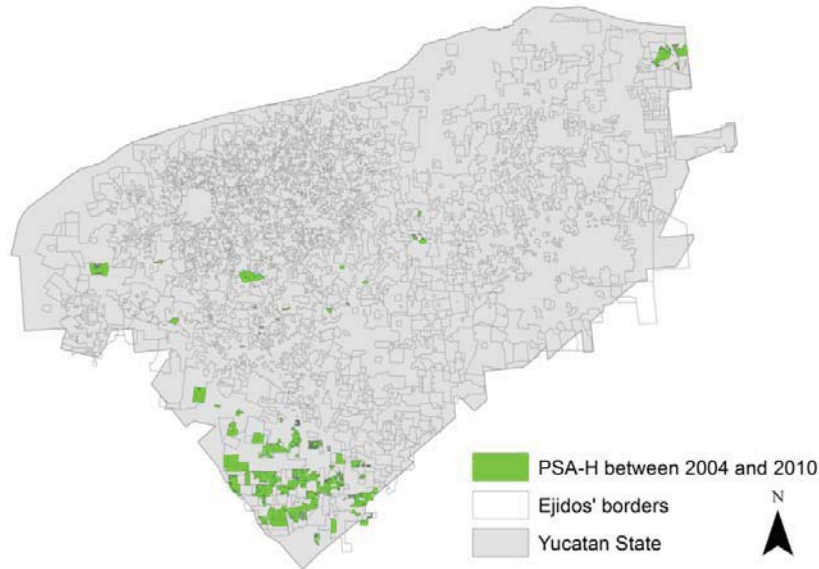


As Mexico was ratifying NAFTA and entering the GATT in the mid-90', the federal government tried to impulse an intensification process in an attempt to modernize Mexican agriculture (Sadoulet et al., 2001). A process of agricultural intensification is undergoing in the peninsula today and concerns both cultivation of commercial crops, such as chili for instance, and traditional maize-bean intercropping. As highlighted by Pascual (2005), the intensification process takes the form of either increased access to new technologies or improvement of efficiency in the traditional sector. Using a stochastic frontier of production, Pascual (2005) shows that, by operating at the efficiency frontier, peasants could clear less land. This would involve a reduction in the fallow period.

In the southern part of the peninsula, Rueda (2010) studied deforestation rates between 1984 and 1993 and between 1993 and 2000. Her findings suggest that deforestation decreased in the latter period. The author attributes this decrease to the change in production behavior and intensification of agriculture. Nevertheless, as emphasized by Schmook (2010), the total impact of agricultural intensification on the environment remains unknown. As a matter of fact, if the reduction of the fallow period is not a problem on the short-run, if yields are reaching a tipping point due to loss of soil phosphorous, this may lead farmers to expand their cultivation and start a new deforestation phase.

The impact of demographic variables and migration on deforestation have also been emphasized by multiple authors. Demographic pressures have been identified as strong determinants of deforestation (Ellis and Porter-Bolland, 2008; Klepeis and Turner Ii, 2001; Turner, 2010; Abizaid and Coomes, 2004). Using t-tests, Schmook and Radel (2008) shows that, if migration may have led to a decrease in land pressure

Figure 2.3: PSA-H allocation in Yucatan



and eventually deforestation, remittances are often invested in pasture. Therefore, the impact of migration on land-clearing remains ambiguous.

PESMIX surveys were implemented in Yucatan State. In Yucatan, PSA-H allocation is mainly concentrated in the southern part of the state in a zone called the *Cono Sur* (see Figure 2.3). For this reason, our surveys were implemented in these areas. Allocation has been concentrated in *Cono Sur* because the *ejidos* from this part of the State have been founded more recently than in other parts. Therefore, there are still large areas of forest owned as commons that have not been deforested. Moreover, the *Cono Sur* has known several period of large deforestation in the past due to cattle ranching and the expansion of mechanised agriculture. In the 1970 and 1980's, the Mexican government proposed subsidies for land clearing and leveling in order to encourage intensive mechanized agriculture. While deforestation has slowed down since the 1990's and the end of agricultural subsidies, it remains an important matter of concern which justifies the fact that most PSA-H funds are allocated in this areas.

To a lesser extent, PSA-H contracts can be found in other areas of Yucatan. The PSA-H is found in the periurban area around the capital Merida. Migration to Merida led to an increase in deforestation close to the city which justified allocation in these areas. Moreover, some PSA-H have also been found in the north-east of the State following the work of a private NGO.

The *Cono Sur* shares many of the features of the rest of the peninsula. *Milpa* remains the main agricultural activity. The degree of intensification is very heterogeneous across the *Cono Sur*. Taking advantage of the flat topography of the region, some *ejidos* have managed to develop highly mechanized agriculture. Cattle-ranching is also very developed in the region.

Figure 2.4: Evolution of eligibility between 2004 and 2012 in Cono Sur



Figure 2.5: The Cono Sur and the first year of PSA-H enrollment by ejido

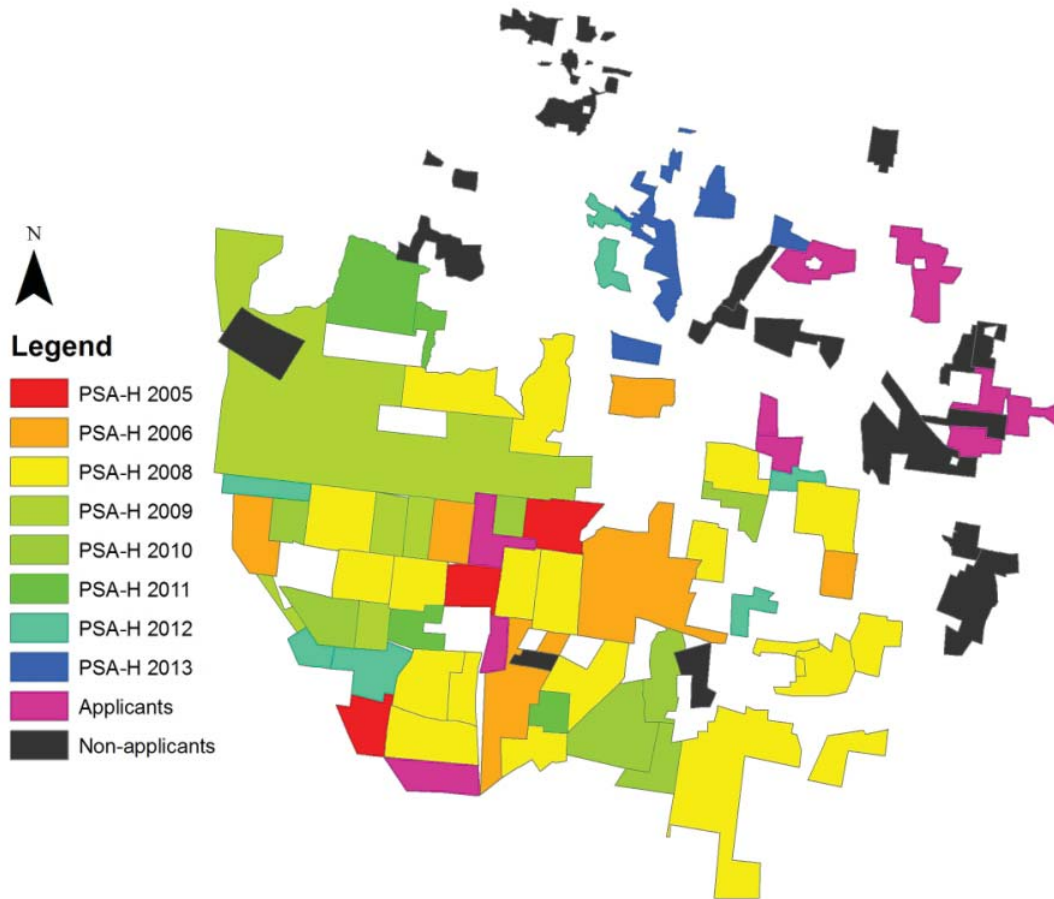


Figure 2.5 and Table 2.4 present the *ejidos* surveyed during the field work. Most *ejidos* of the area benefited from the program but at different periods in time. The main determinant of the reception year was eligibility.

The northern *ejidos* became eligible for the program later than the southern *ejidos*. This may be due to insufficient funds at the beginning of the program. According to CONAFOR's regional office in Yucatan, more information was available about the southern *ejidos* to justify their eligibility. Eligibility zones were later widened as emphasized in Figure 2.4. Nevertheless, the northern *ejidos* are on average less remote and closer to the main roads and cities than the southern *ejidos*.

2.4.1.2 Surveys at the ejido-level

Our sample is composed of all *ejidos* eligible for the program in 2012 with up to a maximum of 300 *ejidatarios*. We decided to limit the number of *ejidatarios* to 300 since *ejidos* with more than 300 *ejidatarios* include the main cities of *Cono Sur* such as Tekax, Tzucacab or Oxkutzcab that no longer rely on traditional *ejido* governance institutions such as the assembly or the *comisariado*. Note that none of

Table 2.4: Number of ejidos that enrolled for the first time per year between 2005 and 2012

2005	2006	2008	2009
3	6	19	5
2010	2011	2012	No-PSA-H
7	4	6	27

these urban centers receive the PSA-H for common forests. The final sample was composed of 77 *ejidos*.

The questionnaire is composed of 12 parts that investigate different characteristics of the *ejido*, including economic activities, governance and repartition of PSA-H payments.

The questionnaire was organized as follow:

- I. History and demography
- II. Participatory mapping
- III. PSA-H
- IV. Land tenure
- V. Land-use
- VI. Economic activities
- VII. Rules for land-use
- VIII. Collective action
- IX. Organization of the *ejido*
- X. Infrastructure
- XI. Other federal program
- XII. Prospects for the future

This questionnaire and pictures of the field work can be found in the Appendix.

The surveys were administered between November and December 2012 by two teams of two interviewers and lasted approximately 2 hours. For each *ejido*, the team first gathered the authorities and all *ejido* members willing to participate. The number of participants for one survey varied from 3, which was the minimum required, to more than 50. The participatory mapping was crucial for the administration of the questionnaires. SPOT images together with official maps given to the *ejido* by *procuraduria agraria* after PROCEDE implementation were used in order to help the *ejidatarios* locate the different types of land-use. Together with the *ejidatarios*, the team divided the *ejido* into multiple polygons corresponding to different land-use (see pictures in the Appendix). The rest of the questionnaire directly refers to these polygons in order to allow the *ejidatarios* to answer the multiple questions regarding land-use and economic activities.

Ejidors from *Cono Sur* are rather small both in size and number of inhabitants as showed in table 2.5. In a national representative surveys, the ENNAF survey presented in Section 2.4.2, *ejidos* are on average five times bigger and the number of *ejidatarios* is multiplied by 3.

This can be explained by the fact that most of these are part of new centers of population founded in the second part of the 20th century. The founders of these

Table 2.5: Main characteristics of the ejidos

	Mean	Stand. dev.	Skewness	Min	Max
Number of <i>ejidatarios</i>	55.44	63.42	2.95	11	368
Number of <i>posesionarios</i>	1.455	4.930	4.412	0	30
Number of <i>avecindados</i>	16.948	53.202	5.596	0	401
Total area (Ha)	2,749.43	4034.20	6.32	594	34,000
Distance to the nearest market (km)	36.28	26.98	0.57	0	100
Mean age of the <i>ejidatarios</i>	51.33	4.72	-0.01	40.29	65

ejidos are part of the last *ejidatarios* that benefited from land allocation under the rule of the first agrarian reform. This fact also explains why there are very few *posesionarios*. *Posesionarios* are often sons of *ejidatarios* that did not inherit the title of *ejidatario*. The number of *posesionarios* can increase over time but this has not happened yet in *Cono Sur* and the vast majority of heads of household are *ejidatarios*.

Another important feature that characterizes the *Cono Sur* is its remoteness, as highlighted by the distance to the market shown in Table 2.5. *Ejididos* from the southern part of our study zone lack crucial infrastructure, including not only roads but also access to running water or electricity. These *ejidos* have been deserted by the population, which has led to the formation of labor-*ejidos* where *ejidatarios* cultivate crops and breed cattle but typically hold a primary residence in the nearest city: Tekax or Tzucacab for instance.

Figure 2.6 presents kernel density estimates for the percentage of land under each land tenure regime. Following PROCEDA, it is possible to distinguish commons from individualized parcels. Nevertheless, within commons, a certain share of land is divided *de facto* by agreement of the assembly. *Ejido* surveys have enabled us to distinguish commons, land parcelized by agreement of the assembly and land parcelized by PROCEDA. While the share of land parcelized by PROCEDA is small in most *ejidos*, we note that considering parcelization by the assembly gives more mixed results. One group of *ejidos* maintained a large share of commons while a smaller group has a larger share of land parcelized by assembly.

Table 2.6 presents the percentage of *ejidatarios* involved in each activity per *ejido*. On average, between 20% and 35% of the *ejidatarios* are involved in each activity but this percentage varies highly from one *ejido* to another. Note that many of them combine different activities. A large variety of land use types can be found in *Cono Sur*, ranging from complete specialization of the *ejido* in one type of land use to a mosaic of various land-use types.

Figure 2.6: Kernel density estimates of the percentage of land in each land tenure regime per ejido

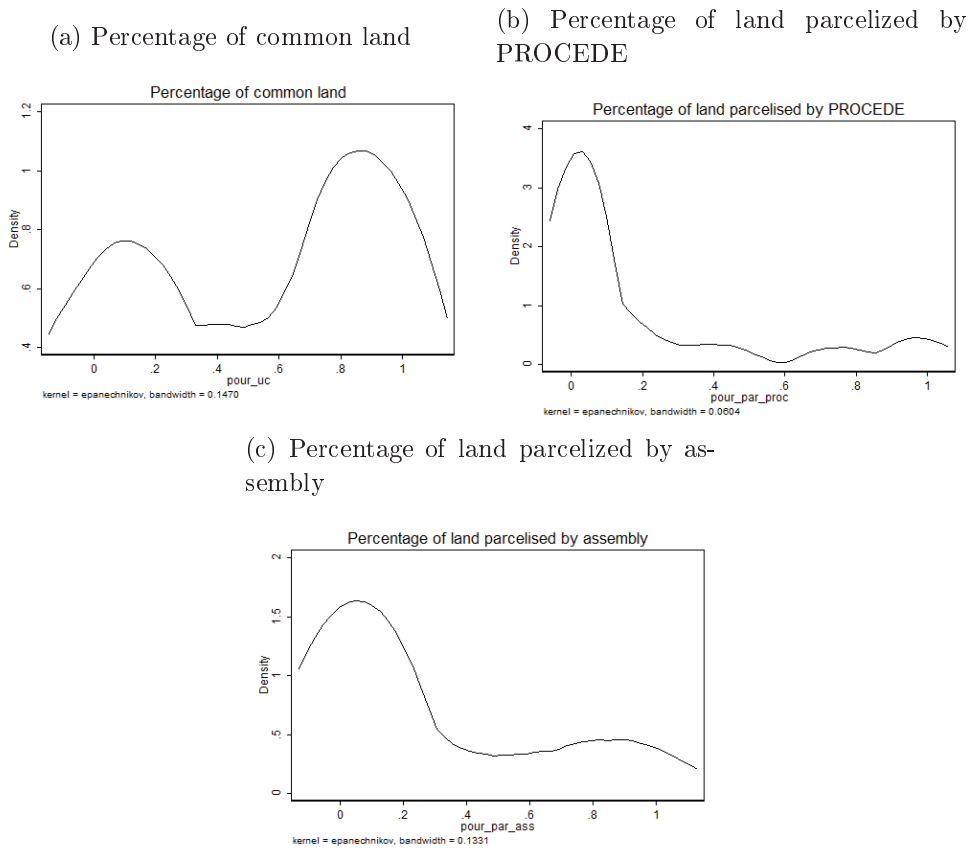
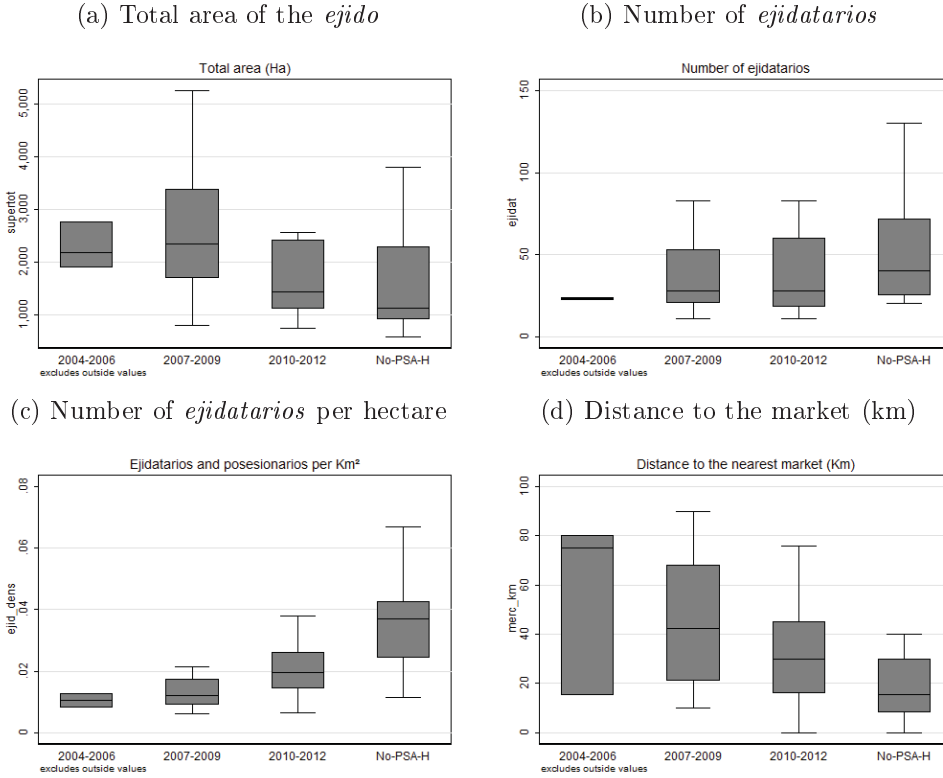


Figure 2.7: Demography and market access according to the first year of PSA-H reception by the ejido

Table 2.6: Percentage of *ejidatarios* or *posesionarios* involved in each activity by ejido

	Mean	Stand. dev.	Skewness
% With mechanised agriculture	0.335	0.334	0.559
% With cattle ranching	0.206	0.215	1.228
% With traditional agriculture	0.306	0.343	0.855
% With only traditional agriculture	0.208	0.286	1.362
% With only off-farm activities	0.318	0.303	0.688

We will now look at PSA-H allocation in the area. Table 2.7 shows the evolution of the beneficiary profiles over time regarding total areas, number of *ejidatarios*, density of *ejidatarios* and distance to the market. One can note that the first PSA-H beneficiaries were *ejidos* with a smaller number of *ejidatarios* and a lower density of *ejidatarios* per hectare.

This suggests that the first ejidos to enter the program were ejidos with a lower risk of deforestation and where it might be easier to reach an agreement at the

Table 2.7: Total number of hectares enrolled and PSA-H payments (in thousands of pesos) received by beneficiary *ejido*

	Mean	Stand. dev.	Skewness	Min	Max
Number of hectare of forest enrolled	1,486.629	1,217.556	1.647	160.314	5,664.786
Percentage of forest enrolled	63.1%	24.7%	-0.493	9.2%	99.4%
Amount received	1,867.837	1,570.252	1.300	84.000	6,915.082
Number of years of reception	4.143	1.791	-0.283	1	7
Amount per year of reception	423.478	285.433	1.527	35.041	1,562.668
Amount per ejidat. or pose-sionarios	57.032	49.309	1.037	1.515	198.464

assembly. As explained in Section 2.3.2, technical assistants from CONAFOR are in charge of promoting the program and helping the ejidos to fill in an application for the program. Their remuneration depends on the number of hectares they enroll into the PSA-H. It is quite likely technical assistants favored ejidos with large amounts of forest and low deforestation pressure at the beginning of the program. Nevertheless, verifying this hypothesis would require more qualitative surveys with the technical assistants than we were unable to implement.

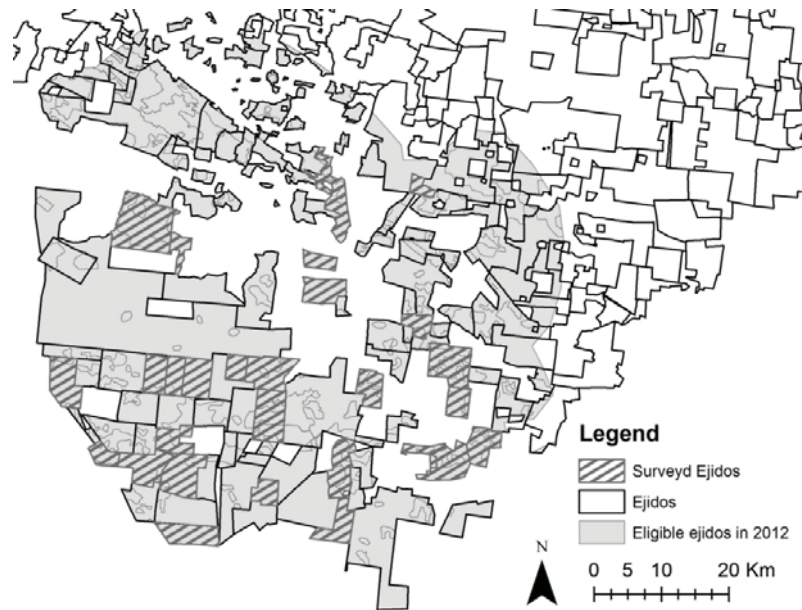
Table 2.7 presents information regarding the number of hectares enrolled in the PSA-H and associated payments for beneficiaries. On average, an *ejido* enrolled 1,486 hectares into the program which correspond to 63% of the total forest. The number of years of reception varies according to the date of the first PSA-H contract and the decision to renew the contract. Some *ejidos* received payments for seven years between 2003 and 2012. On average, *ejidos* received payments for approximately 4 years. Remember that the PSA-H contracts last five years.

The *ejidos* receive substantial payments through the PSA-H. On average, between 2003 and 2012, the *ejidos* of *Cono Sur* received more than 1.8 million Mexican pesos (or more than 140,000 USD). Per year of reception, *ejidos* received on average 423,000 Mexican pesos (or 32,000 USD). Divided by the number of *ejidatarios*, the payments received over ten years are on average 57,000 Mexican pesos (over 4,000 USD) per household. For a comparison, the daily minimum wage in Mexico in 2015 is around 80 pesos per day. Nevertheless, this amount can vary widely, as emphasized in Table 2.7.

2.4.1.3 Surveys at household-level

At the household level, the sample size could not exceed 200 households and for logistical reasons it was impossible to conduct household surveys in all *ejidos*. We randomly selected 27 *ejidos*, including 2 future beneficiaries, and checked the rep-

Figure 2.8: Ejidos that participate to the household surveys



representativity of this sample regarding demography, PSA-H payments and economic activities. Surveying 200 households corresponded to approximately 20% of the total number of *ejidatarios* in the 27 *ejidos* so in each *ejido*, we surveyed 20% of the total number of *ejidatarios*. Nevertheless, it was not relevant to systematically apply the same percentage for each *ejido* since the number of *ejidatarios* varies widely and the results regarding the distribution of the PSA-H within the *ejidos* would have been biased by the decisions made by larger *ejidos*. For this reason, we imposed a maximum limit of 15 households and a minimum limit of 5 households per *ejido*. We deliberately chose to focus the household survey on *ejidatarios*, as they are the main land owners and decision makers at the assembly.

The questionnaire was composed of six parts and mainly focused on economic activities and government support.

- I. Household composition and characteristics
- II. Land use
- III. Agriculture
- IV. Cattle-ranching and livestock
- V. Change in production system
- VI. Timber extraction and other forest products
- VII. Government support
- VIII. Prospects

The field work took place from March to May 2013. It was conducted by one team of two interviewers and lasted approximately 45 minutes per interview.

Table 2.8 presents the principal characteristics of the surveyed households. Households included on average 4.7 members. The household head is on average 54

Table 2.8: Principal households characteristics

Size of the household	
Mean	4.69
Standard deviation	2.28
Minimum	1
Maximum	16
Gender of household head	
Male household head	95.12%
Female household head	4.88%
Age of household head	
Mean	54.47
Standard deviation	13.84
Minimum	24
Maximum	89
Education of the households' head	
Do not write and read	23.41%
Write and read	44.88%
Finished primary school	22.44%
Finished secondary school and more	9.27%
Main residence	
In the ejido	56.59%
Outside the ejido	43.41%
Economic activities	
Traditional agriculture	33.66%
Mechanized agriculture	48.78%
Cattle ranching	24.39%
Off-farm activities	59.02%

years old. Twenty two percent of them are illiterate. Only 55% of the household lives in the *ejido*, which illustrates the phenomena of labour-ejido emphasized in Section 2.4.1.1. About a third of our sample does traditional agriculture (*milpa*) and almost half of the sample practices mechanized agriculture. About a quarter of the sample have cattle-ranching activities. Many households keep a few head of cattle at home but are not really involved in cattle ranching activities. We consider cattle ranchers here as households that use commons of individual pasture for grazing. Around a quarter of our sample has cattle ranching activities. More than half of the *ejidatarios* has permanent or temporary off farm activities.

Table 2.9 presents the number of hectares cultivated for each type of land use. As expected, for traditional agriculture, the *ejidatarios* cultivate on average 2 hectares. Areas cultivated with mechanized agriculture are much larger. On average, the

Table 2.9: Numbers of hectare cultivated per type of land use

	Mean	Stand. dev.	Skewness	Min	Max
Traditional agriculture	2.377	1.790	1.816	0.320	9
Mechanised agriculture	7.609	11.047	4.463	0.500	87
Pasture	18.766	27.707	4.764	0.080	200

Table 2.10: PSA-H payments reception in beneficiary ejidos

	Mean	Stand. dev.	Skewness	Min	Max
Number of years of reception	4.43	2.21	-0.344	0	8
Total amount received	55.09	62.92	2.991	0	504
Average yearly amount received per yr of reception	10.99	9.69	1.750	0	63

ejidatarios cultivate 7.6 hectares but this area can vary widely. A pasture is, on average, 18 hectares but can be shared between *ejidatarios*.

Table 2.10 presents the amount of payments received by the *ejidatarios* in beneficiary *ejidos*. On average, each *ejidatario* received around 55,000 Mexican pesos (4,200 USD) between 2003 and 2013. During the years of reception of payments, each *ejidatario* received on average 10,000 Mexican pesos (or 770 USD). Note that even in beneficiary *ejidos*, some *ejidatarios* did not receive payments. They may have decided to remain outside of the program or may have been excluded by a decision of the assembly. The yearly amount received was as high as 60,000 Mexican pesos (more than 4,600 USD).

Table 2.10 show that the amount of payments are likely to represent significant additional income for the *ejidatarios*. Table 2.11 shows how, on average, they claim to have used this additional income. If 60% of the payments were used for household expenses, about 30% of the payments were invested in either agriculture or cattle ranching. This suggests that the PSA-H may have impacted agricultural activities.

Table 2.11: Use of the payments according to the *ejidatarios*' statements

Household expenses	62.5%
Agriculture	23.9%
Cattle ranching	5.6%
Debt reimbursement	2.2%
Other	5.8%

Table 2.12: Land-use in 2012

Land use	Hectares	Percentage
Infrastructure	1,526	0.709%
Forest	187,004	86.942%
Mechanized agriculture	15,758	7.326%
Traditional agriculture	1,499	0.697%
Pasture	9,302	4.325%
Total	215,089	100%

2.4.1.4 Remote sensing analysis

In order to assess land-use change over time, remote sensing analysis was performed using SPOT images of 1999, 2005 and 2012. The remote sensing analysis was conducted by CIRAD in Montpellier (France) and ECOSUR in San Cristobal de Las Casas (Chiapas, Mexico). The classified images are presented in the Appendix. The remote sensing analysis focused on the land owned by *ejidos* surveyed.

The remote sensing analysis combined information from the SPOT images with ground-truthing data and information from the participatory mapping in order to distinguish pasture, mechanized agriculture and traditional agriculture. The analysis distinguishes 5 main classes of land-use:

- Infrastructure (Roads, villages...)
- Forest
- Mechanised agriculture
- Traditional agriculture (milpa)
- Pasture

The area for each land-use type in 2012 is presented in Table 2.12. Between 2005 and 2013, more than 9,200 hectares were deforested, but we also observed reforestation due to land abandonment and forest regeneration. The gross deforestation rate between 2005 and 2015 is 4.9%. Between 1999 and 2005, the trend is similar with deforestation rates around 4.5%⁵

2.4.2 ENAFF surveys

The ENNAF (*Encuesta Nacional a los Nucleos Agrarios Forestales*) survey is a representative survey of forested *ejidos* in Mexico. These surveys have been implemented by the *Instituto Nacional de Ecología*, the *Universidad Iberoamericana* and

⁵Slight differences between these statistics and others found in the rest of the dissertation are due to the areas of analysis. The remote sensing analysis included areas around *ejido* borders. There are differences in absolute terms but deforestation rates are similar.

Table 2.13: Ejidos from the ENAFF surveys by state

State	Number of ejidos	Percentage
Campeche	7	3.13%
Chiapas	26	11.61%
Chihuahua	14	6.25%
Colima	6	2.68%
Durango	7	3.13%
Guerrero	14	6.25%
Hidalgo	11	4.91%
Jalisco	27	12.05%
Mexico	4	1.79%
Nayarit	11	4.91%
Oaxaca	31	13.84%
Puebla	8	3.57%
Queretaro de Arteaga	1	0.45%
Quintana Roo	13	5.80%
San Luis Potosi	11	4.91%
Sinaloa	6	2.68%
Tabasco	3	1.34%
Tlaxcala	1	0.45%
Veracruz-Llave	20	8.93%
Yucatan	3	1.34%

the *Centro de Investigacion y Docencias Economicas* and focuses on forest management.

The sampling was based on a stratification by size of *ejidos*. Within each strata, a representative number of *ejidos* were randomly selected. The number of *ejidos* per State is displayed in table 2.13. Surveys took place in 2002, 2004, 2006, 2007 and 2010. The *ejidos* surveyed between 2002 and 2007 were all different but, in 2010, some of the *ejidos* surveyed in 2002 have been surveyed again. Our sample is composed of the 223 *ejidos* that have surveyed both in 2002 and 2010.

Table 2.14 presents the main characteristics of the *ejidos*. There were on average 190 *ejidatarios* per *ejido* surveyed. The percentage of forest cover was computed using INEGI Serie IV data with a resolution of 1:250 000.

In this representative survey, 22% of the *ejidos* benefited from the PSA-H for at least one year between 2003 and 2010. Most of the beneficiaries have completed, or are about to complete, the five years of enrollment. We have already observed several *ejidos* that renewed their contracts. One of these *ejidos* received payments for 8 years.

Table 2.16 presents the number of hectares enrolled in the PSA-H and the amount

Table 2.14: Main characteristics of ejidos in the ENAFF surveys

	Mean	Stand. dev.	Skewness	Min	Max
Number of ejidatarios	189.21	343.74	6.89	10	3500
Area (Ha)	10,439.78	20,140.25	3.83	190.21	127733.76
Percentage of forest in 2002	0.46	0.28	0.44	0	1.00

Table 2.15: Number of *ejidos* by years of PSA-H reception in the ENNAF survey

Number of years	Number of ejidos	Percentage
0	175	78.13
1	3	1.34
2	4	1.79
3	7	3.13
4	15	6.70
5	12	5.36
6	5	2.23
7	2	0.89
8	1	0.45
Total	224	100

Table 2.16: Total number of hectares enrolled and PSA-H amount (in thousands of pesos) received by beneficiaries in the ENNAF survey

	Mean	Stand. dev.	Skewness	Min	Max
Amount received	1,705.904	1,666.890	1.367	172.364	6,382.083
Amount per year of reception	422.365	353.996	0.82	36.900	1,247.938
Amount per ejidatarios	13.670	18.148	2.785	0.846	87.821

received between 2003 and 2012, per year of reception divided by the number of *ejidatarios*. The amounts are similar to the amounts found in the PESMIX surveys and presented in Table 2.7.

Challenges for PES Impact Evaluation

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Evaluating the impact of conservation instruments have been emphasized in the literature as a major area of research by many authors (Ferraro and Pattanayak, 2006; Joppa and Pfaff, 2010; Pattanayak et al., 2010; Miteva et al., 2012). Based on existing literature, this chapter proposes a review of the available techniques and the underlying assumptions for their implementation. We also discuss the main issues for IE of conservation instruments with a special emphasis on PES. We show that PES are no common treatment and that lots of caution should be taken in building and interpreting impact analysis.

3.1 Introduction: Evaluating public policies

3.1.1 The missing outcome

Following Rubin (1974), the problem of evaluation can be formalised using potential outcomes. Let us consider the implementation of a new policy, called the treatment, supposed to impact an outcome variable Y . In the context of PES, the treatment would be PES reception and the outcome variable a measure of deforestation. Let's note Y_i the outcome variable for each individual i . Y_i^T corresponds to the outcome when the individual receives the treatment and its counterfactual Y_i^{NT} when the individual do not receive the treatment. Hence, the impact of the program is:

$$E(Y_i^T - Y_i^{NT}) \quad (3.1)$$

In equation 3.3, Y_i^{NT} corresponds to an hypothetical outcome: the outcome of the treatment beneficiaries if they had not been part of the program. Contrary to Y_i^T , this outcome is by definition unobservable. The main challenge of evaluation is to reconstitute this missing outcome.

Two intuitive solutions could be considered to estimate Y_i^{NT} but both of them lead to biased estimates (Joppa and Pfaff, 2010):

- Before/after: Comparing the group of beneficiaries before and after the treatment implementation. One makes the assumption that Y_i^{NT} is equal to the value of Y_i before the program ie that the value of the outcome variable would have not varied if the program had not been implemented. It is easy to understand why this assumption is unlikely to be verified. For example, let's consider a fictive country where the government decides to implement a PES scheme as a response to high deforestation pressures. Meanwhile, a variation in international timber prices makes deforestation less attractive: deforestation rates will decrease as a consequence of the decrease in timber prices. Therefore, comparing deforestation before and after PES for the beneficiaries will lead us to falsely attribute the decrease of deforestation to PES implementation.
- With/without: Another appealing solution is to use a group of non-beneficiaries as a counterfactual for the beneficiaries and assumes that Y_i^{NT} is equal to the outcome of non-beneficiaries. This method is also likely to

be biased. In the context of PES, let's consider two landowners, one that is willing to deforest in the future and another that is not. Without specific targeting system of the program, the latter is more likely to enter into the PES but would not have deforested anyway. Therefore, comparing non beneficiaries with beneficiaries will lead us to overestimate the impact of the program. Now let's consider that the scheme succeeds in targeting landowners with higher willingness to deforestation in the near-future. A control group of non beneficiaries is likely to be constituted of landowners with smaller willingness to deforest. In that case, the impact might be underestimated. In both examples, the impact is biased upward or downward.

IE usually involves a group of beneficiaries and a group of non beneficiaries to reconstitute a counterfactual. We will now introduce the status of individuals regarding treatment D_i and note $D_i = 1$ if i is part of the group of beneficiaries (treated group) and $D_i = 0$ if he is part of non beneficiaries (control group).

As explained by [Chabe-Ferret \(2008\)](#), the impact one is willing to identify is:

$$E(Y_i^T - Y_i^{NT}) = E(Y_i^T - Y_i^{NT} | D_i = 1)Pr(D_i = 1) + E(Y_i^T - Y_i^{NT} | D_i = 0)Pr(D_i = 0) \quad (3.2)$$

With/without estimations implicitly make the assumption that:

- $E[Y_i^{NT} | D_i = 0] - E[Y_i^{NT} | D_i = 1] = 0$ i.e. the expected outcome of beneficiaries if they had not received the program would have been identical to the outcome of non beneficiaries
- $E[Y_i^T | D_i = 0] - E[Y_i^T | D_i = 1] = 0$ i.e. the expected outcome of non-beneficiaries if they had received the program would have been identical to the outcome of beneficiaries

3.1.2 Definitions

The main challenge for IE is to build a counterfactual accounting for the biases presented above. Each technique relies on different assumptions and have its own strengthes and weaknesses. This section presents a few necessary definitions to understand the different techniques.

3.1.2.1 Impact

We introduce four concepts: the average treatment effect (ATE), the average treatment effect on the treated (ATT), the intention to treat effect (ITT) and the local average treatment effect (LATE). The statistical definition of this concept is crucial to interpret the results of an IE and assess their external and internal validity.

Internal validity is the minimum one should question about the estimates. As explained by [Ravallion \(2007\)](#), it concerns the ability to obtain a "*reliable estimate of the counterfactual outcomes in the specific context*". External validity concerns

the extrapolation of the results in other settings ie for another population or in other places for instance.

The *average treatment effect* is defined as follows:

$$ATE = E(Y_i^T - Y_i^{NT}) \quad (3.3)$$

We note that D_i does not appear in equation 3.3. It means that, if the methodology allows to estimate an ATE, it can be interpreted as the impact of the treatment independently of the status of the individuals. This concept has the strongest internal and external validity: one can assume that the impact would have been the same for the whole population of study if they had received the program. ATE can be obtained if the treatment is randomised.

The *average treatment effect on the treated* is defined as follows:

$$ATT = E(Y_i^T | (D_i = 1) - Y_i^{NT} | (D_i = 1)) \quad (3.4)$$

Comparing 3.3 and 3.4, it is straightforward that ATE has a larger validity than ATT. As a matter of fact, ATT's validity is limited to the treated group. One can not hypothesize that the impact would have been the same for the control group if they had received the program.

The *intention to treat effect* is estimated when treatments can be accepted or rejected by participants. Let's assume an invitation Z_i to adopt the treatment D_i . $Z_i = 1$ if the individual is invited and $Z_i = 0$ if he is not. The group can be divided between compliers, who accept the invitation and adopt the treatment and non-compliers that do not accept. The adoption of the treatment D_i may remain unobserved. ITT is defined as:

$$ITT = E(Y_i | (Z_i = 1) - Y_i | (Z_i = 0)) \quad (3.5)$$

In the context of PES for instance, consider that one knows which landowners have been proposed the program but can not clearly identify the parcel enrolled into the program. It is not possible to compute the impact of participation, the ATT, since one can not observe the landowners that accepted the invitation and on which parcel. But the ITT can be computed based on the invitation to participate.

Let us now consider that D_i is observed but one suspects endogeneity of participation and uses Z_i , for instance the invitation to participate, as an instrument to predict the treatment (Angrist et al., 1996)¹. Our sample can be divided between compliers and defiers as in table 3.1.

Table 3.1: Compliers and defiers for LATE estimation

	$Z_i = 0$	$Z_i = 1$
$D_i = 0$	Complier / Never-taker	Defier / Never-taker
$D_i = 1$	Defier / Always-taker	Complier / Always-taker

¹cf Section 3.2.4 and 3.3.2 for instrumental variable estimations

Angrist (1990) evaluates the impact of Vietnam war on veteran life earning using the draft lottery as an instrument. In their study, defiers are the veteran that would have enrolled voluntarily regardless of the result of the draft and the persons that did not enroll despite the draft selected them.

Using Z_i as an instrument, it is possible to identify the LATE defined as:

$$LATE = E((Y_i^T - Y_i^{NT}) | D_i(Z_i = z) \neq D_i(Z_i = w)) \quad (3.6)$$

The LATE's validity is limited to the compliers i.e. observations for which an exogenous variation of the instruments induces a change of behaviour. The validity of the LATE is limited but it can be the most relevant identification strategy in order to insure that the estimates are not biased.

3.1.2.2 Main hypotheses

A fundamental hypothesis of most estimators is the Stable Unit Treatment Value Assumption (SUTVA) (Rubin, 1980). The SUTVA hypothesis states that there are no diffusion effects of the treatment i.e. that the outcome of one individual is only influenced by its own status regarding the treatment. If SUTVA is verified, the fact that $j \neq i$ receives or not the program does not impact the outcome Y_i . In the context of PES, it means that the deforestation rate Y_i of one parcel i does not depend on the fact that its neighbours decide to enroll or not into the PES. In the context of conservation instruments, validating SUTVA automatically requires hypothesis about leakage effects of the programs. We will further discuss this in Section 3.4.

The SUTVA hypothesis can also be violated because of John Henry Effects. This effect refers to changes of behavior by the control group to compensate for their disadvantage compared to the treated group. Indeed, in the case of PES, a growing literature emerged on the issue of crowding-in and crowding-out effects of PES schemes (Rode et al., 2014). If the treatment modifies the behaviour of the control group, it automatically biases the estimation.

Another important hypothesis is the absence of Ashenfelter's dip in the estimation (Ashenfelter, 1978). It states that individuals have not changed their behaviour prior to the program implementation. This change of behaviour could be due to:

- A shock affecting the population of study. In that case, the methods using pre-treatment characteristics such as difference-in-difference (DID) for example (see Section 3.2.2) can not correctly identify the impact.
- Anticipation effects by individuals. If individuals change their behaviour before program implementation, for example in order to be eligible for the program, it might bias the results.

We will also discuss this hypothesis in the context of PES in Section 3.4.

A last important hypothesis is called *uncounfoundedness*. It states that all relevant covariates influencing both treatment reception and the outcome variable are

included in the model. Econometrically, it means that the outcome variable is independent from the treatment conditionally on the observable characteristics included in the model. These covariates are called confounding factors and can be either observable or unobservable.

3.2 Evaluating PES as a treatment

3.2.1 Matching methods

Let's consider a vector of covariates X_i and two groups of observations: the treatment group, $D_i = 1$, and the control group $D_i = 0$. Treatment and control groups are statistically different regarding covariates X_i . Matching methods aims at balancing covariates between the treated group and the control group to make them on average similar in all observable covariates but the treatment itself. The matching procedure weights observations from the control group in order to balance the covariates and makes both groups statistically similar regarding X_i . These methods have been emphasized by [Joppa and Pfaff \(2010\)](#) among others as a good option to deal with selection bias in conservation instruments allocation. There are two main types of matching estimators:

- Propensity Score Matching (PSM) based on the probability to receive the program
- Covariate Matching based on the vectorial distance

3.2.1.1 Propensity score matching

The main hypothesis of PSM is the selection on observable. To comply with unconfoundedness hypothesis, one must make the hypothesis that there are no unobservable covariates influencing both the treatment and the outcome variable.

In order to get an unbiased estimation of the impact, the estimations must include all observable covariates jointly influencing both treatment and outcome variables and, if possible, enough variables to capture the effect of unobservable characteristics ([Ravallion, 2007](#)). Matching methods also requires the SUTVA hypothesis to hold (cf Section 3.1.2). Therefore, PSM relies on the same fundamental hypothesis as ordinary least square (OLS).

An exact matching would compare individuals with the same observable characteristics (X_i). If all relevant variables are included, the treatment becomes orthogonal to the error term. But finding two observations, treated and non treated, with exactly the same characteristics might prove impossible. [Rosenbaum and Rubin \(1983\)](#) theorem states that, if the outcome is orthogonal to participation conditionally on X_i :

$$Y_i \perp D_i | X_i \tag{3.7}$$

Then it is also orthogonal to participation conditionally on the probability to be treated knowing X_i :

$$Y_i \perp D_i | P(X_i) \quad (3.8)$$

Therefore, one can estimate the impact, not by comparing observations with similar X_i , but with similar probability to receive the treatment knowing X_i . This probability is called the propensity score.

Let's consider that our sample of N observations i is divided into two groups: a group of J observations j that received the treatment and a group of K observations k that did not. PSM procedure attributes, for each treated observation, one or more match from the control group. In order to find similar matches for each treated individuals, it is recommended to have a control group much larger than the treated group.

We can distinguish 4 steps in PSM implementation. First, one must estimate the probability to receive the treatment (the propensity score) for each observation usually using a probit or a logit model:

$$Pr(D_i = 1) = f(X_i) \quad (3.9)$$

Second, one restricts the sample to the common support by excluding from the control group the observations with a propensity score lower than the minimum of the treated group and vice versa with the treated group. The existence of a common support is a crucial assumption to the application of matching methods. Note that restriction to the common support is an advantage of matching methods compared to OLS estimations.

Third, weighting matrix ω_{jk} is generated in order to balance covariates between the two groups. Numerous technique are available for the estimation of ω_{jk} such as:

- Nearest-neighbour: Each treated observations is matched with its closer neighbour in terms of propensity score, each neighbour is assigned a weight of one.
- N-nearest neighbour: Each treated is matched with its three nearest neighbours, each neighbour is assigned a weight of $1/n$.
- Radius-matching: Each treated individual is matched with all the observations within a certain tolerance limit regarding difference in propensity score
- Kernel matching: Each treated is matched with the whole distribution of the control group weighted by their distance in terms of propensity score.

It is also possible to define a tolerance limit between observations regarding differences of probability. For example, choose the 3-nearest neighbour matching but impose that the difference of propensity score with the treated observation should not exceed 5%. In that case, some treated observations may only have 1 or 2 matches in the control group.

Matching can also be implemented with or without replacement. As explained by [Caliendo and Kopeinig \(2008\)](#), there is a trade-off between potential bias and variance. On one hand, matching with replacement reduces the possibility of “bad

matches" ie matches that would be highly different from the treated but, on the other hand, it reduces the size of the control group in the common support and consequently increases the variance (Smith and Todd, 2005).

Matching can also be forced within strata. For instance, if there are structurally different groups according to one variable or to impose a matching between observations of the same geographic region, it is possible to restrict the matching within strata. To obtain unbiased estimation, the control group must be large enough within each strata in comparison of the treated group.

Eventually, the impact is computed as:

$$\begin{aligned} ATT &= E(Y_j^T - Y_j^{NT} | (D_i = 1)) \\ &= \frac{1}{J} \sum_j (Y_j - E(Y_j^{NT} | D_i = 1, P_j)) \end{aligned} \quad (3.10)$$

$$(3.11)$$

With:

$$E(Y_j^{NT} | D_i = 1, P_j) = \sum_j \omega_{jk} Y_k^{NT} \quad (3.12)$$

The impact identified is computed conditionally on treatment status D_i : it is an ATT. Its validity is limited to the treated group. One can not hypothesize that the results would have been the same if the control group had received the program.

As explained by Caliendo and Kopeinig (2008), there are no clear rule of thumb about which techniques should be used and they should all converge asymptotically. The choice of the technique is case-specific and depends a lot on the context of the study. There are often trade-offs between variance and bias and the choice depends on the availability of good matches in the control group.

3.2.1.2 Covariate matching and extensions

Covariate matching relies on the same assumptions as PSM (cf Section 3.2.1.1) but the matching between observation is based on vectorial distances instead of propensity scores. Covariate matching is usually based on Mahalanobis distance.

Equation 3.13 presents the usual euclidian vectorial distance between i and j :

$$VD = \sqrt{(X_i - X_j)V^{-1}(X_j - X_i)} \quad (3.13)$$

V is the variance of X .

Euclidian distance takes into consideration the scale of the different variables included in X_i by introducing the variance V . But it does not consider the correlation in the data. For this reason, covariate matching uses the Mahalanobis distance that introduce the covariance matrix S instead the variance V . This metrics puts less weight on the components of X that are more dispersed. The Mahalanobis distance is defined as:

$$MD = \sqrt{(X_i - X_j)S^{-1}(X_j - X_i)} \quad (3.14)$$

Once computed Mahalanobis distance between each treated and control observation, the matching procedure weights the control group according to the technique chosen. The techniques available are the same as the ones presented in Section 3.2.1.1. The ATT is also computed using equation 3.10.

The trade-offs between covariate matching and PSM has been discussed by Zhao (2004). Based on Monte-Carlo simulations, the author's findings suggest that when the correlation between the covariates and the participation is high, PSM performs better but covariate matching can also be used. Nevertheless, with small sample, it is recommended to use covariate matching.

Studying large sample properties of covariate matching, Abadie and Imbens (2006) show that when matching is not exact, the estimations include a bias that may not vanish with finite sample. They propose a correction for this bias making matching estimators consistent. They also provide a software in order to apply this correction.

One notable extension of covariate matching is the Genetic Matching developed by Diamond and Sekhon (2013). The objectives of matching methods is to balance the covariates between the control and treated group. Genetic matching generates an additional weighting matrix G in order to improve the balance between covariates of treated and control group. The vectorial distance is defined by:

$$GMD = \sqrt{(X_i - X_j)GS^{-1}(X_j - X_i)} \quad (3.15)$$

The matrix G is generated by an iterative algorithm.

The IE of Costa-rican PES by Robalino and Pfaff (2013)² between 1997 and 2000 and Robalino et al. (2008) between 2000 and 2005 show how matching methods (PSM and covariate matching) can reduce bias in the estimation compared to with/without or before/after estimations. As a matter of fact, the authors' findings suggest that if deforestation rates are low in treated area, this is mainly due to a national decrease in deforestation rates. Once controlled for distances to the main markets, access to infrastructure and including dummy variable for the different areas, both studies find very low impact of the PES that they attribute to mistargeting of the scheme. Similar methodologies have been applied to IE of protected areas in Costa Rica, Mexico or Thailand (Andam et al., 2008, 2010; Pfaff et al., 2009; Honey-roses et al., 2011). Genetic matching methods have been poorly used so far for IE of conservation instruments. The evaluation of protected areas in Bolivia by Canavire-Bacarreza and Hanauer (2013) constitutes a notable exception. The authors investigate the impact of protected area on a poverty index in Bolivian municipalities and find that protected areas are associated with poverty reduction.

3.2.1.3 Spatial matching

The efficiency of conservation instruments depends crucially on their localisation and spatial interactions with neighbouring observations matter a lot for IE. As a matter

²Also see Pfaff et al. (2008) for a more detailed version.

of fact, the characteristics of neighbouring observations are crucial confounding factors: they influence both the probability to receive the program and the outcome variable. For instance, being located near a road influences both deforestation and the probability to enter into a PES.

Honey-roses et al. (2011) recently developed a spatial-matching estimator in order to evaluate the impact of a natural protected area and PES in Mexico. The authors include in the estimation, not only the characteristics of the parcel i but also the characteristics of the neighboring parcel j .

The additional variables introduced by Honey-roses et al. (2011) are computed as:

$$X_i^{SL} = \sum_j \gamma_{ij} X_j \quad (3.16)$$

γ_{ij} is a contingency matrix that takes a value different from zero if i and j are considered as neighbours. γ_{ij} can have different formulation depending on the definition of neighbouring and the standardisation chosen. More details about contingency matrix can be found in Section 3.3.3. The authors find a positive impact of the conservation on the forest cover.

The rest of the procedure follows the steps presented in the previous sections. Remember that unconfoundedness (see Section 3.2.1.1) is the main assumption of matching estimators. Since spatially-lagged variable are crucial confounding factors for IE of conservation instruments, not including them automatically bias the estimations. Moreover, not introducing spatial interactions can lead to a violation of the SUTVA in the presence of diffusion effects.

3.2.1.4 Testing the matching

In order to test that the matching succeeded in balancing covariates, it is recommended to implement a succession of t-test for each variable of X_i to test if significant difference remain between the tow groups after the matching.

Without weighting the counterfactual, the null hypothesis of the t-test is:

$$\frac{1}{J} \sum_j x_j - \frac{1}{K} \sum_k x_k = 0 \quad (3.17)$$

And after weighting the control group and restricting to the common support, the null hypothesis is: :

$$\frac{1}{J} \left(\sum_j x_j - \sum_j \omega_{jk} x_k \right) \quad (3.18)$$

Statistical difference may appear in 3.17. However, they should not be significant in equation 3.18 if the matchings performed well in balancing covariates. Moreover, for each covariate, one can compute the standardised bias between control and treatment groups before and after weighting such as:

$$\frac{(\bar{x}_j - \bar{x}_k)}{\sqrt{0.5(V(x_j) + V(x_k))}} \quad (3.19)$$

With \bar{x}_j and $V(x_j)$ the mean and the variance of variable x_i in the treated group and \bar{x}_k and $V(x_k)$ the mean and the variance in the control group.

Caliendo and Kopeinig (2008) also recommend to run the test suggested by Sianesi (2004). This test proposes to re-estimate the propensity score on the common support. There should not be any differences in the distribution of covariates of both groups and the explanatory power of the model, the pseudo- R^2 , should be low. It is also possible to run an F-test on the joint-significance of all regressors and compare the results of this test using the whole sample and the common support. We should reject the null hypothesis that all regressors are jointly null on the whole sample and accept it on the the common support.

Rosenbaum (2002) proposes a test of sensitivity to hidden bias. This test checks how sensitive are the results to the existence of unobservable confounding factors or, in other words, how strongly these factors “must affect selection into the treatment to undermine our conclusions”(Andam et al., 2008). Hidden bias could threaten the results if unobservable are influencing selection into the treatment and the outcome variable. Following Andam et al. (2008), we note the odds ratio of the probability to be selected into as PES as $\Pi_i/1 - P_i$. The log odds can be modeled as:

$$\log\left(\frac{\Pi_i}{1 - P_i}\right) = \kappa X_i + \gamma \mu_i \quad (3.20)$$

μ_i are unobserved covariates scaled as $0 \leq \mu_i \leq 1$.

Rosenbaum (2002) proposes to compute bounds on the significance level of the estimates as $\tau = \exp(\gamma)$ varies. The odds of being protected may vary as a result of a hidden bias but the impact can remain significant. The test provides the maximum value of τ for which the results remains significant. The more this limit value is important, the less hidden bias might impact the results. As noted by Andam et al. (2008), the test does not say anything about the existence of such a bias but about how strongly it should influence the selection process to bias the results.

3.2.2 Difference-in difference

3.2.2.1 Introducing control on unobservable

Difference-in-difference method is a combination between before/after and with/without situation. Let's note Y_{it} the outcome of individual i at time t and D_i the reception status.

The equation of the ATT presented in Section 3.1.2 is:

$$ATT = E(Y_i^T - Y_i^{NT} | (D_i = 1)) \quad (3.21)$$

Remember that the outcome for beneficiaries if they had not benefited from the program, Y_{it+1}^{NT} is unobservable by definition. DID estimator assumes that it is possible, based on pre-treatment data of treatment and control group, to approximate this missing outcome by:

$$E(Y_{it+1}^{NT}|D_i = 1) = E(Y_{it+1}^{NT}|D_i = 0) - [E(Y_{it}^{NT}|D_i = 0) - E(Y_{it}^{NT}|D_i = 1)] \quad (3.22)$$

Equation 3.22 assumes that the mean outcome for beneficiaries if they had not received the treatment is equal to the mean outcome of the control group after the treatment corrected by the mean pre-treatment outcome difference between both groups. Combining 3.21 and 3.22, DID identifies the ATT defined as:

$$ATT = E(Y_{it+1}^T|D = 1) - E(Y_{it+1}^{NT}|D = 0) - [E(Y_{it}^{NT}|D = 1) - E(Y_{it}^{NT}|D = 0)] \quad (3.23)$$

The main assumption of DID is that the mean difference between treated and control groups would have remained stable without implementation of the treatment ie that both groups were following *parallel trends*. If the parallel trends assumption is verified, we can identify an ATT (cf Section 3.1.2). While matching methods controlled for observable covariates, DID allows us to control for time-unvarying unobserved heterogeneity.

Let's consider a simple graphic example. Figure 3.1 plots the mean evolution of deforestation for PES beneficiaries, lower line, and non-beneficiaries, upper line, over time. PES is implemented at date t . In this figure, it is easy to understand why before/after methods and with/without methods presented in Section 3.1.1 lead to biased estimates. First, because deforestation is decreasing over time in both groups and second because non beneficiaries (control group) have higher deforestation rates than beneficiaries (treated group). Looking at figure 3.1, one can conclude that the parallel trend assumption seems to be validated by pre-treatment evolution of both groups (between $t - 1$ and t). Let's assume that this parallel evolution would have continued without PES. The dotted line shows the hypothetical evolution of the beneficiaries if they had not received the treatment: the ATT is represented by segment a . If a can not be computed directly, it is straightforward from figure 3.1 that it is equal to $(b - c)$ ie the difference of deforestation rates between treated and control group minus the original difference between the two groups.

DID can be estimated in a simple panel regression framework:

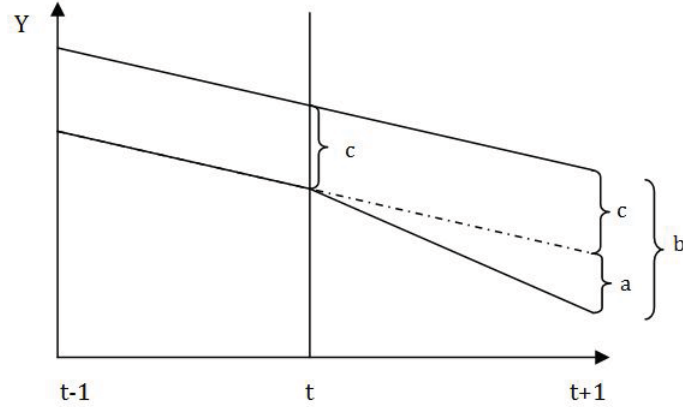
$$Y_{it} = \alpha + \gamma_1 T_i + \gamma_2 t_i + \beta T_i t_i \quad (3.24)$$

Combining equations 3.23 and 3.24, it is easy to show that the ATT is equal to coefficient β . DID can also be estimated using fixed-effect estimator.

It is possible to test the parallel trend assumption using pretreatment data if they are available. It requires estimating equation 3.24 between $t - 1$ and t . If the assumption is validated, β should not be significantly different from zero.

DID controls for all time unvarying covariates: observable or unobservable. The regression framework presented in equation 3.24 is appealing since it allows us, if data are available, to introduce a control on observable time-varying covariates. DID assumptions are less restrictive than matching assumptions since it controls on any

Figure 3.1: Difference-in-difference and parallel trend



time-unvarying covariates and it is possible to introduce a control on observable time-varying covariates. Nevertheless, the SUTVA assumption must still hold in order to correctly identify the impact.

If DID method relies on less restrictive assumption than matching methods, one advantage of the latter is the restriction to the common support and the possibility to select a sample similar to the treated group. It is possible to combine the advantages of both methods using DID-Matching.

3.2.2.2 Combining DID and matching

Compared with simple matching, DID-matching introduces a control on time-invariant unobservable covariates. The conditional independence assumption becomes:

$$(Y_{it+1} - Y_{it}) \perp D_i | X_i \quad (3.25)$$

This assumption can also be called conditional parallel trend.

If we consider that the sample is divided between a group of J beneficiaries j and K non beneficiaries k , the ATT is estimated by:

$$\begin{aligned} ATT &= E((Y_i^T - Y_i^{NT}) | D = 1) \\ &= \frac{1}{J} \sum_j^J [(Y_{jt+1}^T - Y_{jt}^{NT}) - \sum_k^K \omega_{jk} (Y_{kt+1}^{NT} - Y_{kt}^{NT})] \end{aligned} \quad (3.26)$$

The weighting matrix ω_{ij} is computed using covariate matching with [Abadie and Imbens \(2006\)](#)'s correction or PSM. It is recommended to use pre-treatment data to construct the weighting matrix. As a matter of fact, ex-ante covariates are not influenced by the treatment contrary to ex-post data. Matching using pre-treatment data build a counterfactual that was similar to the treated group before

the implementation of the treatment. Matching on post-treatment data might bias the estimations if the treatment has impacted the covariates X_{it+1} .

In the context of PES, this method has been used by [Arriagada et al. \(2012\)](#) and [Chabé-Ferret and Subervie \(2013\)](#). [Arriagada et al. \(2012\)](#) studied the impact of PES in a region of Costa Rica. They perform an analysis at farm-level and match on pre-treatment covariates such as initial forest cover or farm size. Their results suggest that DID matching performs better than covariate matching in balancing covariates. They also perform [Rosenbaum \(2002\)](#) test in order to check for the sensitivity of their results to potential unobservable confounder. As [Pfaff et al. \(2008\)](#) before, they find a low impact of the program that they attribute to mistargeting.

In their study of the impact of European Union agro-environmental schemes (AES), [Chabé-Ferret and Subervie \(2013\)](#)³ develop a theoretical model in order to understand the decision of the farmers to adopt an AES. The authors identify the potential bias for their estimations by discussing SUTVA, conditional parallel trend assumption and common support in the context of their model. Once discussed the assumption of the estimator, they provide estimations of ATT for 5 AES at farmer-level. Nevertheless, the multiplicity of AES and the possibility to cumulate them makes the definition of control and treated group more complicated. They define the control group as the farmers that did not adopt any AES. The treated group for a given AES is composed of the farmers that adopted at least this AES of interest independently of the number of other AES adopted. Hence, the ATT identified for this given AES is a weighted average of the treatment effect of each combination of AES including the AES of interest.

3.2.3 Regression discontinuity design and pipeline regressions

Regression discontinuity design (RDD) and pipeline regression are two different IE methods both using eligibility rules of the program in order to estimate the impact ([Khandker et al., 2010](#)). The first one is based on the targeting criteria and the second on progressive entry into the program.

3.2.3.1 Regression discontinuity design

RDD uses eligibility cutoffs as an instrument to identify the impact of the program. Let us consider that eligibility is based on a variable S , an index of deforestation risk for instance, with i eligible for program reception if $s_i > s^*$. The group of eligible observations is likely to be different from the one of non-eligible. Nevertheless, if we consider only the individuals which are located just below and just above the threshold: these two groups are likely to be similar. RDD uses individuals with s_i slightly lower than s^* as a control group for individuals with s_i slightly higher than s^* . We identify a LATE defined as:

$$LATE_{RDD} = E(Y_i | S_i = s^* + \epsilon) - E(Y_i | S_i = s^* - \epsilon) \quad (3.27)$$

³Also see [Chabé-Ferret and Subervie \(2009\)](#)

When the threshold is enforced, the discontinuity is said *sharp*. But there might be individuals located above the threshold that do not receive the treatment and vice-versa: in this case the discontinuity is said *fuzzy*. In that case, the threshold is not used directly to identify the impact but as an instrument for the probability to receive the program (see Section 3.2.4 for more details about instrumental variable estimations). Let's consider a dummy variable $E_i = 1$ if $S_i > s^*$, one can compute the probability to receive the program:

$$Pr(D_i = 1|E_i) \tag{3.28}$$

If S_i and E_i are both included in the model, being above or below the threshold will not influence the outcome variable: the threshold is said exogeneous. Then it is possible to estimate the impact using instrumental variables with the threshold as an instrument for participation to the program.

RDD allows us to estimate a LATE for the individuals located around the threshold. Its internal validity is very limited since results can not be extrapolated to other groups of beneficiaries. Nevertheless, RDD can identify an unbiased impact of the program without additional assumption such as selection on observable or parallel trend. There is a trade-off between larger validity and unbiased identification of the impact. Note that RDD does not relax the SUTVA assumption.

An example of the implementation of fuzzy-RDD can be found in [Alix-Garcia et al. \(2013\)](#). The authors analyse the impact of a Mexican social program called Oportunidades on deforestation. Oportunidades offers cash payments to marginal households conditionally on children's school attendance and health checkups. The authors hypothesize that the program can relax a credit constraint and increase deforestation. Oportunidades is allocated to households in localities considered as marginal according to a marginality index based on measures of education, infrastructures or access to energy among others. The authors use the threshold as an instrument to identify the impact of the program on deforestation. As a matter of fact, if marginality can impact deforestation, if we control for the value of the marginality index, we can credibly make the hypothesis that being above or below the threshold won't affect deforestation. Their results confirm that the program has increased deforestation.

3.2.3.2 Pipeline regressions

Pipeline regressions uses progressive entry into the program to evaluate its impact. It is based on the assumption that entry into the program is random given application. The control group is composed of observations that are about to receive the program in the forthcoming years. Pipeline regressions are similar to RDD but instead of using a threshold, they estimate the impact for each new cohorts entering into the program using the future beneficiaries as a control group. ([Ravallion, 2007](#)).

3.2.4 Instrumental variable methods

The unconfoundedness assumption is highly restrictive. If one is unable to deal with observable and/or unobservable confounding factors, instrumental variable methods allows to identify a LATE.

Let us consider the estimation of a simple model using Ordinary Least-square (OLS):

$$Y_i = \alpha + \beta D_i + \gamma X_i + \varepsilon_i \quad (3.29)$$

If one estimates this equation using OLS, the estimate of β might be biased because of endogeneity of D_i . This endogeneity may arise for different reasons but we here focus on:

- Inverse causality: Y_i impacts D_i . Deforestation rates can influence the reception of a conservation instruments such as PES
- Omitted variable: ε_i is correlated with both D_i and Y_i . There are unobserved variable influencing conjointly deforestation rates and reception of the scheme (unconfoundedness)

If endogeneity arises, $E(D_i, \varepsilon_i) \neq 0$ and the impact of the treatment can not be accurately identified. Let us now consider that the selection process can be modeled as:

$$D_i = \theta + \phi Z_i + \sigma X_i + \mu_i \quad (3.30)$$

With Z_i a vector of exogeneous instruments. This vector of instruments must comply with the exclusion restriction stating that:

- $E(Z_i, \varepsilon_i) = 0$
- $E(Z_i, D_i) \neq 0$

OLS estimations are biased because of the correlation between ε_i and μ_i . There are two ways to account for endogeneity in the estimations. The first one, control functions model, is based on predictions of μ_i while the second, two-stage least square (TSLS), is based on predictions of D_i .

In both cases, a LATE is identified an its validity is limited to the observations for which the instrumental variable impacts the reception of the treatment. Therefore, it is crucial to have instruments that are strong predictors of the treatment.

3.2.4.1 Control functions model

Control function model is part of "Heckman-type" models. In Heckman sample selection model, also called Tobit type II (Wooldridge, 2002), the explained variable is censored meaning that its true value is only observed if the observation satisfies with an underlying selection process. Heckman proposed to estimate the selection

process in order to take into account this issue. In our case, we are not concerned about censoring of the explained variable but about a selection bias in the attribution of the program: the explanatory variable. Control functions have been developed as an extension of original Heckman model to deal with this issue Heckman and Navarro-Lozano (2004).

Control functions model is based on predictions of the error term of the selection process. In the previous section, we noted that the coefficient γ obtained by an estimation of equation 3.29 using OLS was biased because of the correlation between ε_i and μ_i . Introducing predictions of μ_i in 3.29 allows to account for this correlation in the estimation.

The first step is to estimate the probability to receive the treatment using a probit model:

$$Pr(D_i = 1) = \theta + \phi Z_i + \sigma X_i + \mu_i \quad (3.31)$$

Note that Z_i must comply with the exclusion restriction as defined in the previous section.

From 3.31, it is possible to compute the Inverse-Mills Ratio (IMR) for participants and non-participants by estimating equation 3.32 and 3.33.

$$IMR_p = \begin{cases} E(\mu_i|Z_i, X_i, D_i = 1) = \frac{\phi(\cdot)}{\Phi(\cdot)} & \text{if } D_i = 1 \\ 0 & \text{if } D_i = 0 \end{cases} \quad (3.32)$$

And for non participants:

$$IMR_{np} = \begin{cases} E(\mu_i|Z_i, X_i, D_i = 0) = \frac{\phi(\cdot)}{1-\Phi(\cdot)} & \text{if } D_i = 0 \\ 0 & \text{if } D_i = 1 \end{cases} \quad (3.33)$$

The IMR is the ratio of:

- $\phi(\cdot)$: The density function of the probability to receive the program ie the predicted probability that $D_i = 1$ conditionally on Z_i and X_i .
- $\Phi(\cdot)$: The cumulative distribution function of the probability to receive the program.

We include both IMR in equation 3.29:

$$Y_i = \alpha + \beta D_i + \gamma X_i + \rho_p IMR_p + \rho_{np} IMR_{np} + \varepsilon_i \quad (3.34)$$

By introducing the IMR in the estimation, we purge the error term ε_i from the part correlated with the outcome variable and correct the selection bias. A test of joint-significance of both Mills-ratio indicates if there is a selection bias in the OLS estimation.

3.2.4.2 Two-stage least squares

Contrary to control function model, TSLS method is based on the introduction of predicted value of D_i in equation 3.29. Let's compute the predicted value of D_i such as:

$$\hat{D}_i = \theta + \phi Z_i + \sigma X_i \quad (3.35)$$

and introduce it into the model as a second stage:

$$Y_i = \alpha + \beta \hat{D}_i + \gamma X_i + \varepsilon_i \quad (3.36)$$

By using a predicted value \hat{D}_i , we isolate the exogeneous variation of D_i ie non correlated with ε_i . D_i being a binomial variable and not a continuous variable, it would be necessary to estimate the first step using a probit or logit model. To our knowledge, no estimators based on predicted value have yet been developed with a binomial model as a first-stage. Therefore, the first step is usually estimated using OLS and the procedure simplifies into two-stage least square as presented in Section 3.3.2.

Nevertheless, estimating the first step model using linear probability (OLS estimation with a dummy explained variable) does not take in consideration the binomial nature of D_i . [Imbens and Wooldridge \(2007\)](#) explain that this method is inconsistent and has no know properties. The authors propose to:

1. Estimate the probability to receive the program (equation 3.31) using a probit model
2. Extract the fitted probabilities to receive the program from the probit estimations
3. Estimate the model by 2SLS and use the fitted probabilities as instrument for reception

[Imbens and Wooldridge \(2007\)](#) state that this method is fully robust but might be less efficient than the control function method.

3.2.5 Selection and pre-processing of the data

An alternative way to estimate equation 3.29 in a regression framework is to deal with selection by preprocessing the data. We will here introduce pre-matching and propensity scores weighting.

3.2.5.1 Pre-matching methods

Matching methods can also be implemented as non-parametric pre-processing of the data ([Ho et al., 2007](#)). Pre-matching uses a matching procedure to restrict the sample to the common support before estimating the impact using a parametric model. The sample can also be restricted to a matched control group by applying a

matching techniques (nearest-neighbour, caliper etc...). Through this process, one is trying to insure that treated and control groups are similar. Propensity scores can also be added to the vector of regressors X_i in order to control for the heterogeneity of propensity scores.

The pre-processing relies on selection on observable assumption. Identifying a relevant control group remains the most crucial issue, pre-processing must only be considered as a complement in order to identify within the control group which observations are the most similar to the treated and exclude outliers.

It is the method chosen by [Alix-Garcia et al. \(2012\)](#) for IE of a Mexican's PES (the PSA-H). In their analysis, the authors used rejected applicants as a counterfactual for PSA-H beneficiaries during the first year of implementation. In 2003, too many *ejidos* applied for the scheme in comparison of its budget and applications got rejected only because the program lacked of funding. In the context of PES, one of the main unobservable confounding factor is the willingness to participate in the program. The pool of rejected applicants proved willingness to participate so they constitute a relevant counterfactual. Once restricted their sample to rejected applicants for lack of funds, [Alix-Garcia et al. \(2012\)](#) preprocess the data using [Abadie and Imbens \(2006\)](#) bias-adjusted matching in order to select the most similar control group regarding observable characteristics. Once selected their control group, they use a Tobit model ⁴ to estimate the impact of PSA-H. They find a small but significant impact of the program on avoided deforestation. Pre-matching has also been used by [Ferraro et al. \(2011\)](#) to evaluate the efficiency of protected area in Costa Rica and Thailand.

3.2.5.2 Propensity Score Weighting

Propensity Score Weighting uses propensity scores as sample weights in a regression framework. PSW allows us to balance covariates between treated and non-treated observations. It is implemented as follows ([Hirano and Imbens, 2001](#); [Lunceford and Davidian, 2004](#); [Austin, 2011](#)):

1. Estimate propensity scores using a probit or a logit model
2. Generate sample weight using predicted propensity scores
3. Estimate the model using Weighted Least Squares (WLS)

PSW has mainly been applied with a dummy variable in the second step of the estimation. In that case, [Robins et al. \(1995\)](#) showed that the estimator was doubly robust. The estimates are unbiased if either one of the two models are correctly specified. Moreover, [Hirano et al. \(2003\)](#) showed that using non parametric estimates of the propensity scores led to efficient estimation of the average treatment effect. Nevertheless, as emphasized by [Wooldridge \(2002\)](#), it is difficult to estimate the

⁴The measure of deforestation used by the author is censored: it is the reason why they use a Tobit model. Note that more details about the methodology can be found in the working paper version: [Alix-Garcia et al. \(2010\)](#)

asymptotic variance of the estimates using this method and little is probably lost using a logit or a probit model.

In a first step, one must estimate the propensity score

$$pscore_{ij} = Pr(D_i = 1) = \theta + \phi W_i + \mu_i \quad (3.37)$$

In a second step, one can estimate the ATT using WLS. Sample weights are equals to:

$$w_{ij} = \begin{cases} pscore_{ij}/(1 - pscore_{ij}) & if\ psa_{ij} = 0 \\ 1 & if\ psa_{ij} = 1 \end{cases} \quad (3.38)$$

The covariates W_i included in the estimation of the propensity scores do not have to be the same as X_i included in equation 3.29.

3.3 Evaluating PES as a continuous variable

So far, most IE used a dummy variable for PES reception. As highlighted by [Miteva et al. \(2012\)](#), reception of the PES may also be analysed as a continuous variable. Exposure to the treatment varies according to the share of forest enrolled or the number of years of reception. In this section, we suggest methodologies that could be applied with a continuous treatment.

3.3.1 Generalised propensity scores

Generalised propensity scores (GPS) is a generalisation of propensity score methods to continuous treatment developed by [Hirano and Imbens \(2004\)](#). It relies on the same assumptions as the one exposed in Section 3.2.1.1 regarding SUTVA and confounding factors. Let us consider the conditional density of a continuous treatment variable T_i given covariates X_i : $r(t_i, x_i)$.

Remember that PSM compares observations with similar probability to receive the treatment. By analogy, the GPS compares observations with similar value of $r(t, x)$. As explained by [Hirano and Imbens \(2004\)](#), GPS has “balancing property similar to that of the standard propensity score. Within the same strata of $r(t_i, x_i)$ the probability that $T = t_i$ does not depend on the value of X_i .

The objectives of GPS is to estimate an average-dose-response function defined as:

$$E[Y(t)] \quad (3.39)$$

GPS are implemented in three steps. First, one must estimate the conditional distribution of the treatment given the covariates $r(t_i, x_i)$. Using this estimated conditional distribution, it is possible to compute an estimated generalised propensity score \hat{R}_i .

Second, one can estimate the expectation of outcome variable Y_i conditionally on R_i for each observation. [Hirano and Imbens \(2004\)](#) recommends using a quadratic form:

$$E(Y_i|T_i, \hat{R}_i) = \alpha_0 + \alpha_1 T_i + \alpha_2 T_i^2 + \alpha_3 \hat{R}_i + \alpha_4 \hat{R}_i^2 + \alpha_5 T_i \hat{R}_i \quad (3.40)$$

Finally, the average expected outcome of treatment, the equation 3.41, is computed as the average value of 3.40:

$$\hat{E}[Y(t)] = \frac{1}{N} \sum_{i=1}^N (\hat{\alpha}_0 + \hat{\alpha}_1 t_i + \hat{\alpha}_2 t_i^2 + \hat{\alpha}_3 \hat{r}(t_i, X_i) + \hat{\alpha}_4 \hat{r}(t_i, X_i)^2 + \hat{\alpha}_5 t_i \hat{r}(t_i, X_i)) \quad (3.41)$$

The method has been applied to the Costa-rican PES by [Arriagada \(2008\)](#). The author considers the percentage of area under protection for each landowner. He estimates the average-dose response function following the procedure presented here but does not find a significant impact of the program on the whole distribution. Nevertheless, by plotting the dose-response function, he identifies a threshold in program impact. [Arriagada \(2008\)](#) finds that the program impact is increasing until a certain point (20% of census tract under protection) and later decreasing.

Balancing tests of PSM usually consist in difference-in means tests between treated and control group. With continuous treatment, one can not implement these types of tests. [Arriagada \(2008\)](#) divided his sample in quintile of GPS distribution and tests the difference in means between groups for each covariate.

3.3.2 Two stages least squares

Let us consider the estimation of the following model with Y_i the deforestation rate in village i , T_i the amount of payments received for PES scheme⁵ and X_i a vector of control variable.

$$Y_i = \alpha + \beta T_i + \gamma X_i + \varepsilon_i \quad (3.42)$$

For the reasons explained in Section 3.2.4, a selection bias generates endogeneity in the estimation. Nevertheless, with a continuous treatment, the reasons for which endogeneity may arise are slightly different. One is not only concerned about endogeneity of treatment reception, but also about the exposure to the treatment. If treatment exposure is defined as the amount received or the time spent in the program, inverse causality means that deforestation rates are not only influencing reception of scheme but also the amount of paiement or the order of entry into the program.

Two-stages least square (TSLS) proposes to correct for endogeneity using instrumental variables. One must first predict T_i by estimating equation 3.43:

$$T_i = \theta + \phi Z_i + \sigma X_i + \mu_i \quad (3.43)$$

and introduce it into the model as a second stage:

$$Y_i = \alpha + \beta \hat{T}_i + \gamma X_i + \varepsilon_i \quad (3.44)$$

⁵ T_i can also be defined as the time spent in the program or the number of hectare under protection. See Section 3.4 for more discussions about the definition of the treatment

To be valid, instruments Z_i must be strong predictors of the treatment T_i and not have direct impact on the outcome variable Y_i . In econometric terms, Z_i must valid the exclusion restriction:

1. Be correlated with the treatment variable: $cor(Z_i, T_i) \neq 0$
2. Be uncorrelated with the error term : $cor(\varepsilon_i, T_i) = 0$

Three main tests are usually implemented following TSLS. First, one must perform an F-test of joint significance of instruments Z_i after estimating equation 3.43. Following the results obtained by [Staiger and Stock \(1994\)](#), a common rule of thumb is to consider that if the value of the F-test is inferior to 10, the instruments must be considered as weak and are not good predictors of T_i ([Araujo et al., 2004](#); [Cameron and Trivedi, 2005](#)).

A second test is the [Sargan \(1988\)](#)'s overidentification test. This test checks the validity of the exclusion restriction ie that Z_i is uncorrelated with ε_i . It can only be implemented if the model is overidentified ie if the number of instrumental variables Z_i is superior to the number of endogeneous variable T_i . From equation 3.44, one can predict $\hat{\varepsilon}_i$ and estimate the following regression using OLS:

$$\hat{\varepsilon}_i = \phi_2 Z_i + \sigma_2 X_i + \varsigma_i \quad (3.45)$$

In the null hypothesis, the instruments are valid and the explanatory power of this regression is null. Sargan's test is a χ^2 and test's statistics is $S = N.R$, N being the size of the sample, and R , the R^2 of the test equation.

The last test is the Dubin, Wu and Haussman test in the version proposed by [Nakamura and Nakamura \(1981\)](#). It checks for exogeneity of variables T_i and is only valid if the instruments validates the exclusion restriction. If T_i is exogenous, it is more appropriate to estimate the model using OLS. If T_i is endogenous, there is a correlation between μ_i and ε_i . From equation 3.44, it is possible to predict $\hat{\mu}_i$ and estimate the following equation:

$$Y_i = \alpha + \beta T_i + \gamma X_i + \rho \hat{\mu}_i + \varepsilon_i \quad (3.46)$$

The test is a Student-ratio test on coefficient ρ and in the null hypothesis $\rho = 0$. If the null hypothesis can not be rejected, T_i can be considered as exogenous. In this case, OLS are convergent with minimal variance and it is recommended to use this estimator ([Araujo et al., 2004](#)).

This methodology has been used by [Sims \(2010\)](#) to evaluate the impact of protected areas on poverty reduction in Thailand. The author investigates the impact of protection on average consumption and poverty rates at locality level. The protection is instrumented using the positions of the localities regarding the majors tributary rivers. Historically, one of the objectives of protected area in Thailand was to protect upper watersheds of the rivers flowing into the major cities in order to increase water quality. Therefore, position of the localities nearby these rivers influences the share of land protected but is not supposed to directly impact poverty. The author finds a positive and significant impact of protected area on poverty which they attribute mainly to the development of tourism in these regions.

3.3.3 Introducing spatial dimension

Geographical characteristics matter a lot for IE of conservation instruments and it is crucial to consider spatial interactions between observations. Non-spatial estimations rely on the assumption that observations are independent (Le Gallo, 2002) but if they are not independent, the SUTVA does not hold.

Let us define neighbors using a matrix of contingency ω_{ij} that takes a value different of zero if i and j are considered as neighbours. Contingency can be defined in various ways such as:

- Neighbourhood: $\omega_{ij} = 1$ if i and j share a common border or are located within a certain distance
- K-nearest neighbour: $\omega_{ij} = 1$ if j is one of the k-nearest neighbour of i
- Distance: ω_{ij} equals the distance between i and j . The distance can be computed from the centroid of the polygons, the border, etc... One can impose a maximal distance above which $\omega_{ij} = 0$ or choose a specific functional form such as the inverse of the distance
- Length of common borders

It can be relevant to standardize ω_{ij} i.e. to divide the weights by $\sum_j \omega_{ij}$. Hence, the weights range from 0 and 1 for each observation and capture the relative distance from i to each neighbour j .

Let us consider the estimation of the simple model presented in equation 3.42 in the context of PES. Spatial correlation could arise for three reasons (Le Gallo, 2002):

1. The deforestation rate of surrounding villages j influences the deforestation rate in village i :

$$Y_i = \alpha + \beta T_i + \gamma X_i + \rho \sum_{j \neq i} \omega_{ij} Y_j + \varepsilon_i \quad (3.47)$$

The endogenous variable is said spatially lagged. If one does not consider the inclusion of a spatially lagged-variable, the coefficients estimated are biased and estimations are inefficient. This type of model can be estimated using instrumental variables or maximum-likelihood. More details can be found in LeSage and Pace (2009).

2. The reception of PES in surrounding villages j influences the deforestation rate in village i :

$$Y_i = \alpha + \beta T_i + \rho \sum_{j \neq i} \omega_{ij} T_j + \gamma X_i + \varepsilon_i \quad (3.48)$$

The exogenous variable is spatially-lagged. In that case, not including the spatially lagged variable can be more or less problematic:

- If the spatially lagged variable influences conjointly D_i and Y_i , omitting this variable generates endogeneity: the estimations are biased and inefficient. This

is the case when leakage occurs. Including the spatially-lagged exogenous variable corrects for endogeneity.

- If the spatially lagged variable influences only Y_i and do not have indirect impact through D_i , omitting this variable do not bias the coefficient but the estimations remains inefficient. Moreover, if the estimation of β is unbiased, it only captures the impact of the program reception on Y_i but does not capture the fact that reception of the program in neighbouring areas may also impact Y_i . The total impact of the program is composed of both effects and not including the neighbouring observations leads to partial estimates of the impact.
3. Error terms are spatially correlated such as:

$$\varepsilon_i = \phi \sum_{j \neq i} \omega_{ij} \varepsilon_j + \mu_i \quad (3.49)$$

Autocorrelation between error-term can arise because there are spatially auto-correlated variables, observable or unobservable, that are not included in the model or because shocks are spatially correlated. From this statement, it is straightforward that omitting an exogeneous or an endogeneous variable will automatically generate spatial correlation between error terms. An autoregressive process on the error term is usually specified to account for spatial autocorrelation.

3.4 Methodological challenges and knowledge gaps

This chapter proposed a summary of the different techniques available for IE based on existing literature. Nevertheless, if many authors emphasized the need for more empirical evidence regarding conservation instruments, the relevancy of these methodologies in the context of environmental policies, and especially PES, has been poorly discussed⁶.

Enrollment into a PES is voluntary which generates a well-known selection bias in the with/without type methodologies. Dealing with the selection bias is basically the rationale underlying IE methodologies (Ravallion, 2007). But, if for many reasons, a great number of PES can be analyzed as a *green* CCT (Martin Persson and Alpizar, 2012) new questions arise concerning the design of an IE. IE techniques have been widely used to study social programs or microfinance for instance. But with PES for forest conservation, the impact is not found within households or communities anymore but on the forest cover. The result is that the spatial and temporal boundaries of an IE within which it should be evaluated, and how to estimate the impact, are unclear. Standard IE methods can consequently not be applied directly without adjustment. Moreover, relevant issues that have been explored for other CCT have not been given enough attention in the context of PES.

⁶A version of this section has been adapted as a working paper co-authored with Céline Dutilly

The purpose of this last section is to review possible methodological trade-offs when designing an evaluation of the impact of a PES on forest cover. We focus on PES for forest conservation but some of the analysis can be extended to asset-building or practice-based PES. By analogy with the literature on CCT, the landowners who enroll land in a PES program are referred to as the beneficiaries of the program and the term treatment refers the PES reception. The aim of the IE is to evaluate the additionality of the program, i.e. avoided deforestation that can be attributed to the PES program.

In this section, we track the design of an IE starting with the choice of the sample of beneficiaries and non-beneficiaries to the interpretation of the results, and discuss the different trade-offs involved. Our aim is not to identify the best IE practices, but to propose guidelines, discuss methodological choices, and identify knowledge gaps. First, we discuss the boundaries of an IE and the choice of geographic scale, the unit of observations, and the timeframe of the evaluation as important aspects to frame PES evaluation. After which, we discuss impact estimation and more specifically, the definition of treatment, the assumption of the estimators, including widely-used matching estimators, the choice of a control group, and impact heterogeneity.

3.4.1 Setting boundaries

3.4.1.1 Geographical scale

The first step in designing an IE is choosing the geographic scale. Should all the beneficiaries of a PES be included in the sample or should the focus be on a more homogeneous sub-area? Is it important that the area concerned is contiguous?

One group of studies uses an exhaustive or a representative sample of all PES contracts. Geographic boundaries are the same for the PES and the IE. Examples are [Alix-Garcia et al. \(2012\)](#) and [Robalino and Pfaff \(2013\)](#), who studied the impact of a national PES using a sample of beneficiaries and non beneficiaries respectively in Mexico and Costa Rica. Other studies set boundaries by focusing on a specific zone at regional or sub-regional level. [Honey-roses et al. \(2011\)](#) and [Costedoat et al. \(2015\)](#) also studied the impact of national PES⁷ but at the regional level in different states in Mexico. [Arriagada et al. \(2012\)](#) evaluated a national PES in the Sarapiquí region of Costa Rica. All these authors used similar procedures to select a control group but the validity of the results and the assumption of the estimators were not the same.

Compared to many economic instruments, one characteristic of conservation instruments is that their expected impact is highly location-specific. Geographic characteristics matter because they are impact moderators ([Ferraro et al., 2013](#)) and the impact differs from one region to another. Second, geographic characteristics are crucial confounding factors that influence not only deforestation but program reception. The main characteristics of the OC including soil fertility, land tenure, slope and other agro-ecological characteristics, are location-specific. Some of these

⁷Among other programs for [Honey-roses et al. \(2011\)](#)

factors are observable, others are not which could bias the estimations.

Unobservables are more likely to be well balanced in regional studies, but obviously the validity of the results will remain limited to the sample used for the estimation and cannot be extrapolated to other regions. For these reasons, they can only be considered as case studies. But one crucial advantage of dealing with smaller area is that it might be possible to have a geographically contiguous sample. Dealing with a contiguous zone makes it possible to model spatial interactions, especially leakages, using tools provided by spatial econometrics (LeSage and Pace, 2009).

Conversely, national-scale analyses estimate the impact of the program on a representative sample. If they are well designed and if the assumption of the estimators hold, they have strong and large internal validity. The results can be extrapolated to the whole population therefore making them more relevant for decision-making. However, the average treatment effects give us only limited information about the impact of a PES and it is crucial to investigate heterogeneity.

3.4.1.2 Unit of observation

The second choice concerns the unit of observation. PES evaluation relies to a great extent on remote sensing analysis but the question is, which pixel aggregation is a relevant unit of observation? Should the analysis be at landowner level? Should one pixel or a group of pixels be used? What is the optimal image resolution?

The choice of the relevant unit of observation for conservation instrument studies has already been discussed in the literature (Alix-Garcia, 2007, 2008; Andam et al., 2010). At which level should forest cover change be computed? We will differentiate three types of unit of analysis: pixel, gridding (Robalino and Pfaff, 2013; Costedoat et al., 2015) or landowners (Honey-roses et al., 2011; Arriagada et al., 2012).

Using a method based on pixels (Pfaff et al., 2009; Robalino and Pfaff, 2013) focuses on land use and makes it possible to accurately account for any geographic heterogeneity in the area under protection. It also allows multiplication of the size of the sample which is statistically very convenient. The optimal resolution depends on the ecological context, particularly on forest density, the size of the unit of observation, the magnitude of the expected land-use change and the underlying causes of deforestation. A particular resolution may be appropriate for identifying land-use changes attributed to planting soya in Brazil, but not for two hectares of maize planted by a peasant in Mexico. Moreover, some PES may reduce deforestation while others targets degradation which modify the type of satellite images needed (Blackman, 2013). In addition, although low resolution images may not enable accurate measurement of land-use changes at local level, higher resolution images can lead to misclassifications in the remote sensing analysis if not combined with ground-truthing. Small-scale degradation could be classified as deforestation or ecological modifications as reforestation. Using gridding allows these imperfections to be corrected by averaging deforestation in a given area. Note that the size of the grid should be carefully chosen as it can influence the construction of the

counterfactual and hence the results of the IE.

But, since the landowner is the decision maker, it seems more in line with theoretical work to aggregate pixels at the landowner's level to account for land tenure and governance of the resource⁸. In this case, each unit of observation corresponds to one landowner. However, this approach could fail to account for the heterogeneity of the geographic characteristics of the area. In addition, as pointed out by [Arriagada \(2008\)](#), at landowner level, one may have to deal with a mixture of forest that is protected and forest that is not. Building polygons overlapping land tenure, homogeneous land use, and PES reception, as suggested by [Honey-roses et al. \(2011\)](#) may be an appropriate intermediate solution if the size of the forest owned by each landowner is not too heterogeneous.

3.4.1.3 Timeframe

The next choice concerns the timeframe. During what period should the impact of the program be evaluated? Should the evaluation be limited to the period of the contract? What if something happened before or happens after the implementation of the program? What about contract renewal? How can a sample be selected when all the participants did not join the program at the same time?

PES are evaluated at one point in time and are usually fixed-term contracts. A source of bias in IE that remains to be explored is related to possible ex-post and ex-ante impacts of the PES. Some landowners may anticipate the arrival of the program and reduce their rate of deforestation in order to send a signal of good behavior to the authorities. A contrary hypothesis is that individuals will anticipate the future ban on converting land by cutting more trees before the ban becomes effective. Moreover, if the amount of payments is a function of a baseline, it may be tempting to increase deforestation to influence the baseline ([Pattanayak et al., 2010](#)). Land use before the program is implemented is usually considered to be exogenous but if landowners anticipate the program, this assumption cannot be validated and we face an Ashenfelter's dip ([Ashenfelter, 1978](#)) and the direction of the anticipation effect is unknown.

PES may also have lagged impacts. One hypothesis is that, if deforestation slows down during the lifetime of the program, it is only delayed and the beneficiaries will catch up after the program ends. PES could even increase deforestation if it temporarily relaxes a liquidity constraint but leads to more deforestation once the forest is no longer under protection ([Jayachandran, 2013](#)). On the contrary, PES can help finance a transition to non-degrading activities and permanently reduce deforestation ([Pirard et al., 2010](#); [Karsenty, 2011](#)). PES may thus have both positive and negative ex-ante or ex-post effects on forest cover. The direction of the bias is theoretically unknown and can also vary from one beneficiary to another.

⁸Note that the decision-maker can be a household or a community when dealing with forest in commons. In the latter case, one can suspect more unobserved heterogeneity, related to social capital for instance. It might be more difficult to find a relevant control group and data collection on motivational aspects can be heavier than for households

Another issue concerns contract renewal. To gain in flexibility and to be able to adjust PES schemes over time, contracts are usually short [Rodríguez et al. \(2011\)](#). Because PES are now well established, contracts are being renewed, a new selection process begins that has to be accounted for in the analysis. Landowners may choose to renew their contract on the same parcel, to enroll a new parcel or choose to leave the scheme. This decision will determine the long-term impact of the PES. Analyzing the sequence of renewal and abandon of a PES scheme can help understand a landowner's motivation for joining, along with potential crowding-in and crowding-out effects ([Rode et al., 2014](#)).

The existence of these effects leads us to question the timeframe of the IE. PES should intuitively be evaluated over the period of the contract. But in this case, anticipated effects and lagged impacts are not accounted for and the estimates are consequently partial. On the other hand, if the impacts are evaluated over a longer period⁹, it may be impossible to disentangle the different effects. Every year, new cohorts of beneficiaries enter the program while the contracts of older cohorts come to an end. At a given point in time, a sample of beneficiaries is inevitably composed of beneficiaries who belonged to the program during the period of analysis, plus early beneficiaries who are no longer in the program, and late beneficiaries who were not in the program at the beginning of the analysis. If yearly panel data about the forest cover are not available, the impact identified is a mixture of treatment, and of anticipated and lagged effects. Both [Alix-Garcia et al. \(2012\)](#) in Mexico, and [Robalino and Pfaff \(2013\)](#) in Costa Rica, used a sample of early beneficiaries but, as the former pointed out this sample might not be representative of all beneficiaries. Early beneficiaries may have the closest relations with the authorities or have stronger intrinsic motivation for conservation. One possible way of dealing with this problem is to exclude contracts that have not been renewed ([Arriagada et al., 2012](#)) but this implies focusing on a sub-sample. Running robustness tests on sub-samples that include and exclude beneficiaries who leave the program would also be interesting. If one wants to include the lagged impacts of the program, the period of analysis needs to be extended and separate analysis would be required to analyze what happens after the PES contract. In any case, the actual duration of the program with respect to the period of time analyzed matters and is probably a variable that should be considered in the empirical analysis.

3.4.2 Estimation

3.4.2.1 Treatment definition

Given the boundaries of the study, an appropriate treatment definition is required. Is PES reception systematically a dummy variable? If not, how should heterogeneous exposure be accounted for in the analysis? What are the possible definitions for continuous treatments?

⁹Note that in the context of carbon PES, the forest needs to be maintained for many decades in order to sequester carbon. So, even though it is not practically speaking feasible, the appropriate timeframe for an IE would be over a century.

According to recent literature on IE, PES programs are usually modeled using a dummy variable. The protection is binomial and using a dummy variable appears to be reasonably straightforward at least when pixels are used. With other units of observation, protection may be heterogeneous if the entire forest is not covered by the program. Moreover, as exposure to the treatment becomes heterogeneous with respect to the time spent in the program, the payments received and the area protected, protection is no longer binomial

Continuous treatments can be defined in different ways. When dealing with commons or collective forests like in Mexico, defining payments is even more complicated since the amount received by one landowner depends not only on the number of hectares enrolled, but also on the number of people who share the commons, along with the allocation rules applied by the community concerned (Corbera et al., 2007; García-Amado et al., 2011). Recent literature (Alix-Garcia et al., 2012; Jayachandran, 2013) pointed out that credit constraints could influence the impact of PES. Note that, despite the fact that the impact of the payments and the impact of conditionality cannot be disentangled in a voluntary scheme¹⁰, the definition of the treatment implicitly focuses on either the payment or on the conditionality.

Choosing a continuous treatment also changes the way of dealing with endogeneity. The concern here is not only the date of entry into the program but also the percentage of land enrolled in the program or the order of entry as the characteristics of the landowners enrolled may change over time (Rolon et al., 2011; Sims et al., 2014).

3.4.2.2 Estimator and assumption

The definition of the treatment affects the choice of an estimator and its underlying assumption. Which is the best estimator? What are the strengths and weaknesses of different estimators? What is a relevant control group?

Most estimators, including widely-used matching methods, rely on three main assumptions: Stable Unit Treatment Value (SUTVA), the absence of Ashenfelter's dip, and unconfoundedness. We already discussed the absence of an Ashenfelter's dip, stating that the program has no anticipation effects in the previous section, here we focus on SUTVA and confounding factors.

SUTVA states that the program has no diffusion effects, i.e. that the outcome of an individual is only influenced by his own status regarding PES. If SUTVA is validated, deforestation by one individual is not affected by the fact that other individuals belong or not to the program. Therefore, validating SUTVA automatically requires a hypothesis concerning the leakage effects of the program. Considerable attention has been paid to leakages in the academic literature on PES (Wu, 2000; Wunder, 2008). What are the implications of leakage for impact identification? If leakages occur within observations of the sample, SUTVA does not hold and the

¹⁰Landowners choose to enroll land in exchange for payments. Without payment, they would not enroll their land in the scheme, so it is difficult to dissociate the impact of the conditionality from the impact of the payment.

impact of the program cannot be identified. A solution to this problem is to remove the buffer zone from the control group (Honey-roses et al., 2011). Under the assumption that no secondary leakages occurred due to market equilibrium effects, removing the buffer zone makes it possible to correctly identify the impact. Nevertheless, it only captures the impact of the program on conserved land, while total estimates of additionality should also include leakages. Focusing only on protected land may overestimate the impact because leakages can reduce this additionality (Pattanayak et al., 2010; Miteva et al., 2012). Moreover, as emphasized in Section 3.1.2, the IE can be biased as a result of behavioral changes through crowding-in or crowding-out effects (Rode et al., 2014).

Turning now to confounding factors, it should be remembered that matching methods do not control for unobservables. It is important to control for spatially-lagged variables in the covariates (Honey-roses et al., 2011; Costedoat et al., 2015). These variables are crucial confounding factors. Past deforestation trends should also be included in the model, either as control variables or, if panel data are available, more explicitly through panel estimation or synthetic control matching. Miteva et al. (2012) pointed out that, up to now, few authors have used instrumental variable methods, such as control functions (Heckman and Navarro-Lozano, 2004) or two-stage least squares, for IE of conservation instruments. Sims (2010) evaluation of the impact of natural protected areas on poverty in Thailand is a notable exception. The lack of use of these estimators is probably due to the difficulty in finding relevant exogenous instruments that comply with the exclusion restriction. Unlike matching methods, these methods introduce a control on unobservable confounding factors. However, it is important to note that these estimators identify a LATE. The validity of the LATE is limited to observations where the instruments influence the reception of the program. The question of the relevancy of LATE for policy recommendations led to a lively debate among academics (Deaton, 2009; Imbens, 2009; Heckman and Urzua, 2010).

The choice between the different matching estimators have already been discussed (Zhao, 2004; Caliendo and Kopeinig, 2008). With continuous treatment, Generalised Propensity Score estimator (Hirano and Imbens, 2004) can be used as done by Arriagada (2008). Note that genetic matching methods (Diamond and Sekhon, 2013) used by Canavire-Bacarreza and Hanauer (2013) with Bolivian protected areas has not been yet applied in the context of PES. Matching can also be combined with DID as done by Chabé-Ferret and Subervie (2013) to control for time unvarying unobservable. Balancing tests and details about the common support should be provided to assess the quality of the matching. It is also useful to perform the bounds test proposed by Rosenbaum (2002) to check for the sensitivity of the results to unobservable confounding factors (Andam et al., 2008; Arriagada et al., 2012).

It should not be forgotten that matching can be used to select a sample of observations but it cannot be used to identify pairs of observations. For instance, if a PES is assigned to three landowners, identifying three control landowners through matching will not balance covariates between the two groups and it will not be pos-

sible to identify the impact of the program. Matching balances covariates between a group of beneficiaries and a group of non-beneficiaries. If both groups are large enough, matching methods can weight the observations in the control group to build a counterfactual that is statistically similar to the treatment group. The difference between individual pairs of observations cannot be interpreted independently of the rest of the distribution. Moreover, since the intervention is at village level, most of the confounding factors are measured at village level and investigating many households in only a few villages will not solve this issue.

3.4.2.3 Control group

Many observable and unobservable variables can impact deforestation so the choice of the control group is crucial to balance confounding factors (Ferraro, 2009). Among many other examples, [Alix-Garcia et al. \(2012\)](#) used applicants who were rejected from a PES program due to insufficient funding to control for willingness to join the program, while [Arriagada et al. \(2012\)](#) used landowners located in a buffer zone around areas under PES contracts. There can be no pre-defined rule for the choice of a control group, as it relies on a good knowledge of the allocation mechanism over time and space. In the case of national PES, understanding allocation often goes beyond studying the official allocation rules. During the decentralisation process, many actors have a stake in the allocation process and the same program may be interpreted and allocated differently in different regions or states. The choice of the control group should be based on a deep understanding of the entire process and should exclude landowners who are structurally too different from the beneficiaries and unlikely to be accepted into the program. Pre-matching methods may be useful to select the sample, but it should not be forgotten that pre-matching does not control for the unobservable ([Alix-Garcia et al., 2012](#)).

If finding an appropriate control group is impossible, studying exposure heterogeneity may be the only relevant issue. Let us consider a watershed where all the landowners are expected to be accepted for the program. The only landowners who are not in the PES program are likely to be structurally different from the others and will thus not constitute a control group. Looking for a hypothetical control group inside or outside this watershed is bound to fail as important confounding unobservable factors will not be taken into consideration.

3.4.2.4 Impact heterogeneity

Finally, we discuss the interpretation of the impact. Is the average effect an appropriate estimate for decision making? How can studying impact heterogeneity help decision making? What are the possible impact moderators?

A moderate impact does not necessarily mean no impact at all. The impact might even be positive for some beneficiaries and negative for others. For this reason, it is important to investigate impact heterogeneity and, "go beyond average treatment effects" ([Ferraro and Miranda, 2013](#)). As explained above, the impacts

of PES programs are location-specific and it is indispensable to investigate heterogeneity and try to understand the transmission channel. Moreover, as highlighted by Vincent (2015), environmental benefits can vary from one area to another but costs of implementation can also be heterogeneous so the higher impact will not automatically be found where intervention is the most effective in term of cost-benefit analysis.

Many authors have already studied impact heterogeneity in protected areas (Pfaff et al., 2009; Sims, 2010; Ferraro et al., 2011, 2013) but few have investigated this issue in the context of PES. So far, impact heterogeneity has mainly been explored over time (Pfaff et al., 2008; Robalino et al., 2008), according to transaction costs or infrastructure (Pfaff et al., 2009) or according to a poverty index and geographic area (Alix-Garcia et al., 2012). Other important moderators have received little attention so far, including those related to the economic activity of the landowner. "PES do not operate in a vacuum" (Corbera et al., 2009): other institutional factors matter in determining its efficiency. PES often interacts with other policy instruments, such as regulatory environment or other subsidies (Ferraro, 2011), which modify the incentive structure. Agricultural subsidies or anti-poverty CCT may have perverse effects on the forest cover (Schmook and Vance, 2009; Alix-Garcia et al., 2013). Another worthwhile investigation of the impact heterogeneity of PES would be to examine the policy-mix defined as the different instruments in place that interact in a given landscape (Barton et al., 2009).

3.4.3 Concluding remarks

In this last section, we explored the challenges that arise when trying to assess the impact of PES schemes on forest cover using experimental or quasi-experimental designs. Seven main recommendations can be derived from this section.

1. Both impact and confounding factors are location-specific, the design of the IE should take this into account while choosing geographic boundaries and the scale of the unit of observation.
2. Knowledge of land tenure and resources governance play a crucial role in the choice of a unit of observation.
3. There is no ideal timeframe for an IE, but ex-post and ex-ante effects of PES schemes should not be forgotten.
4. Modeling PES reception using dummy variables should not be systematic as exposure to the treatment may vary from one beneficiary to another.
5. Other estimators than matching methods can be implemented for PES IE and attention should be paid to the assumptions of the estimator, especially if leakages are likely to occur.
6. When choosing the control group, attention should be paid not only to the official allocation rules but also to the behavior of all the agents involved in

the allocation process and the motivations of the forest owners in enrolling in the program.

7. The ATE has limited implications and impact heterogeneity should be investigated.

Although the main focus of this section was on the methodological challenges that arise when assessing additionality, other dimensions than additionality matter for PES evaluation. The impact of conservation instruments on poverty reduction is the subject of wide debate in the literature (Grieg-Gran et al., 2005; Pagiola et al., 2005; Zilberman et al., 2008, 2009). Important studies have examined the impact of protected areas or PES on poverty in Costa Rica and Thailand using matching methods and/or instrumental variables (Andam et al., 2010; Robalino and Villalobos-Fiatt, 2010; Sims, 2010; Ferraro et al., 2011) but this question nevertheless deserves more attention. By focusing too much on short-term additionality, the other impacts of PES can easily be overlooked. Placing IE in a broader environmental and social evaluation framework is therefore crucial to identify alternative theories of change initiated by PES programs (Mickwitz and Birnbaum, 2009). More investigation outside the forest is needed to understand the long-term impact of PES schemes. Understanding the impact of PES on governance and social capital is also crucial in the long run. Behavioral aspects related to fairness or motivational effects also deserve more attention. And since most of the schemes offer only short-term contracts, examining the impact on agricultural production strategies, off-farm work and migration is essential to identify possible perverse lagged effects.

Evaluating PES impact and leakages in Yucatan: A spatial approach

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A version of this Chapter has been adapted as a working paper co-authored with Alexandre Sauquet and Sergio Cortina for future publication.

4.1 Introduction

A large debate surrounds PES efficiency and the way payments should be allocated in order to achieve a sustainable decrease in deforestation (Engel et al., 2008; Muradian et al., 2013). In recent years, many authors have called for more IE of conservation instruments (Ferraro and Pattanayak, 2006; Pattanayak et al., 2010; Miteva et al., 2012). However, as highlighted by Ferraro and Pattanayak (2006) evaluating effectiveness entails more than monitoring indicators such as the number of hectares protected.

To evaluate the impact of PES, one must take into account the selection bias in the estimations. Deforestation rates are likely to be different in beneficiary and non beneficiary parcels but these differences may not be attributable to the program. Moreover, PES schemes for forest conservation are likely to generate leakages (Aukland et al., 2003; Wunder, 2008). Avoided deforestation in protected parcels may just have been displaced to other areas.

In this Chapter, we propose a new methodology to evaluate the impact of a PES scheme and apply it in the context of the PSA-H in a sub-region of Yucatan. First, we define our units of observation as land cover overlapping with land tenure and protection by the PES but we combine these with gridding. Second, we consider leakage effects in our analysis and simultaneously estimate PES impact and leakages using tools provided by spatial econometrics. Third, we consider exposure heterogeneity regarding time enrolled in the program and contract renewal. Finally, we use pre-matching to account for selection bias in the regression analysis. Our empirical analysis is based on remote sensing analysis using 20m resolution SPOT images and *ejido*-surveys carried out in all of the *ejidos* in our sample.

The following section reviews previous IE of PES schemes and leakages. Section 4.3 presents our study area and the data. In Section 4.4, we present our methodology and apply it in the Section 4.5.

4.2 Evaluating PES additionality

A growing body of empirical literature looking at PES impact has recently emerged (Alix-Garcia et al., 2012; Arriagada et al., 2012; Robalino and Pfaff, 2013, among others). This literature relies on existing IE methodologies developed in other fields of economics such as microfinance, health economics and education (Ravallion, 2007). Evaluating PES impact requires reconstituting a counterfactual in order to evaluate the additionality of the program ie the avoided deforestation on protected parcels. However it also requires taking into account leakages that may undermine the additionality. Leakages result in an increase of deforestation outside of the protected parcels. These effects, likely negative, may decrease or even offset the impact of the program.

4.2.1 Estimating avoided deforestation

Evaluating additionality requires reconstituting a counterfactual (Ferraro, 2009). A first step toward IE was the acknowledgement that before and after or with and without comparisons were biased and could not be considered as relevant estimations of the impact of an environmental program (Joppa and Pfaff, 2009, 2010). Indeed, PES program beneficiaries differ from non beneficiaries according to many characteristics. Because these characteristics also affect the groups' respective deforestation rates, comparisons between the two groups are irrelevant. In econometric terms, there are confounding factors that affect both the PES reception and deforestation itself; hence, not accounting for these confounding factors in the estimation automatically biases the estimation of avoided deforestation attributable to the PES scheme. In the context of PES programs, many confounding factors are geographic variables, including the percentage of forest cover as well as major determinants of deforestation such as population density, slope and elevation and distances to roads, cities and agricultural fields (Angelsen and Kaimowitz, 1999; Pfaff et al., 2009; Honey-roses et al., 2011). Using instrumental variables, Robalino and Pfaff (2012) also find that one landowner's decision to deforest is influenced by those of his neighbors. This result suggests that spatial interactions must be taken into account in the estimation. Moreover, beyond geographic characteristics, unobservable confounding factors also include variables affecting the deforestation rates and participants' willingness to enter a PES scheme.

Reconstituting a counterfactual for a PES beneficiary is likely to be very complex. Confounding factors are often unobservable and the control group must be very similar to the treated group in order to balance unobservable factors. IE usually chooses a control group in the same agro-ecological area as the beneficiaries (Arriagada et al., 2012, among others). A sample of non beneficiaries located in a buffer zone around the beneficiaries might appear to be an optimal control group to balance confounding factors but, as explained in Section 4.2.2 leakages should be controlled for. To control for the willingness to enroll in a PES scheme, Alix-Garcia et al. (2012), for instance, propose using as a control group applicants rejected for budget insufficiency. We also drop non applicants from our sample in order to control for the willingness to enroll in the PES scheme. If no credible control group is available, the estimates using a different area would automatically be biased and lacking in relevance. For this reason, we focus here mainly on beneficiaries and explore the heterogeneity of exposure to the program.

Most empirical analysis relies on matching methods such as PSM (Robalino and Pfaff, 2013) or covariate matching (Arriagada et al., 2012). A notable exception is the study by Alix-Garcia et al. (2012) in Mexico that used matching as a preprocess in order to select a relevant control group and estimated the impact using a Tobit model¹. In the context of protected areas, other estimators have been employed including Sims (2010) and Andam et al. (2010) who used a two stage least square

¹The data available was censored as it only included information on deforestation and none on reforestation thus justifying the use of a Tobit model.

estimator in Thailand and Costa Rica and [Canavire-Bacarreza and Hanauer \(2013\)](#) who used genetic matching in Bolivia.

PES impact studies also differ according to the choice of the unit of observation. Some authors look at deforestation in pixels while others compute deforestation by forest owners. [Honey-roses et al. \(2011\)](#) proposes building polygons by overlapping pixels of land cover, land tenure and protection by PES or natural protected areas. Following [Amin et al. \(2014\)](#), we combine this approach with gridding in order to consider heterogeneity within the polygons.

Most studies have concluded that the impact of PES on deforestation is low and attribute this finding to weak capacity of schemes to focus on threatened forest and to overcome adverse selection. However, PES impact is likely to be very heterogeneous and the ATT might be a restrictive estimate for evaluating the impact of the program. Beyond ATE, a vast area of research investigates the impact of the PES in different areas and according to different impact moderators ([Miteva et al., 2012](#); [Ferraro and Miranda, 2013](#)). We here investigate heterogeneity regarding the first year of participation in the program and the decision to renew the PES contract.

4.2.2 Estimating leakage effects

For carbon sequestration projects, leakage is defined by the International Panel on Climate Change (IPCC) as “*the indirect impact that a targeted land use, land-use change and forestry activity in a certain place at a certain time has on carbon storage at another place or time*” ([Watson et al., 2000](#)). This definition, while simple, can encompass a wide variety of mechanisms. An important distinction is made between activity-shifting and market effects² ([Wu, 2000](#); [Schwarze et al., 2002](#), among others).

As explained by [Schwarze et al. \(2002\)](#), activity-shifting is “*the displacement of an activity outside of the project’s boundaries*”. Let us consider the example of a landowner clearing forest to extract timber or to cultivate an agricultural commodity. He may shift his activities to another area following the implementation of the PES scheme. In most cases, the beneficiary of the project is the agent shifting activities but leakages can also result from the behavior of another agent. Indeed, if the beneficiary of the PES begins purchasing agricultural commodities, this may increase deforestation by his neighbors ([Aukland et al., 2003](#)). In the case of PES for conservation, this type of leakage is likely to undermine the scheme’s additionality. Leakages may even be larger than the positive effect of the PES if the scheme relaxes a credit constraint ([Jayachandran, 2013](#)).

Market effects occur if an environmental project such as a PES scheme affects the prices of commodities. If conservation decreases the supply of commodities, their price may increase which generates an incentive for additional deforestation. Among indirect leakages, this effect through prices is the most cited in the literature ([Wu, 2000](#); [Wu et al., 2001](#)) but conservation programs can have other indirect effects. For instance, let us consider a project proposing alternative livelihood options as in

²This distinction is often made in the academic literature, sometimes under different terminology (eg: primary, direct or substitution effects vs secondary, indirect or output price effects).

the ICDP, if these options are very attractive, the project may generate an influx of population and increase deforestation (Aukland et al., 2003).

The type of project (conservation, reforestation, ICDP, etc...) and the context in which it will be implemented may influence both the channel through which leakages are likely to emerge and their magnitude (Aukland et al., 2003; Wunder, 2008). On one hand, a PES scheme for conservation may increase labor supply and land demand in turn generating leakages through activity-shifting and a possible increase in timber prices. On the other hand, a reforestation PES scheme, will have an opposite effect on the labor market and may increase sustainable timber extraction instead of decreasing it. Leakages are also determined by the characteristics of the landscape such as the concentration of the forests or the agents (Delacote et al., 2015). Scale matters as leakages can be found at the micro-level but also at the international-level, for example for carbon-markets (Schwarze et al., 2002; Gan and McCarl, 2007). Output price effects should not be overlooked for large scale projects. Wu et al. (2001) showed that the magnitude of the output price effect will depend on the program targeting and the correlation between environmental benefits and land productivity. However, if capital and labor are not mobile, leakages due to market effects are very unlikely to emerge (Schwarze et al., 2002; Wunder, 2008).

As highlighted by Aukland et al. (2003), in a conservation project such as the Mexican PSA-H, leakages are very likely to occur and almost completely offset the impact of the program if no alternative livelihood options relaxing dependence on the forest cover are provided. Nevertheless, as Wunder (2008) reminds us, the existence of such an alternative does not guarantee that, over time, no leakages will occur. If an alternative activity provides high returns, one can expect a negative "rebound effect" through credit constraints which would generate more deforestation in the long-run.

Leakage effects are essential determinants of PES effectiveness. The impact of a program can be undermined or even annulled if it induces deforestation on neighboring parcels. To identify the net impact of PES, it is necessary to measure the direct and the indirect impact (leakages) of a given scheme. Moreover, if the buffer zone outside the project area is used as a control group, not accounting for leakages will automatically bias the estimations (Mas, 2005; Ewers and Rodrigues, 2008).

We distinguish two approaches in the literature that have attempted to evaluate the extent of leakages. The first approach estimates a baseline of deforestation based on a theoretical model (Geres and Michaelowa, 2002; Chomitz, 2002; Murray et al., 2004; Sohngen and Brown, 2004). The second approach uses econometrics and impact analysis tools. Our methodology derives from this second approach. In the context of Brazilian NPAs, Amin et al. (2014) use instrumental variables and a spatially interrelated cross sectional equation to take into account the fact that NPAs are not randomly created. The authors provide evidence that the decisions to deforest of neighboring municipalities are complements and that NPAs generate leakages. Using IE methodology, Alix-Garcia et al. (2012) define as treated the unprotected parcels that are in the same *ejido* as a forest protected under the PSA-H

and compare deforestation in these parcels with deforestation in rejected parcels. Honey-roses et al. (2011) compare the coefficients' magnitude of the impact of the PES with and without bordering parcels included in the control group. They infer the leakage effects in the border area from this difference. We here propose evaluating leakages using spatial econometrics tools and simultaneously estimate avoided deforestation and leakages.

4.3 Study area

As presented in Chapter 2, *ejido*-surveys were conducted in 76 *ejidos* in the *Cono Sur* which constitutes an exhaustive sample of all of the *ejidos* that were eligible for PSA-H reception in 2012. Among these *ejidos*, 40 participated in the program for at least one year in 2013. Most of the non beneficiaries are located in the northern areas and had just been eligible for a few years. Half of the non beneficiaries had already applied to the program previously. Following Alix-Garcia et al. (2012), we kept only the 22 non-beneficiary *ejidos* that had previously applied to the program to control for the willingness to join the program. Among those 22 *ejidos*, 16 entered the program in the two next years. On average, rejected applicants were accepted into the program two years after their first application. Our final sample is composed of 62 *ejidos*. Figure 4.2 displays the initial PSA-H enrollment date.

Figure 4.1 presents the evolution of eligibility zones in the *Cono Sur* between 2004 and 2012. Eligibility of an area is decided at the federal level by CONAFOR but regional offices can suggest including new areas. According to CONAFOR's regional staff, the northern area became eligible later than the southern areas because information concerning the forest cover loss in the area was not available and funds were insufficient at the federal level to cover all of the *Cono Sur*.

Remote sensing analysis was conducted using 20 meter resolution SPOT images for 1999, 2005 and 2012. This classification allows us to distinguish between forests, agricultural fields (including pasture) and roads and infrastructure. The remote sensing analysis combined various sources of information, including ground-truthing data and participatory mapping in each *ejido*.

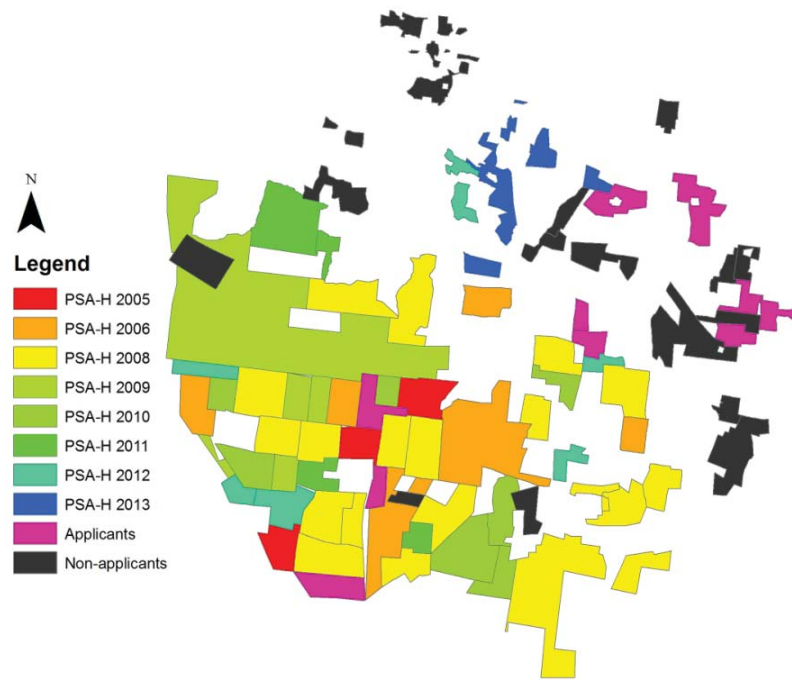
4.4 Methodology

We propose a new methodology for evaluating PES impact. First, we propose building polygons by combining gridding, land tenure and PES reception. Second, we explicitly introduce leakages in our estimation using spatial econometrics. Third, we introduce the time spent in the program and heterogeneity in the enrollment date. Fourth, we propose a regression framework and use pre-matching to account for the selection bias.

Figure 4.1: Eligibility between 2004 and 2012 in Cono Sur



Figure 4.2: PSA-H first reception



4.4.1 Combining gridding with land tenure and PES reception

In order to be able to estimate additionality and potential leakages, our unit of observation must:

1. Explicitly consider land tenure. A unit of observation must not be located in two *ejidos*.
2. Be small enough to consider heterogeneity of deforestation risk across the *ejido* but large enough to correspond to a relevant unit of decision for the *ejidatarios*.
3. Be homogeneous regarding exposure to the treatment i.e. not only PSA-H reception but also the number of years spent in the program.
4. Include only forests in 2005.

In this section, we explain how, considering the prerequisites presented above, we build our unit of observation. Our final units of observations are polygons combined with gridding.

First, we combine *ejido* borders with a gridding of 500 m in order to take into account the heterogeneity of exposure within the *ejidos*. Some polygons are more likely to be deforested than others, for example those located near the agricultural fields. We use a grid of 500 m (each cell is 25 ha). According to our data, the median size of one grassland field is around 50 ha while the median size of an agricultural fields is around 40 ha. Given these measurements, a 25 ha grid seems appropriate

to capture land-use change. Note that on average the polygons are 25 ha but may be smaller at the borders of the *ejidos*.

Second, following Honey-roses et al. (2011), we overlap the gridding of the *ejidos* with PSA-H reception. Since we want to consider heterogeneity in the number of years of reception, we need to merge the PSA-H contract using data provided by CONAFOR. Within an *ejido*, a first polygon can have been enrolled in the program in 2005 followed by a second polygon in 2010. Similarly, within an area enrolled in 2005, half of this area may have been enrolled again in a new contract five years later and another half left outside of the PSA-H. Within the *ejidos*, we do not only distinguish between PSA-H and non PSA-H land but also according to the number of years a parcel has been enrolled in the program. To take into consideration this heterogeneity, we merge PSA-H beneficiary polygons as presented in figure 4.3.

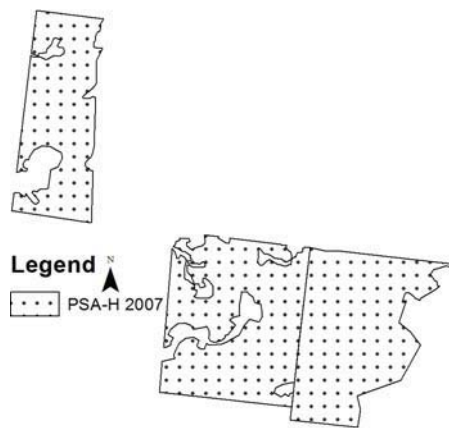
Figure 4.3 presents a zoom in an area of *Cono Sur* with an example of PSA-H polygons for years 2007, 2008 and 2012 and merged polygons. We note that the polygons do not overlap between 2007 and 2008³. In 2012, contracts made in 2007 come to an end and can be renewed. Looking at merged polygons, we can observe that the southern PSA-H areas enrolled in 2007 have not been completely renewed in 2012. In the merged PSA-H polygons, each polygon corresponds to a homogeneous area regarding the number of years of reception. Thus, a PSA-H polygon can be split into two or more parts if some of these areas have been renewed after five years and some have not. In figure 4.3, for illustration, the polygon that represents 2007 contracts located in the south east has been split into two parts: the area that has been renewed in 2012 and the area that has not.

Now that we have built polygons that are homogeneous in terms of years spent in the PSA-H program, we merge these polygons with the gridding of the *ejidos* as presented in figure 4.4. Therefore, a cell of the grid can be split in two if one area has been enrolled in the PSA-H and another has not. Similarly, the cell of the grid can be split in two if one part of it has been enrolled for eight years and another for only five years.

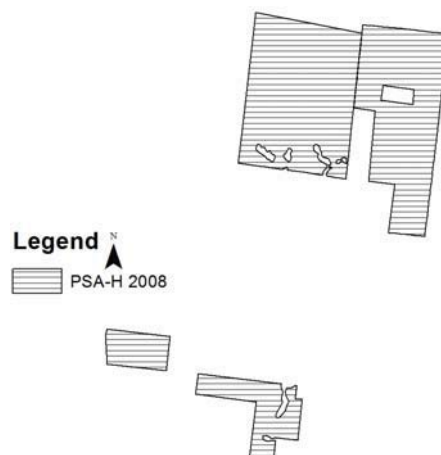
Finally, we overlap these polygons with the land cover classes from the remote sensing analysis and restrict our sample to the areas classified in 2005 as forest as shown in figure 4.5. The final polygons used as units of observations are in green in figure 4.5 and were composed only of forest in 2005. These polygons are slightly heterogeneous in size but homogeneous in terms of program status (i.e., protected or not), number of years of reception and land tenure. By overlapping forest polygons of 2005 and 2012, we can compute the percentage of forest loss within each polygon during the first years of PSA-H implementation. For each forest polygon, we also compute geographic variables such as distances to the roads and agricultural fields, elevation, slope and spatially lagged variables presented in Section 4.4.2. We complete these data with information at the *ejido*-level from the *ejido*-surveys conducted in December 2012.

³The only overlapping areas are due to small geo-referencing errors.

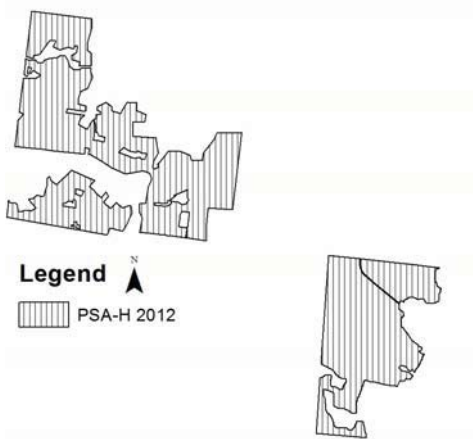
Figure 4.3: Example of PSA-H contracts



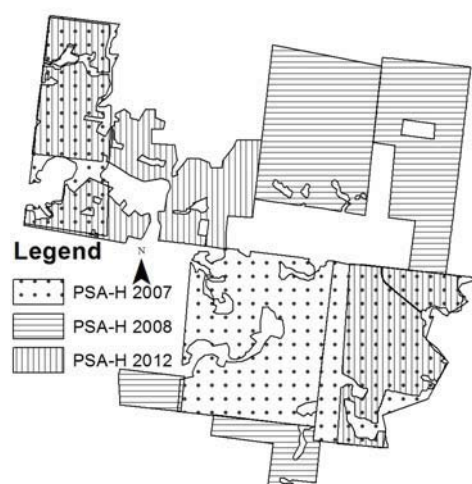
(a) Three 2007 PSA-H contracts



(b) Three 2008 PSA-H contracts



(c) Two 2012 PSA-H contracts including an area of 2007 PSA-H contracts renewed in 2012



(d) PSA-H merged between 2007, 2008 and 2012

Figure 4.4: Building homogeneous polygons

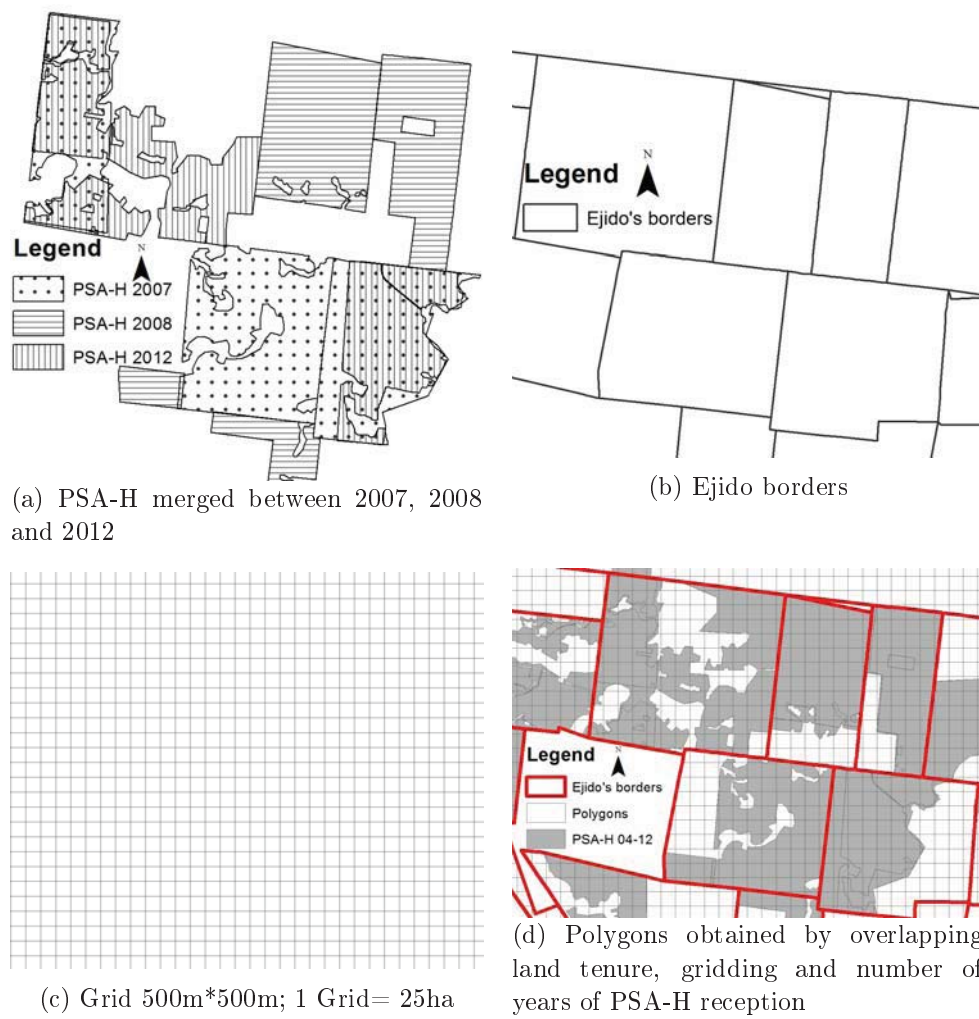
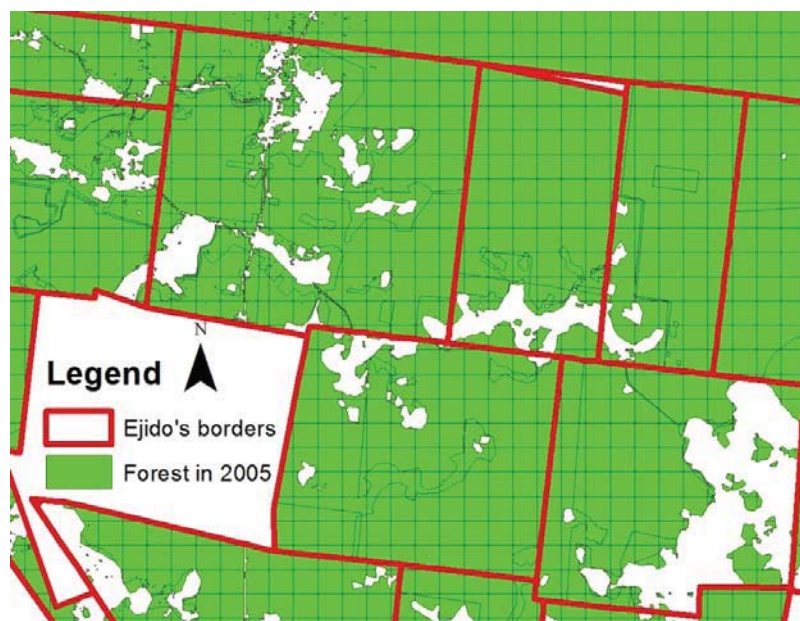


Figure 4.5: Final polygons



We drop polygons of less than 0.5 hectares since they result mainly from mis-
overlap of the original PSA-H polygons. These observations represent less than 1%
of our study area. Our final sample is composed of 10,352 polygons. There are, on
average, 170 polygons per *ejido*. In our study area, forest covered more than 174,000
hectares in 2005. Approximately 77,000 hectares have been enrolled in the PSA-H
at various points in time between 2005 and 2013. During this period, 7,900 ha of
forest have been lost, which corresponds to more than 4.7% of the total forest cover
in 2005.

To conclude, this approach allows us to have homogeneous polygons in terms
of exposure to the PES scheme. The approach also explicitly considers land tenure
when building the unit of observation. Decisions by the landowners to clear are
made in plots and not in pixels. Thus, aggregating pixels using a 25 ha grid seems
more in line with theoretical work than using pixel as units of observation. More-
over, desegregating all of the forest through gridding allows us to consider forest
heterogeneity within the *ejido*.

4.4.2 Introducing leakages

4.4.2.1 Leakages within the ejido

We start by presenting the traditional estimation of a (direct) scheme impact. The
estimated equation takes the following form:

$$def_{ij} = \alpha + \beta psa_{ij} + \tau X_{ij} + \pi X_j + \varepsilon_{ij} \quad (4.1)$$

The unit of analysis is the polygon i from *ejido* j . def_{ij} is defined as:

$$def_{ij} = \frac{(forest05_{ij} - forest12_{ij})}{forest05_{ij}} \quad (4.2)$$

Our measure of deforestation is the percentage of forest cover loss between 2005 and 2012. As explained above, our polygons are generated by overlapping gridding, PSA-H protection, land tenure and forest cover in 2005.

Our unit of analysis is defined based on the area classified as forest in 2005. Therefore, the variable def_{ij} does not capture forest regeneration but only deforestation within each forested polygon. This definition is consistent with the PSA-H's conservation objectives. Comparing forested areas under conservation with areas in regeneration may bias our results since PSA-H areas are, by definition, already entirely covered by forest.

We define psa_{ij} as a dummy variable for PSA-H reception if polygon i is protected by the program. We will introduce heterogeneity of exposure to PES treatment in the next section. The impact of the scheme is captured through the parameter β . X_{ij} and X_j are vectors of control variables at polygon and *ejido* level.

Recall that the activity shifting effect leads to leakages inside the *ejido*. Inside leakages are captured by estimating the following equation:

$$def_{ij} = \alpha + \beta psa_{ij} + \delta wpsa_j^1 + \tau X_{ij} + \pi X_j + \varepsilon_{ij} \quad (4.3)$$

with

$$wpsa_j^1 = \frac{\sum_k^K \Omega_{ikj} forest05_{kj} \cdot psa_{kj}}{\sum_k^K \Omega_{ikj} forest05_{kj}} \quad (4.4)$$

Ω_{ik} is equal to one if the polygon k is in the same *ejido* as i . Hence, $wpsa_j^1$ is the percentage of forest protected by the PSA-H program in *ejido* j . Once controlled for psa_{ij} , δ captures the leakage effects i.e. the impact of the program on unprotected land. We implicitly assume that the greater the constraint induced by the PES on the forest cover, the larger leakages effects on unprotected land will be. Note that the denominator is the amount of forest in the *ejido*:

$$forest05_j = \sum_k^K \Omega_{ikj} forest05_{kj} \quad (4.5)$$

4.4.2.2 Leakages in neighbouring ejidos

The PSA-H may also lead to leakages outside of the *ejido* either because the *ejidatarios* choose to deforest outside of their *ejido* (activity shifting) or because the *ejidatarios* want to buy more agricultural commodities from their neighbor, increasing deforestation pressure in surrounding *ejidos* (outsourcing). Outside leakages are captured by introducing a second spatially lagged exogenous variable to the estimated equation:

$$def_{ij} = \alpha + \beta psa_{ij} + \delta wpsa_j^1 + \gamma wpsa_j^2 + \tau X_{ij} + \pi X_j + \varepsilon_{ij} \quad (4.6)$$

with

$$wpsa_j^2 = \frac{\sum_{m \neq j}^M \omega_{jm} forest05_m . wpsa_m^1}{\sum_{m \neq j}^M \omega_{jm} forest05_m} \quad (4.7)$$

The new weighting factor ω_{jm} is equal to one if the *ejido* m is located in a buffer zone around *ejido* j . $forest05_m$ is the amount of forest in 2005 in *ejido* m . Hence, $wpsa_j^2$ captures the presence of the PSA-H in surrounding *ejidos* and the coefficient γ captures leakages in neighbors' *ejidos*. For this study we set the buffer at 10km around the centroid of the *ejido*.

Using this methodology, we are not able to capture market's effects (or secondary leakages) since all *ejidos* are part of the same market zone. If there is a market effect, through commodity prices, it affects all of the area making its identification impossible. Nevertheless, as highlighted by Wunder (2008), market effects are likely to emerge if markets are well-functioning, which is probably not the case in the *Cono Sur*.

4.4.3 Introducing time in the estimation

4.4.3.1 Exposure heterogeneity

We now introduce heterogeneity of exposure to the treatment regarding time spent in the program. We study the impact of the PES scheme over 8 years between 2005 and 2012. PSA-H contracts last 5 years and the time spent in the program by each observation is heterogeneous as shown in figure 4.6. For this reason in equation 4.6, we replace psa_{ij} by tps_{ij} : the time spent in the program.

$$def_{ij} = \alpha + \beta tps_{ij} + \delta wtps_{ij}^1 + \gamma wtps_{ij}^2 + \tau X_{ij} + \pi X_j + \varepsilon_{ij} \quad (4.8)$$

with

$$wtps_{ij}^1 = \frac{\sum_k^K \Omega_{ikj} forest05_{kj} . tps_{kj}}{\sum_k^K \Omega_{ikj} forest05_{kj}} \quad (4.9)$$

and

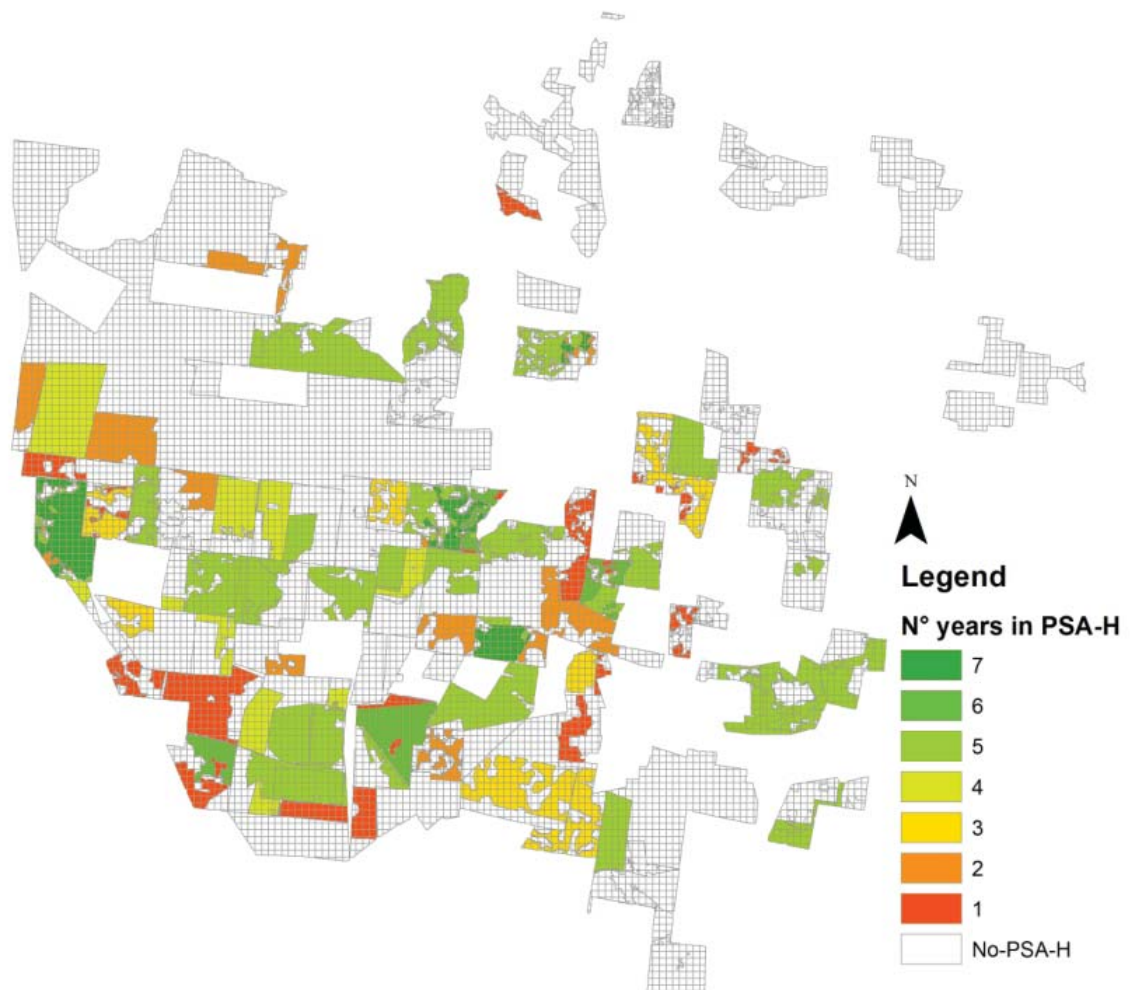
$$wtps_{ij}^2 = \frac{\sum_{m \neq j}^M \omega_{jm} forest05_m . wtps_m^1}{\sum_{j \neq m}^J \omega_{jm} forest05_m} \quad (4.10)$$

In equation 4.8, coefficient β gives the impact on deforestation of one year of enrollment in the program by polygon i . Coefficients δ and γ capture the leakages effect but the interpretation is more subtle than in equation 4.6. Coefficients δ and γ capture the impact on deforestation in polygon i of the average time spent in the PSA-H by one hectare of forest located in *ejido* j ($wtps_{ij}^1$) and in surrounding *ejidos* located in the buffer zone ($wtps_{ij}^2$).

4.4.3.2 Enrollment date

Our sample is not homogeneous in terms of the time of program entry. On the contrary it is composed of early beneficiaries that left the program after five years,

Figure 4.6: Number of years spent in the PSA-H by polygons



late beneficiaries that only participated in the program at the end of our period of analysis and beneficiaries that were enrolled in the program at the beginning and subsequently renewed. The latter were enrolled in the PSA-H for almost 8 years.

In order to disentangle the impact for these different cohorts, we split the variable $tpsa_{ij}$ into three variables: $tpsaearl_{ij}$ corresponds to the time spent by polygons that were enrolled before 2008 but whose *ejidos* did not renew the PSA-H contract. In 2013, these polygons had all been enrolled for only five years and had not been protected for two to five years. The $tpsaalw_{ij}$ variable corresponds to the time spent in the program by polygons enrolled before 2008 and whose contract had been renewed. In 2013, these polygons had been enrolled in the program for at least six years. The $tpsalate_{ij}$ variable corresponds to the time spent in the program by polygons enrolled after 2008. In 2012, these polygons had not yet completed their first contract.

We estimate the following equation:

$$\begin{aligned} def_{ij} = & \alpha + \beta_1 tpsaearl_{ij} + \beta_2 tpsaalw_{ij} + \beta_3 tpsalate_{ij} \\ & + \delta wtpsa1_j + \gamma wtpsa2_j + \tau X_{ij} + \pi X_j + \varepsilon_{ij} \end{aligned} \quad (4.11)$$

Our period of analysis is between 2005 and 2012. Nevertheless, we were able to observe contract renewal in 2013. Therefore, we choose 2008 as a threshold as the contracts made before 2008 had come to an end at least two years before 2013. This left enough time for the *ejido* to enroll the land again.

4.4.4 Identification strategy

4.4.4.1 Pre-matching: Dealing with selection

We use a regression framework to analyze the impact of the PSA-H for two reasons. First, it allows us to directly estimate leakage effects through spatially lagged variables. Second, contrary to usual IE techniques, we use a continuous treatment to take into consideration the time spent in the program.

Only 43% of the polygons in our sample receive the PSA-H. There are confounding factors impacting both deforestation and reception of the program so we must take into account the selection process in order to correct the bias. In order to be able to estimate our model using OLS, we use a matching procedure based on propensity scores to select our sample.

We estimate the following model for propensity scores:

$$pscore_{ij} = Pr(psa_{ij} = 1) = \theta + \phi Z_{ij} + \sigma Z_j + \mu \quad (4.12)$$

The probability of a polygon i receiving the PSA-H depends on the decision of the *ejido* to join the PSA-H and the choice of the *ejido* to enroll polygon i rather than another. For this reason we include variables at the *ejido* and polygon-level.

Based on the distribution of the propensity scores for treated and control groups, we restrict our sample to the common support. Moreover, for each treated observation, we keep in our sample the three nearest neighbors in terms of propensity score

with replacement. Through this process, we ensure that our control group is similar to our treated group. In order to take into account heterogeneity of propensity scores, we introduce the propensity score as a control variables in our estimation. The variable $pscore_{ij}$ is the probability that the polygons received the PSA-H conditionally on Z_{ij} and Z_j .

Given the large number of observations in our sample, one may fear that the significance of our results might be partially driven by the sample size. To avoid this caveat, we cluster our error terms by *ejidos*.

An alternative approach would be to use PSW as developed by [Robins et al. \(1995\)](#) in order to estimate the impact of the PSA-H on the forest cover. However, to our knowledge, a PSW estimator allowing clustering of the error terms has not yet been developed. Nevertheless, our results are robust to this alternative estimation.

4.4.4.2 Unobserved heterogeneity

Our results rely on two important assumptions regarding unobserved heterogeneity. First, we assume that, in our sample, there are no unobservable confounding factors affecting both the selection and the deforestation rate⁴. Regarding this unobserved heterogeneity, recall that we only kept in our sample non-beneficiaries that had already applied to the program but had not yet been approved⁵. Nevertheless, they are likely to be accepted in the forthcoming years. Non applicants represent 12,000 hectares and our sample includes 162,000 hectares of forest in 2005. The deforestation rate with the non-applicants is 4.7% and it decreases to 4% after dropping the non-applicants. This confirms our hypothesis that non-applicants have higher intrinsic motivation to deforest so they do not constitute a relevant counterfactual.

Second, we assume that once considered the selection process, there are no omitted confounding factors affecting the time spent in the program and deforestation rates. Order of entry into the program is mainly influenced by eligibility to the program. We introduce the variable $telig_{i,j}$ in our control variables at both steps of the estimation ($X_{i,j}$ and $Z_{i,j}$). This variable captures how many years polygon i has been eligible. Hence, we control for potential differences due to the evolution of PSA-H targeting.

Moreover, we include temporally lagged values of our explained variable at the *ejido*-level and in a buffer zone in order to control for unobserved heterogeneity.

⁴An approach such as control function ([Heckman and Navarro-Lozano, 2004](#)) may seem more appropriate to control for unobserved heterogeneity but it would be difficult to implement such an approach for at least three reasons. First, it would be difficult to find relevant instruments validating the exclusion restriction at the polygon-level. Second, the spatially lagged variables capturing leakages, including internal leakages should be included in the probability and it would not make sense to explain the enrollment in the PSA-H at the polygon-level by the reception at the *ejido*-level. Third, control functions have not been used thus far with a continuous explanatory variable in the second step of estimation and the properties of such an estimator are unknown

⁵Unlike [Alix-Garcia et al. \(2012\)](#), we were unable to precisely determine the reason why their application was rejected. Nevertheless, most of the applications in the area get rejected at least once for a lack of adequate administrative papers and because of budget limitations. Therefore, the *ejidos* are likely to receive the PSA-H in the forthcoming years.

The variable $lagdefejid_j$ is the deforestation rate, as computed in equation 4.2, but at *ejido* level and between 1999 and 2005. And the variable $lagbuffer_{ij}$ is the average of past deforestation in *ejido* j in a buffer zone of 1km around the frontiers of polygon i . Note that it only captures the average past deforestation in the same *ejido* as i : it is the average pressure in this area of the *ejido*. If there is adverse selection in the allocation of the PSA-H, we expect this variable to be negatively correlated with the reception of the program.

4.5 Estimation

Many control variables are included at both steps of the estimation. As explained in Section 4.4.4.2, we control for past deforestation at the *ejido*-level ($lagdefejid_{ij}$) and in a buffer zone around the polygon ($lagbuffer_{ij}$) as explained above. The polygons are heterogeneous in size so we control for the size of the forest in 2005 ($forest05_{ij}$). To control for adverse selection, we introduce various variables influencing the probability to be deforested in the future. We control for the average slope ($slope_{ij}$) and distances to the roads and agricultural fields within the *ejidos* in 2005 and to the nearest city of more than 2,500 inhabitants in km ($droad05_{ij}$, $dagri05_{ij}$ and $dcity_{ij}$). We control for the number of years of eligibility ($telig_{ij}$) and the conditional probability that the polygon received the PSA-H ($pscore_{ij}$) as explained in Section 4.4.4

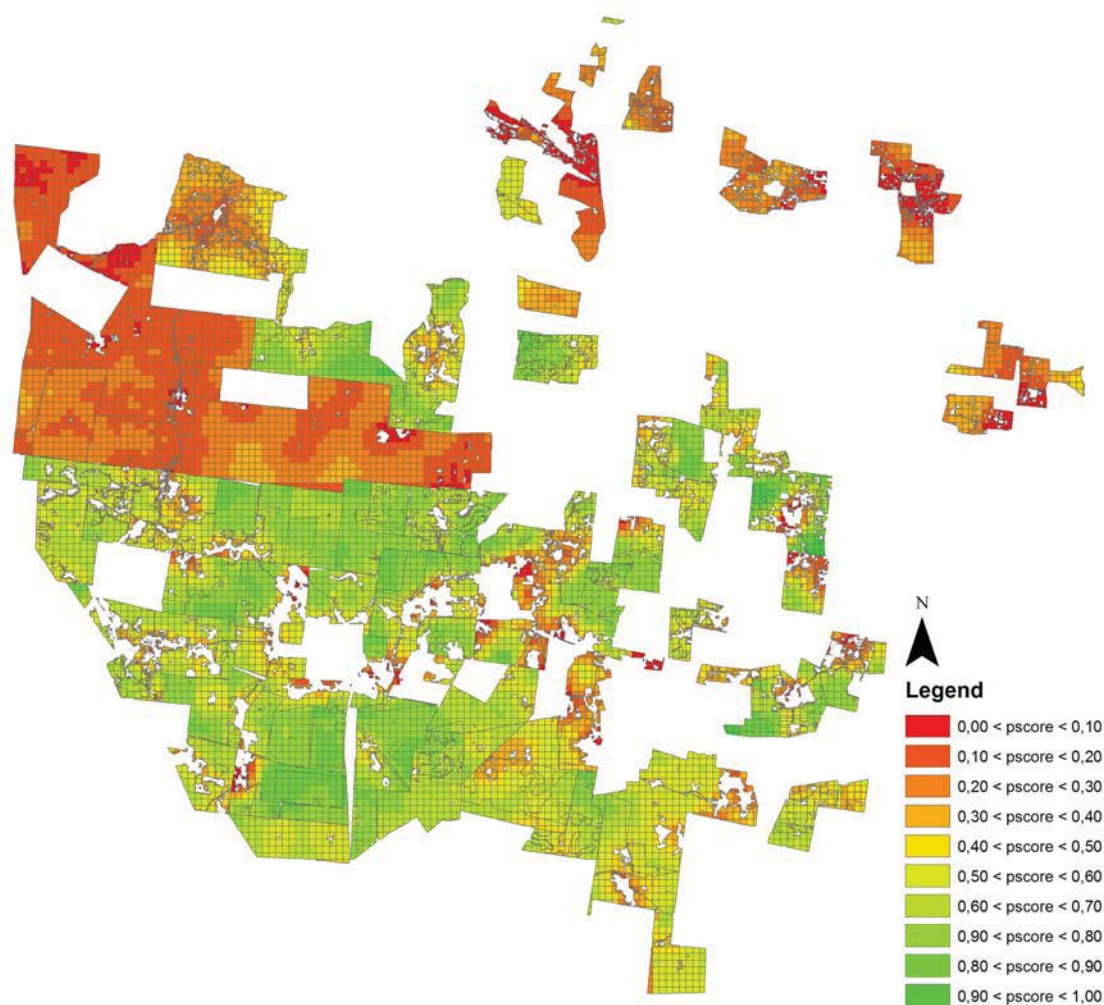
At the *ejido*-level, we control for the size of the *ejido* in thousands of hectares, percentage of forest cover and the number of *ejidatarios* per hectare ($areaejid_j$ and $ejiddens_j$). We also control for two major PSA-H selection criteria likely to influence deforestation: the marginality index computed by CONAPO in 2005 and the deforestation risk index ($defrisk_j$ and $margi05_j$) (Muñoz-Piña et al., 2008).

4.5.1 Propensity scores

Table 4.1 presents the results of the estimation of propensity scores. Column (1) includes only polygon-level variables and column (2) includes variables computed at the *ejido*-level. In order for our study to be relevant, it is crucial to be able to discriminate between polygons from the same *ejido* which have a higher probability to be accepted into the program. We note that the model presented in column (1) explains around 15% of the total variance and many covariates computed at the polygon-level remain significant in column (2).

The deforesting pressure in the area is captured by the $lagbuffer_{ij}$ variable. PSA-H polygons tend to be located in areas with a lower ex ante deforestation rate. This result illustrates the adverse selection issues in PES allocation highlighted by Ferraro (2008) and studied by Muñoz Piña et al. (2011) in the context of the PSA-H. Moreover, PSA-H polygons also tend to be located farther from agricultural land and in less densely populated *ejidos*. Both of these variables are crucial determinants of deforestation, (Angelsen and Kaimowitz, 1999) which confirms the adverse selection in the allocation of the PSA-H. The effect of the $margi05_j$ and $defrisk_j$ variables

Figure 4.7: Propensity scores



on the probability to receive the PSA-H also illustrates the difficulty of targeting *ejidos* at the micro-level using such indicator.

Estimation (2) in Table 4.1 allows us to compute propensity scores. Figure 4.7 maps the propensity scores in the *Cono Sur*. We restrict our sample to the common support and to the three nearest neighbors as proposed in Section 4.4.4 and drop 1,620 observations. Our final sample is composed of 8,732 observations. The distribution of propensity scores for PSA-H beneficiaries and non-beneficiaries once restricted to this subsample are presented in figure 4.8. We note that both distributions are highly skewed but overlap well.

4.5.2 Additionality

Table 4.2 presents the results regarding additionality estimated using OLS. Column (1) presents the results using a dummy variable. Column (2) introduces the time

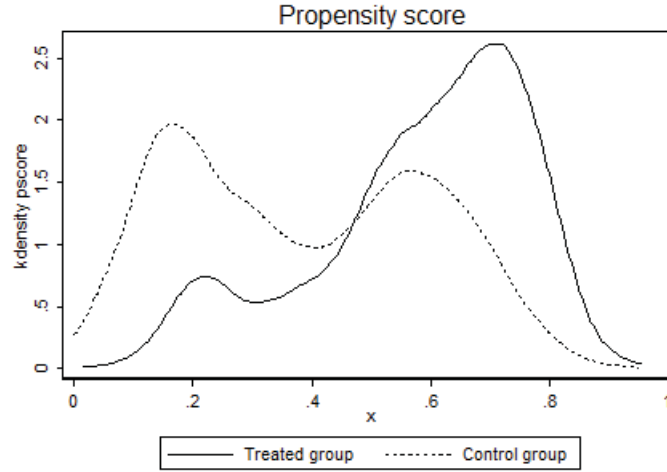
Table 4.1: Propensity score estimation: Probit

VARIABLES	(1) psa	(2) psa
forest05	-0.0057*** (0.0016)	0.0080*** (0.0017)
slope	-0.0525*** (0.0106)	0.0025 (0.0114)
droad05	-0.0683*** (0.0046)	0.0031 (0.0055)
dagri05	0.1608*** (0.0211)	0.1756*** (0.0223)
dcity	0.0006 (0.0017)	-0.0054*** (0.0019)
telig	0.1385*** (0.0085)	0.1187*** (0.0093)
lagbuffer	-3.8120*** (0.2666)	-7.2069*** (0.3608)
areaejid		-0.0417*** (0.0016)
lagdefejid		-9.9719*** (0.5533)
ejiddens		-22.4633*** (1.6096)
margi05		-0.0993*** (0.0211)
defrisk		-16.4223*** (2.4569)
Constant	-0.7795*** (0.0735)	0.1762 (0.1282)
Pseudo R-squared	0.0703	0.1565
Observations	10,352	10,352

Standard errors in parentheses adjusted for 62 clusters

*** p<0.01, ** p<0.05, * p<0.1

Figure 4.8: Common support



spent in the program. Both variables are significant: presence of the program had a negative effect on deforestation. A five year contract generates an average additionality of 2% which, for a polygon of 25 ha corresponds to 0.5 ha. Note that higher propensity scores are also associated with lower deforestation which confirms adverse selection and the necessity to account for the selection bias in our results. Regarding control variables, one should be careful in interpreting the estimates. For many of them including $dagri05_{ij}$ or $defrisk_j$, their impact is captured by the propensity scores. Introducing them allows us only to correct for remaining imbalances between the control and the treated group after controlling for $pscore_{ij}$.

Column (3) and (4) introduce the two variables that capture leakages. The coefficient for variable $wtpsa2_j$ that captures leakages in surrounding *ejidos* is not significant. However, the variable $wtpsa1_j$ that captures leakages within the *ejidos* has a significant effect and is of the expected sign.

These results tend to show that if the program effectively decreases pressure in an enrolled parcel, this pressure is displaced to other areas of the *ejido*. Nevertheless, it is not possible to directly interpret the difference of magnitude between the two coefficients. The variable $wtpsa1_j$ is the average protection of one hectare in the *ejido* and does not only depend on the number of hectares protected but also on the total stock of forest. Moreover, looking at the issue of heterogeneity leads us to reconsider the results presented in Table 4.2.

4.5.3 Heterogeneity over time

Table 4.3 presents the results of the estimation of equation 4.11. In this model, we differentiate between polygons that were only in the program in the early years and did not renew their contracts ($tpsaearl_{ij}$), those that only entered at the end of the program ($tpsalate_{ij}$) and those that were in the program continuously ($tpsaalw_{ij}$)

Table 4.2: Impact of the PSA-H and leakages

VARIABLES	(1) def	(2) def	(3) def	(4) def
psa	-0.0445*** (0.0072)			
tps		-0.0042*** (0.0012)	-0.0058*** (0.0017)	-0.0058*** (0.0016)
wtps1			0.0057* (0.0030)	0.0059** (0.0030)
wtps2				0.0021 (0.0060)
pscore	-0.6609*** (0.1980)	-0.6692*** (0.2150)	-0.6746*** (0.2166)	-0.6790*** (0.2155)
forest05	-0.0001 (0.0006)	-0.0001 (0.0006)	0.0000 (0.0006)	0.0001 (0.0006)
slope	-0.0018 (0.0016)	-0.0015 (0.0017)	-0.0015 (0.0017)	-0.0014 (0.0017)
droad05	-0.0000 (0.0010)	0.0001 (0.0010)	0.0000 (0.0010)	0.0000 (0.0010)
dagri05	0.0271** (0.0108)	0.0262** (0.0117)	0.0272** (0.0118)	0.0278** (0.0117)
dcity	-0.0016*** (0.0005)	-0.0016*** (0.0005)	-0.0015*** (0.0005)	-0.0016*** (0.0005)
telig	0.0269*** (0.0086)	0.0267*** (0.0091)	0.0263*** (0.0091)	0.0261*** (0.0094)
lagbuffer	-0.9230* (0.5241)	-0.8872 (0.5641)	-0.9076 (0.5689)	-0.9175 (0.5686)
areaejid	-0.0096*** (0.0028)	-0.0095*** (0.0030)	-0.0093*** (0.0030)	-0.0094*** (0.0030)
lagdefejid	-2.2936*** (0.7229)	-2.2747*** (0.7527)	-2.2573*** (0.7447)	-2.2691*** (0.7414)
ejiddens	-4.7676*** (1.5102)	-4.8240*** (1.5700)	-4.5446*** (1.5919)	-4.5287*** (1.6013)
margi05	-0.0304*** (0.0092)	-0.0299*** (0.0096)	-0.0300*** (0.0094)	-0.0298*** (0.0096)
defrisk	-3.0060** (1.2613)	-2.9666** (1.3050)	-2.8395** (1.2994)	-2.8406** (1.2865)
Constant	0.4493*** (0.1175)	0.4384*** (0.1254)	0.4215*** (0.1265)	0.4207*** (0.1268)
Observations	8,732	8,732	8,732	8,732
R-squared	0.1948	0.1765	0.1782	0.1784

Standard errors in parentheses adjusted for 62 clusters

*** p<0.01, ** p<0.05, * p<0.1

between 2005 and 2012. Section 4.4.3 provides more details about how the different variables are computed.

Looking at Table 4.3, we note that the coefficient of $tpsaearl_{ij}$ is not significant⁶. Two hypotheses can be advanced to explain this result. One explanation would be that these forests were not threatened. Sims et al. (2014) show that over the years, the PSA-H has improved its focus on threatened forest. This could explain why these areas have not been renewed. Another plausible explanation would be that the *ejidatarios* decided to withdraw those lands from the program in order to clear them. Hence, if the PSA-H protected the forest for five years, the *ejidatarios* caught up on their original deforestation rate in the subsequent years. Moreover, we note that once this heterogeneity is taken into account, the magnitude of the impact for the variables $tpsagate_{ij}$ and $tpsaaalw_{ij}$ is very similar to the figures shown in Table 4.2.

With a 95% confidence interval, the avoided deforestation between 2005 and 2012 in protected parcels is between 1,000 and 2,800 ha. Proportionally to the numbers of hectares enrolled, this corresponds to an additionality between 1.3 and 3.6%. However, we estimate that leakage effects within the *ejidos* would vary between 200 ha and more than 3,000 ha. This estimation tends to show that most of the avoided deforestation in the *ejido* has been displaced to other areas of the *ejido*. In the more optimistic scenario involving the maximum of avoided deforestation and the minimum leakages, the additionality of the PSA-H corresponds to approximately 3% of the areas enrolled. In the worst case scenario, leakages completely offset the impact of the PSA-H.

These results concerning leakage effects should be interpreted with caution. As highlighted in Chapter 2, deforestation pressure decreased in the *Cono Sur* prior to the program's implementation. Therefore, additionality of the PSA-H is quite low in the area and small leakage effects would be sufficient to entirely offset the impact.

4.5.4 Robustness tests

We run four robustness tests using different estimators and withdrawing the larger *ejido*. Results of the robustness tests are displayed in the Appendix B.

4.5.4.1 Propensity Score Weighting

We use PSW as developed by Robins et al. (1995) in order to estimate the impact of the PSA-H on the forest cover. It might be more appropriate to deal with the selection bias with PSW than a pre-matching. However, to our knowledge, this methodology does not allow clustering of the standard errors. For this reason, we preferred to perform a pre-matching. PSW allows us to balance covariates between

⁶Note that even once the selection process is taken into account, the decision of contract renewal may not be exogenous. We acknowledge that there may be unobservable factors impacting both deforestation and the decision to enter the program later or not to renew. Therefore, one should be cautious when comparing the magnitude of the coefficient for these three variables.

Table 4.3: Impact heterogeneity

VARIABLES	(1) def
tpsalate	-0.0114*** (0.0029)
tpsaalw	-0.0090*** (0.0019)
tpsaearl	-0.0001 (0.0026)
wtpsa1	0.0069** (0.0031)
wtpsa2	0.0026 (0.0060)
pscore	-0.7001*** (0.2097)
forest05	0.0003 (0.0006)
slope	-0.0014 (0.0017)
droad05	0.0003 (0.0009)
dagri05	0.0294** (0.0116)
dcity	-0.0018*** (0.0005)
telig	0.0273*** (0.0092)
lagbuffer	-0.9932* (0.5551)
areaejid	-0.0097*** (0.0029)
lagdefejid	-2.3386*** (0.7242)
ejiddens	-4.5886*** (1.5250)
margi05	-0.0292*** (0.0094)
defrisk	-2.8699** (1.2665)
Constant	0.4259*** (0.1214)
Observations	8,732
R-squared	0.1878

Standard errors in parentheses adjusted for 62 clusters

*** p<0.01, ** p<0.05, * p<0.1

treated and non-treated observations. It is implemented as follows (Hirano and Imbens, 2001; Lunceford and Davidian, 2004; Austin, 2011):

1. Estimating propensity scores using a probit or a logit model
2. Generating sample weight using predicted propensity scores
3. Estimating the model using Weighted Least Squares (WLS)

Based on the estimation of the propensity score presented in Table 4.1, we estimate the ATT using WLS. We estimate equation 4.6 with sample weights equals:

$$w_{ij} = \begin{cases} pscore_{ij}/(1 - pscore_{ij}) & if\ ps_{ij} = 0 \\ 1 & if\ ps_{ij} = 1 \end{cases} \quad (4.13)$$

Results are presented in the Appendix in Table B.1.

4.5.4.2 Pre-matching using Covariate matching

We used PSM in our analysis in order to select a control group and account for the selection bias. An alternative to this approach is to use Covariate matching which is based, not on propensity scores, but on Mahalanobis vectorial distance. This method might more appropriate if we are not able to predict correctly the propensity scores (Zhao, 2004).

It is crucial to control for the propensity scores in the estimations so, for the purpose of consistency, we have chosen PSM to select our sample. Nevertheless, we provide the results using Covariate matching with three nearest neighbors as a robustness test.

Results are presented in Table B.2 in the Appendix. The estimates are not significantly different from those obtained with PSM and remain significantly different from zero.

4.5.4.3 Withdrawal of the larger ejido

As can be seen in figure 4.2, there is one *ejido* located in the north-east of the *Cono Sur* that is much larger than the others. This *ejido* represents approximately 10% of our area of study. In order to ensure that this *ejido* alone is not driving our results, we run a robustness test without this *ejido*. The results of this estimation are presented in Table B.3 in the Appendix and confirm our results.

4.5.4.4 Selection and leakages estimation

The pre-matching allows us to take into account the selection process in the estimation. Section 4.5.1 showed that the polygons under protection were less threatened. Therefore, the pre-matching conducts us to keep less threatened forest in our sample, which could bias our estimations of leakages. In fact, leakages may be lower in these parcels.

To check for the existence of such bias, we run the same model on the sample of beneficiary and applicant *ejidos* without sample selection, propensity scores and clustering of the error terms. The result of this naive estimation are presented in columns (1) and (2) in Table B.4 in the Appendix. The coefficient for $wtpsa_{1ij}$ is not statistically significantly different from zero.

Note that the coefficient for $tpsa_{ij}$ is also similar to the one found in Table 4.2. This is not surprising considering the fact that about a third of the polygons received the PSA-H. The control variables, including lagged measures of deforestation, introduce a control on observable covariates. The pre-matching would more useful if the proportion of treated polygons was lower.

Column (3) proposes an estimation without any control variables. The result of this estimation clearly shows that, without any control on observable covariates, the impact of $tpsa_{ij}$ and leakages would be highly overestimated.

4.6 Concluding remarks

We propose a new methodological approach to evaluate PES impact and leakages. Following Honey-roses et al. (2011), our approach explicitly considers land tenure in the unit of observation but also allows us to take into account heterogeneity within forests owned by the same landowner. Moreover, we simultaneously estimate direct impact and leakages using tools provided by spatial econometrics. We also introduce heterogeneity of exposure to the treatment as we consider the time spent in the program and contract renewal. Our econometric model is estimated on a sample of beneficiaries and applicants as Alix-Garcia et al. (2012). We estimate an ATT using matching to pre-process the data and introduce an ex-ante spatially lagged measure of deforestation to control for unobservable heterogeneity.

We apply this methodology in the context of the Mexican PSA-H in the *Cono Sur* of Yucatan State. Our results suggest a strong adverse selection issue of PSA-H allocation within the *ejidos*. Indeed, most PSA-H contracts are found in areas with low deforestation pressure. Moreover, we show that leakages should not be overlooked. As emphasized by Aukland et al. (2003), leakages are very likely to occur following the implementation of conservation projects if land is easily available and if the project does not provide alternative livelihood options. In our study area, most of the avoided deforestation has been displaced to other areas within the *ejidos*. Moreover, looking at impact heterogeneity, we note that no additionality has been found in the areas where the *ejidatarios* decide not to renew their contracts after five years. One possible explanation is that the *ejidatarios* withdraw lands from the program in order to clear them.

The implications of our study are twofold. First, for future IE, we demonstrate that care should be taken in monitoring the indirect effects of a PES program over space and time. Leakage effects may undermine or even offset the additionality of the program. Moreover, one may fear a negative rebound-effect after the end of the program on protected parcels. Therefore, evaluating the program's impact on

protected land and only during the time the area is under conservation may lead to strongly overestimating the program's impact.

Second, from a policy perspective, monitoring leakages and rebound effects will not prevent these effects from occurring. PES schemes are based on voluntary enrollment and conservation cannot be enforced on all forest parcels over time without the beneficiary's agreement. Providing alternative livelihood options and sustainable use of the forest cover through agroforestry or sustainable forestry seem a relevant alternative to ensure permanence and minimum leakages. Nevertheless, PES designers should learn from ICDP's failures in order not to generate negative rebound effects. If PES schemes do not provide a new path for sustainable development, they may be doomed to reproduce the same failures as other conservation instruments with uncertain indirect impact over both time and space.

Reward or compensation? PES distribution in Mexican common forests

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A version of this Chapter has been adapted as a working paper co-authored with Céline Dutilly, Driss Ezzine de Blas and Chloë Fernandez for future publication.

5.1 Introduction

PES are innovative forest conservation instruments that have developed extensively during the last decade (Engel et al., 2008). But a fierce debate remains about the most effective solution to achieve additionality. A first paradigm is that PES must remunerate landowners at the OC of the land. It also follows that payments should not be directed toward landowners that already conserve the forest since their OC on the forest cover is null (Ferraro, 2008; Martin Persson and Alpizar, 2012). To achieve maximum additionality, PES must be designed as compensation instruments for the loss of future income due to forest conservation or restoration (Pascual et al., 2010). Analyzed as such, the emergence of PES represented an original shift from the polluter-pays principle to a Coasean polluter-paid agreement (Wunder, 2005, 2015).

This vision of PES has been criticised by many authors as it ignores the social and institutional process behind PES. This second paradigm considers PES as incentives for greener behavior (Muradian and Rival, 2012; Muradian, 2013). Making the scheme acceptable and efficient on the long-run often requires better considering equity and legitimacy in the attribution of payments (Adger et al., 2003; Corbera et al., 2007). It is accepted that PES may reward current conservation more than compensate OC. This second paradigm is based on the assumption that compensation of OC is impossible to implement for many reasons. Moreover, on the long-run, these incentives may impulse behavioral changes from the agents that deforest

CONAFOR has developed a complex targeting system in order to focus its intervention (Muñoz Piña et al., 2011; Rolon et al., 2011). Interactions between CONAFOR and different stakeholders has led to an hybridization of the program into a multiple objectives program (Shapiro-Garza, 2013; Sims et al., 2014). Reflecting the objectives of different stakeholders, the scheme targets threatened forests but also NPA or marginal areas. But CONAFOR's main objective is to focus on threatened forest in order to maximize additionality which shows that they conceive PES as a compensation for foregone revenues and not as reward for current and past conservation. As we will demonstrate, the scheme's design still has a strong compensation component reflecting CONAFOR's conception of the instrument.

However, as emphasised by Corbera et al. (2007), since forests are owned in commons, the final beneficiary is not clearly identifiable. As a matter of fact, once payments are received by the *ejido*, an assembly of *ejidatarios* decides how to use the payments. The *ejidatarios* can choose either to invest the payments in public goods or to share them among themselves. The final allocation of the PSA-H depends on how the members of the assembly decide to redistribute the payments. Whilst the scheme has been designed as a compensation instrument, other conceptions of fairness at the *ejido*-level may exist, which influence the final allocation of the program (Pascual et al., 2010).

In this article, we study how the land-use heterogeneity impacts PSA-H redistribution. Within *ejidos*, the *ejidatarios* have different economic activities and rely more or less on the forest cover. Does the land-use affects inequality in payments

redistribution? Are the payments allocated higher or lower for the *ejidatarios* with higher OC? Studying the interaction between land-use type and redistribution of the PSA-H within the *ejidos* allows us to understand how the program's objectives may have been appropriated by the *ejidos* and what conception of fairness their distribution choices reflect. Within the *ejido* different types of land users more or less dependent on the forest cover coexist. We show that inequality in payment allocation is directly linked to the land-use type involved and that *ejidatarios* are likely to receive relatively higher payments if they are less dependent on the forest cover. The PSA-H is not understood as a compensation but as a reward for greener practices.

The next section of this article presents an overview of the literature regarding fairness and PES allocation. Section 5.3 presents the targeting system of the PSA-H and discusses payment repartition within the *ejidos*. Section 5.4 presents the Cono Sur of Yucatan. Finally Section 5.6 presents the results of our empirical analysis regarding payment redistribution within an *ejido* in Cono Sur.

5.2 PES: A conservation instrument designed as a compensation?

5.2.1 PES as a compensation

According to Wunder's definitions (Wunder, 2005, 2015), PES are a direct application of Coase theorem (Coase, 1960). Through their production activities, landowners generate a negative externality which decreases the quantity of ES provided. This externality is not valorised by any market but if transaction costs are low and property rights well-defined, the buyer and the provider of the ES can find a monetary agreement to ensure that the provider will change his behaviour in order to provide the ES.

To be environmentally effective, PES must demonstrate additionality and focus on credible threats of deforestation (Wunder, 2007). Following the Coasean approach, payments should be set to, at a minimum, compensate landowners for land OC (Wunder, 2005; Engel et al., 2008). Indeed, providers won't accept a price below the revenues that could be obtained from the land if it was used for production. Payments may also include an additional premium to ease and secure the provision of ES especially for "asset-building" PES¹ (Pagiola et al., 2004a).

The paradox of PES is that to be environmentally effective they must target landowners with non-null OC, but in order to minimize the costs, they have to focus on areas where protection is cheaper, i.e. where OC are lower (Wunder, 2005, 2007; Wünscher et al., 2008). In areas with high OC, protection is too costly to be achieved by a PES and other types of instruments are needed.

Empirical studies of Costarican and Mexican PES highlight that the effectiveness

¹Wunder (2005) differentiates land-use restricting PES involving conservation of existing forest from asset building PES involving reforestation for instance

of the mechanisms was undermined by their weak ability to target final beneficiaries (Muñoz Piña et al., 2011; Alix-Garcia et al., 2012; Arriagada et al., 2012; Robalino and Pfaff, 2013). This adverse selection in PES programs due to asymmetric information has also been highlighted by Ferraro (2008). The phenomenon generates informational rents for the landowners with lower OC. Ferraro (2008) proposes using reverse auctions, as practiced in Indonesia, Malawi (Ajayi et al., 2012) or Australia (Comerford, 2014) or to base targeting on costly-to-fake signals. Using a theoretical model, Alix-Garcia et al. (2008) also provide evidence that indexing payments on the deforestation risk increases the efficiency of PES schemes.

5.2.2 PES as a reward

This Coasean vision of PES has been criticised by many authors because it ignores the institutional process that leads to the emergence of the PES. In reality, PES are shaped by local institutions (Muradian et al., 2010, 2013) and/or existing regulations (Brimont et al., 2015) and often do not look like a Coasean agreement.

This is especially true when dealing with PES funded by an intermediary such as a State or an NGO. The intermediary, in our case the state, often becomes the key decision-maker in PES implementation (Corbera et al., 2009; Kosoy and Corbera, 2010; Vatn, 2015) and the instrument becomes, in many respects, similar to CCT (Rodríguez et al., 2011; Martin Persson and Alpízar, 2012). In that case, designing PES as a compensation may not be possible or effective for many reasons.

First, because estimating OC remains challenging and highly sensitive to the calculation methods. Moreover, OC vary widely from one area to another and from one land user to another. In Mexico, Borrego and Skutsch (2014) showed that OC can be highly heterogeneous according to the type of land use implemented. In their study, cattle ranching provide the largest return so compensation should be higher for these types of land users.

Second, PES are shaped by local institutions and perceptions of fairness. Pascual et al. (2010) emphasises that the focus on compensation is not systematic. Compensating income loss attributed to conservation might be seen as a fair allocation for PES but it automatically excludes the landowners that do not wish to deforest since their OC is null. Another fair allocation of PES is to reward forest owners that do not deforest. It should not be forgotten here that PES are exceptions to the polluter-pays principle. A scheme may not be seen as legitimate and fair if it only remunerates landowners that are willing to deforest (Adger et al., 2003). From an economic perspective, designing PES as a compensation for foregone revenues and focusing on threatened forest is optimal in order to maximise additionality at minimal cost on the short-run. Nevertheless, such a polluter-paid solution may be perceived as unfair by landowners and prove counterproductive on the long-run.

Third, paying only for threatened forest may change the behavior of the forest owners that already conserve the forest. These landowners may try to blackmail the buyers and start clearing in order to receive payments. One may need to remunerate these landowners to avoid this change of behavior (Wunder, 2007). Moreover, this

change of behavior may not be the results of a voluntary blackmail. As highlighted by Rode et al. (2014) through a number of case studies, paying for good practices can crowd-out intrinsic motivations to conserve without payments. The authors cite numerous mechanisms through which PES can crowd-out intrinsic motivations to conserve and associated case studies.

According to many authors such as Corbera et al. (2007), Muradian et al. (2013) or Pascual et al. (2014), to be effective, PES must pay attentions to local conceptions of a fair allocation². It may be more effective to encourage good practices in accordance with local institutions and procedural justice than to try to compensate the forest owners that deforest. Payments are here conceived more as an incentive for good practices and collective action than as a compensation mechanism (Muradian and Rival, 2012; Muradian, 2013). It may involve rewarding forest owners that already conserve in order to send a signal acknowledging the good practices. On the long-run, one can hope it will impulse a shift in motivation to conserve, a crowding in effect, for the forest owners that deforest.

The distinction between reward and compensation is very subtle. As a matter of fact, reward can be conceived as compensation received *ex post*. We here consider two main distinctions. First, if PES are rewards, payments must first be directed toward the landowners that deforested less in the past. Second, if PES are compensation, the payments must increase with the OC.

5.3 Design of the PSA-H

Was the PSA-H conceived as compensation or a reward mechanism? As highlighted by McAfee and Shapiro (2010) and Shapiro-Garza (2013), interactions with civil society and other stakeholders, such as NPA commissions, forced CONAFOR to consider multiple objectives. These interactions tended to “*hybridize*” the program into a multiple objectives scheme targeting not only toward threatened forests but also marginal areas. Sims et al. (2014) showed that, through adaptive management of the selection criteria, the PSA-H succeeded in combining both objectives. Studying allocation rules of the program, one can distinguish three types of criteria: administrative, marginality and environmental priority. We here focus on environmental priority. From CONAFOR’s point of view, was the environmental objective of the program to protect threatened forests by compensating the OC or to reward good forest managements with payments? We will show in the forthcoming section that CONAFOR conceived the PSA-H as a compensation instrument.

According to CONAFOR’s rules, the primary objective of the PSA-H and the PSA-CABSA is to “*offer payments for environmental services generated by forest ecosystems*”(CONAFOR, 2009). Rural development only appears as one of many

²Beyond effectiveness and in a social justice perspective, compensation is problematic when dealing with poor landowners. The OC of poor landowners is close to zero so one can achieve maximum additionality by targeting poorer landowners. But it involves paying landowners at a price that is not sufficient to increase their capabilities and transforming them in “*conservation rentiers*” at the expense of economic development (Karsenty, 2004).

Figure 5.1: Evolution of eligible areas



Source: Authors

objectives of Proarbol " *through valorisation, conservation and sustainable exploitation of forest resources*³".

Every year, CONAFOR defines eligibility zones based on land-use change maps, advice and propositions from regional offices and a deforestation risk index. The eligibility zones are defined as "*areas or forest ecosystems where degradation process endangers biodiversity and environmental services*"⁴ (CONAFOR, 2009). The deforestation risk index is computed by the *Instituto Nacional de Ecología y Cambio Climático* (Muñoz-Piña et al., 2008). It predicts, at the pixel-level, the risk of deforestation based on past deforestation trends, agro-ecological characteristics and socio-economic variables⁵. Figure 5.1 shows the evolution of eligibility zones between 2004 and 2012. Eligible areas have been widely enlarged since 2003 and now cover about a quarter of the Mexican territory⁶.

Every year, CONAFOR receives new applications for the scheme and ranks these applications according to predefined ranking criteria. Because of budget constraints, only the highest ranked *ejidos* are accepted into the program. The deforestation risk index is also part of the ranking criteria together with other environmental indicators such as soil degradation, over-exploitation of aquifers or water availability, among others (CONAFOR, 2009).

Eventually, the amount of payments allocated per hectare of forest enrolled varies according to the deforestation risk index. Originally, the payments were set at the average income that could be obtained from one hectare of maize in order to reflect the OC of one hectare of forest (Muñoz-Piña et al., 2008). The payments were later diversified per type of forest and deforestation risk to capture OC heterogeneity. The amount of payments are presented in Table 5.1.

Note that NPA, and other priority zones such as areas under the RAMSAR conventions, are de facto eligible. Moreover, in the allocation criteria, localization

³Translation by the authors

⁴Translation by the authors

⁵See Muñoz-Piña et al. (2008) for more details regarding the econometric analysis

⁶Authors' calculations based on data provided by CONAFOR

Table 5.1: Payments areas by vegetation types and deforestation risk

	Type of forests	Deforestation risk	Payment
Area 1	Bosque Mesofilo	Very high	1.100 Pesos per Ha
Area 2	Bosque Mesofilo	Low to high	700 Pesos per Ha
Area 3	Bosque de coniferas, selva subcaducifolia and bosque de encino	Very low to very high	550 Pesos per Ha
Area 4	Selva alta perennifolias	Very low to very high	382 Pesos per Ha

Source: (CONAFOR, 2009)

inside an NPA increases the chance to receive the program. It results from interaction with other stakeholder such as the NPA commission (CONANP). CONANP's argument was that through the NPA system, they generated additionality without compensation for many years so they should be eligible to receive compensation ex-post. Environmentally, the emphasis put on NPA shows that the scheme also rewards good practices and past avoided deforestation. If CONAFOR conceived the PSA-H as compensation instrument, this reward elements is a good illustration of how the program has been hybridized to take into consideration multiple claims.

Nevertheless, apart from NPA, the above elements shows that CONAFOR conceived the PSA-H as a compensation mechanism as it targets threatened forest and as the amount of payments are intended to reflect income loss attributable to conservation. As highlighted above, interactions with civil societies and other groups of interest forced CONAFOR to consider other conceptions of PES and integrate new objectives. This hybridization may be responsible for the low additionality observed in the early cohorts of beneficiaries (Muñoz-Piña et al., 2008; Muñoz Piña et al., 2011; Alix-Garcia et al., 2012). Nevertheless, Sims et al. (2014) highlight that, through adaptive management of the targeting criteria, the designers succeeded over time at combining both objectives. One can hope that additionality increased if the scheme focused more on threatened forest.

In this article, we analyse the distribution of the payments within the *ejidos* in order to understand how the objectives of the PSA-H are understood and whether the internal distribution complies or conflicts with compensation logic. We explore this issue in a sub-region of Yucatan State: the Cono Sur.

5.4 The Cono Sur in Yucatan

5.4.1 Sample at ejido and household level

As presented in Chapter 2, our sample is composed of 47 *ejidos* receiving the PSA-H. They constitute a quasi exhaustive sample of all of the *Cono Sur* beneficiaries once excluding outliers⁷. At the *ejido* level, we conducted participatory surveys with

⁷Two *ejidos* were much larger than the rest of the distribution and received larger payments. Given the size of our sample, they were very likely to bias the results

the authorities and with *ejidatarios* willing to participate. The surveys explored land-use, household economic activities, governance, and infrastructure and PSA-H payment distribution, among other criteria.

At the household level, the sample is composed of 163 households living in an *ejido* enrolled in the PSA-H. Among those 163 households, 151 declared that they had received payments from the PSA-H. The average households' size is 4.8 members. The household's head is on average 54 years old and 22% of them are illeterate. Total payments received between 2005 and 2013 range from 3,000 to 180,000 Mexican pesos (230 to 13,850 USD in 2010). Most of this heterogeneity is explained by the fact that some ejidos have only received the program for one year whilst others participated during the entire period of analysis. Nevertheless, if on average the *ejidatarios* received around 10,000 Mexican pesos (770 USD in 2010) per year of reception, this amount varies between 600 and 34,000 per *ejidatarios* (46 to 2615 USD in 2010).

5.4.2 Economic activities and associated opportunity costs

In line with Coasean vision of the PES, we define the OC of enrollment as the income that would be obtained from the land if the ejidos had not enrolled in the PSA-H. This OC depends on the profitability of the type of land-use that could be implemented but also on the probability that the owner will deforest in the near-future. As a matter of fact, landowners may not be willing to deforest because of a trade-off between on-farm and off-farm activities or because they are credit-constrained among many things.

There are four main economic activities in the area. The *ejidatarios* often combine these four sources of income:

- **Traditional slash-and-burn agriculture:** Shifting cultivation of maize inter-cropped with beans is the traditional form of agriculture called *milpa*. In our sample, traditional producers cultivate 2 hectares on average. Producers shift parcels every two or three years and fallow periods last for 10 to 15 years. Yields that can be obtained from this activity remain low and vary according to the climatic conditions (around 600 kg/ha/year). Being poorly profitable, traditional agriculture tends to be abandoned or is maintained in combination with other activities. In our sample, 50 *ejidatarios* implemented slash-and-burn agriculture in 2005 and 47 in 2013.
- **Mechanised agriculture:** This form of intensive non-rotative agriculture developed in *Cono Sur* in the late 1970's with the implementation of PRON-ADE. The area under cultivation in our sample varies from 1 to 22 hectares. The yields that can be obtained are three to four times superior to those obtained by slash-and-burn if combined with an irrigation system. The OC may seem greater for those producers but they are not directly dependant on the forest cover. They are sedentary, at least in the short-run. Indeed, although

this form of agriculture is profitable, cultivating new land requires high investment in land-leveling that most producers cannot afford. In our sample, 81 *ejidatarios* engaged in this type of activity in 2005 and 85 in 2013.

- **Cattle-ranching:** The *Cono Sur* is also a traditional cattle-ranching area. In our sample, 30% of the *ejidatarios* have at least one head of cattle but some of them only breed a few heads at home for savings or short-term profit. More than 20% of our sample have individual pastures or use common pasture and forest for grazing. In our sample, 29 *ejidatarios* engaged in cattle-ranching activities in 2005 and 41 in 2013.
- **Off-farm:** Off-farm wages and remittances are also important sources of income for agricultural households. A quarter of the surveyed *ejidatarios* have temporary or permanent off-farm activities.

These activities yield heterogeneous returns and have varying opportunity costs on the forest cover. Mechanised agriculture is sedentary in the short-run so the OC of these land-users is close to zero. Traditional producers cultivate very small areas with moderate returns so the amount necessary to compensate these producers is also low. Moreover, as highlighted by [Borrego and Skutsch \(2014\)](#), if fallow period are long enough, this type of agriculture is likely to be sustainable. In Jalisco, the authors showed that the highest return on clearing activities were obtained by cattle ranchers. Moreover, land cleared for pasture is larger than for traditional agriculture. In this context, cattle-ranchers are the main agents to compensate in order to achieve additionality.

If PES is seen as a compensation, cattle-ranchers are the main agents to target and should receive more payments than the other land users since their OC is higher. However, if the PES is seen as a reward, cattle ranchers, the main agents that deforest, should receive less payments than mechanised and traditional producers. As a matter of fact, mechanized producers do not rely on the forest cover and traditional producers clear very small areas.

5.5 Distribution of the PSA-H in the ejidos

5.5.1 Appropriation of the PSA-H by the ejidos

Section 5.3 demonstrated that CONAFOR designed the PSA-H as a compensation instrument. However, as explained above, once payments are allocated to the *ejido*, the assembly decides how to distribute the payments to the *ejidatarios*. Payments can be redistributed among *ejidatarios*, invested in public goods (roads, school, new income generating activities etc...), or used to remunerate activities related to the program such as patrolling into the forest or building firebreak. This last use of PSA-H payments has been found in other Mexican States but, in our sample, excepting minor collective investment, all the payments were redistributed among the

*ejidatarios*⁸. However, different *ejidatarios* from the same *ejido* won't necessarily receive the same amount of payments. Qualitative surveys with the authorities allowed us to explore the distribution rules and their justification in the 47 *ejidos*.

In order to understand how the *ejidatarios* share the payments, we provide three meaningful examples of the distribution rules. The rules vary over time and between *ejidos* but are often a combination of these three examples. A first distribution rule consists in dividing all the payments equally among the *ejidatarios*. In this example, remuneration is not directly linked to the forest as some *ejidatarios* use the commons more than others. Nevertheless, since all of them have land-use rights and voting rights at the assembly, they receive equal payments. Another rule is to divide the payments, not equally among each member, but rather inversely proportional to the share of common forests they have cleared. Each *ejidatario* owns an equal share of commons and therefore an equal share of the common forest. This forest cover can be converted to agricultural fields or pasture for personal use with the permission of the assembly. The more the *ejidatario* has converted of his share of forest, the less remuneration he receives. A last example of a distribution rule involves sharing payments but only among a certain group of *ejidatarios* willing to participate. The *ejidatarios* that do not wish to join the program are either those who were absent during the assemblies or those who want to keep their share of forest out of the program. The latter, often cattle-ranchers, do not join either because they consider that payments are not high enough or because they feel that environmental programs threaten their activities. None of these three examples of allocation rules follows the compensation logic of the PSA-H. On the contrary, the latter two tend to show that the PSA-H is directly linked to land use but is perceived as a reward for not using the forest more than as a compensation for foregone revenues.

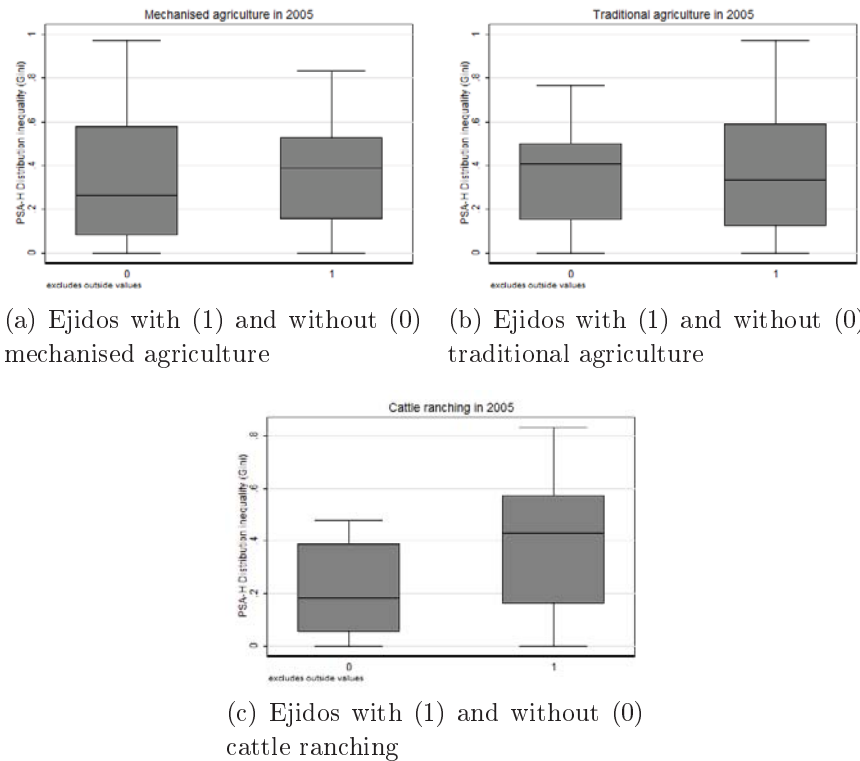
5.5.2 Land use and allocation of the payments

As highlighted by Corbera et al. (2007) when resources are owned as commons, the provider of the ES is not clearly identifiable. In Chiapas, multiple authors showed that participation and distribution of the payments within the community was not egalitarian and tended to reflect existing power relationships within the community (Corbera et al., 2007; García-Amado et al., 2011; Hendrickson and Corbera, 2015). Our studies complete these results with an emphasis on the type of land-use and the logic of the distribution rules.

We hypothesise that the scheme has been reinterpreted at the *ejido*-level as a reward for good behaviour. Community forests are perceived as areas managed by a homogeneous group. Focusing on more threatened areas addresses between-*ejido* heterogeneity but the design of the PSA-H implicitly assumes the absence of the heterogeneity that exists within *ejidos*. This heterogeneity leads to the emergence of a second adverse selection problem. Within the *ejido*, some *ejidatarios* benefit

⁸We hypothesize that the use of the payments can be influenced by regional authorities' vision of the program. This is probably the reason why all payments have been redistributed in our study area.

Figure 5.2: Gini of PSA-H distribution inequality by type of economic activities



more from the scheme than others, and these differences are directly related to the land use. [Borrego and Skutsch \(2014\)](#) showed that OC varied across land users in Mexico, studying allocation rules allows us to understand if the distribution, at *ejido*-level follows logic of compensation or reward.

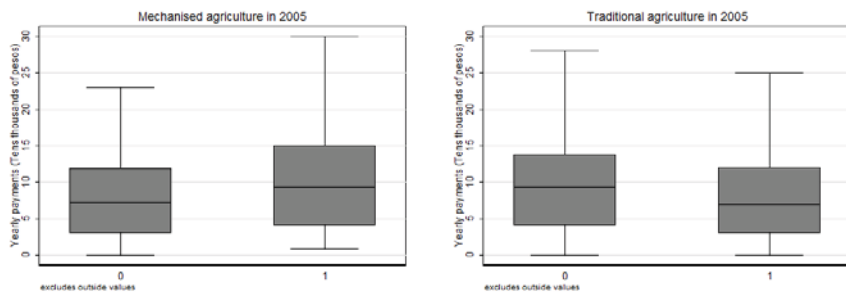
Traditional producers are dependent on the forest cover but only cultivate a small area (about two hectares). Moreover, their production behaviour is rotative which allows for forest regeneration. Mechanised producers cultivate larger areas but are sedentary in the short-run. Moreover, they cultivate mainly on parcelised land and not on commons. In compensation logic, these types of land-uses would not be targeted. However, if the scheme is a reward for not using the forest, these land users would be the main beneficiaries. Cattle ranchers are the main forest-users. They use the forest for grazing, which is forbidden by the PSA-H, and convert it into pasture. Thus, they are the primary agents to compensate in order to avoid deforestation.

Figure 5.2 presents the distribution of the Gini coefficient of inequality in the distribution of payments in the 47 *ejidos* according to the presence of the three main economic activities in the *ejido*. Calculations of the Gini are based on the total amount of payments received by each *ejidatario* in the 47 *ejidos* that received payments between the beginning of the PSA-H and 2012. We note that the presence of cattle-ranching in the *ejido* tends to be associated with more unequal distribution.

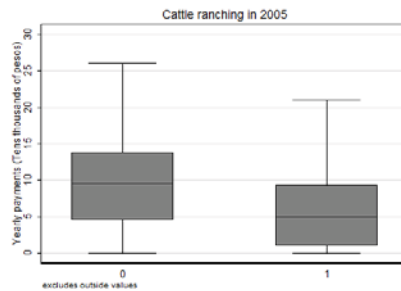
This pattern seems less marked with mechanised and traditional agriculture.

At the household-level, Figure 5.3 presents the yearly amount of payments received by the 163 *ejidatario* surveyed according to the three types of land use: mechanised agriculture, cattle-ranching and traditional slash-and-burn. The land use can be impacted by the PSA-H so we use activities in 2005, before PSA-H reception, to avoid endogeneity. Moreover, we use the average reception per year because the total amount is highly influenced by the year of entry of the *ejido*, making irrelevant the comparison between households of different *ejidos*. According to Figure 5.3, the *ejidatarios* who practiced mechanised agriculture tended to receive more payments, whilst *ejidatarios* who practiced cattle-ranching received less.

Figure 5.3: PSA-H yearly payments received by the households by type of activities



(a) Households with (1) and without (0) mechanised agriculture (b) Households with (1) and without (0) traditional agriculture



(c) Households with (1) and without (0) cattle ranching

Note that the amount of payments received by the *ejidatarios* depends on the amount received by their *ejido*. In order to analyse the distribution of the payments, it is crucial to compare the amount of payments received by one *ejidatario*, not with the amount received by the entire sample, but by the other *ejidatarios* living in the same *ejido*. In the econometric analysis presented in the following section, we use a pseudo-panel to capture between-*ejido* heterogeneity and focus on within-*ejido* heterogeneity.

5.6 Econometric analysis

This section proposes an empirical analysis of the repartition of the payments within the *ejidos*. The first section of the econometric analysis investigates the determinants of inequality in payment distribution at the *ejido*-level. The second section explores the determinants of the yearly amount of payments received by one *ejidatario* compared to other *ejidatarios* from the same *ejido*.

5.6.1 Distribution inequality at *ejido*-level

5.6.1.1 Identification strategy

We explore the determinants of inequality of payment distribution within the *ejidos* by estimating an OLS model with the Gini index of payment distribution between 2003 and 2012 as our explained variable. Our hypothesis is that inequality in distribution is directly linked to land-use heterogeneity within the *ejido*. We estimate the following model:

$$psa_gini_j = \alpha + \beta L_j + \gamma X_j + \varepsilon_j \quad (5.1)$$

In equation 5.1, L_j corresponds to the different land use in *ejido* j as presented in Section 5.4. We use the 2005 level of each variable in order to avoid endogeneity. In a first step, we consider dummy variables that are equal to one if mechanised agriculture ($mec05_ejid_j$), traditional agriculture ($trad05_ejid_j$) or cattle-ranching ($ranch05_ejid_j$) are present in the *ejido*. In a second step, we introduce the percentage of *ejidatarios* implementing each activity⁹ (per_mec05_j , per_trad05_j and $per_ranch05_j$). X_j include control variables likely to influence inequality such as number of *ejidatarios* ($ejidat_j$), the average and standard deviation of *ejidatarios*' age (age_j and age_sd_j), average participation to the assembly ($partasemb_j$), area of common forests in hectare ($forest05_j$) and percentage of total superficie of the *ejido* (per_forcom_j). We also include a dummy variable for labor-*ejido* defined as the *ejido* with less than 20 inhabitants¹⁰ ($labejid_j$). Eventually we control for the average annual amount received by the *ejido* ($psaejid_yr_j$). We estimate equation 5.1 on a sample of 47 beneficiary *ejidos*.

5.6.1.2 Results

Table 5.2 presents the results for the estimation of equation 5.1. Column (1) presents the results of the estimation with only the control variables. Column (2) adds dummy variables for each activity and column (3) adds the percentage of *ejidatarios* implementing each activity. Comparing the R-squared of column (1) with columns

⁹Note that we do not include off-farm activities here. First because they are not directly related to a land-use and second because we only have poor information on this matter at *ejido*-level.

¹⁰Remember that, as explained in Chapter 2, economic activities are implemented in the *ejido* despite the fact that the *ejidatarios* are currently living outside the *ejido*

(2) and (3), we note that considering the type of land-use in the estimation adds to the explanatory power of the model.

As suggested by the box-plots presented in Figure 5.2, the presence of cattle ranching seems to increase distribution inequality. According to the results of column (3), the more cattle ranchers there are in the *ejido*, the more unequal is the distribution. Our results also suggest the opposite results for mechanised agriculture. The more *ejidatarios* with mechanised plots, the less unequal is the distribution. Our results also suggest that the distribution has been more equal in the labor-*ejido* and in the *ejidos* with higher participation rate at the assembly. Moreover, the larger is the share of forest, the more equal is the distribution. Eventually, the distribution may be more equal when yearly payments received are higher but the coefficient of *psaejid_yr_j* is only significant in column (3).

This result suggests that inequality in payment distribution is linked to the type of land-use involved. As a matter of fact, whilst *ejidos* relying on mechanised agriculture tend to have more equal rules of allocation, the *ejidos* involved in cattle ranching have more heterogeneity in individual payments, confirming our hypothesis. Nevertheless, these results do not tell us who benefits more from the program. In the next section, we study the amount received by each *ejidatario* according to their land use.

5.6.2 Distribution of the payments

5.6.2.1 Identification strategy

Our hypothesis is that the objectives of the PSA-H have been reinterpreted by the *ejidatarios* as a reward for conserving the forest. We test this hypothesis using a pseudo-panel. The pseudo-panel estimation allows us to capture between-*ejido* heterogeneity and focus on within-*ejido* heterogeneity, i.e. the difference between the payments received by one *ejidatario* compared with other *ejidatarios* from the same *ejido*. We test the impact of the type of land use implemented by the *ejidatario* before PSA-H implementation on the amount of PSA-H received.

We estimate the following models respectively with fixed effects (5.2) and random effects (5.3):

$$psahyrij = \alpha + \beta A_{ij} + \gamma X_{ij} + \eta D_j + \varepsilon_{ij} \quad (5.2)$$

$$\begin{cases} psahyrij = \alpha + \beta A_{ij} + \gamma X_{ij} + \varepsilon_{ij} \\ \varepsilon_{ij} = \rho_j + \mu_{ij} \end{cases} \quad (5.3)$$

In equation 5.2 and 5.3, *psahyrij* corresponds to the average yearly amount of payments received by *ejidatario i* in *ejido j* during one year of reception. Some *ejidatarios* joined the program several years after the other *ejidatarios* either due to absence from the *ejido* or a reluctance to participate at the program's onset. For this reason, we chose to use average yearly payments during the years of reception rather than total payments.

Table 5.2: Determinants of inequality in PSA-H payments' distribution

VARIABLES	(1)	(2)	(3)
	psa_gini	psa_gini	psa_gini
mec05_ejid		-0.2436** (0.1093)	
trad05_ejid		-0.0061 (0.0902)	
ranch05_ejid		0.1828* (0.1078)	
per_mec05			-0.3945*** (0.1397)
per_trad05			-0.1391 (0.1366)
per_ranch05			0.4682*** (0.1131)
ejidat	-0.0025 (0.0016)	-0.0036 (0.0022)	-0.0029 (0.0019)
age	-0.0048 (0.0082)	-0.0033 (0.0087)	-0.0038 (0.0075)
age_sd	-0.0203 (0.0141)	-0.0285** (0.0139)	-0.0334** (0.0138)
labejid	-0.1430* (0.0788)	-0.1953** (0.0910)	-0.2391*** (0.0742)
partasemb	-0.4321** (0.1885)	-0.3770** (0.1836)	-0.3950* (0.2001)
forestuc	0.0002** (0.0001)	0.0002*** (0.0001)	0.0002*** (0.0001)
per_forcom	-0.5013*** (0.1627)	-0.6280*** (0.1696)	-0.6121*** (0.1516)
psaejid_yr	-0.0030 (0.0023)	-0.0018 (0.0021)	-0.0050** (0.0024)
Constant	1.4807*** (0.5105)	1.5319*** (0.4656)	1.7335*** (0.4495)
Observations	46	46	46
R-squared	0.3615	0.4234	0.4884

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

In order to check whether or not the random effect estimator is convergent, we run an overidentification test as suggested by Cameron and Trivedi (2005). Contrary to Hausman’s test, this test is robust to heteroskedasticity. We cannot rule out that both estimations are convergent so the random-effects estimator is the most efficient. Nevertheless, we present both models in Table 5.3.

A_{ij} are dummy variables that correspond to the type of economic activities of household i . As in Section 5.6.1, we use the level of the variables in 2005 in order to avoid endogeneity. Three of these variables are linked to land-use: $mec05_hh_{ij}$, $trad05_hh_{ij}$ and $ranch05_hh_{ij}$ respectively for mechanised agriculture, traditional slash-and-burn and cattle ranching. We consider as cattle ranchers only households using either pasture or common land for grazing. We also include one dummy variable to control for permanent off-farm activity ($off05_{ij}$). X_{ij} include control variables such as the age of household’s head (age), a dummy variable equals to one if the household knows how to write and read ($write_{ij}$), the size of the household ($size05_{ij}$) and a measure of the assets computed using principal component analysis ($assets05_{ij}$). Eventually, we include a dummy variable equals to one if the *ejidatario* is a member of the *ejido* authorities ($orgejid_{ij}$) and the average percentage of assemblies in which he participated ($partasemb_hh_{ij}$). Our sample is composed of 163 *ejidatarios*.

5.6.2.2 Results

Table 5.3 presents the results of the econometric analysis regarding distribution of the payments. Column (1) and (2) presents the results of the estimation of the models presented in equations 5.3 and 5.2. Our three main variables of interest, $mec05_hh_{ij}$, $trad05_hh_{ij}$ and $ranch05_hh_{ij}$, are all significant. The main beneficiaries were the *ejidatarios* who engaged in mechanised activities and traditional agriculture. Producers with cattle-ranching activities received less payment than others.

Our results are robust in many settings. Columns (3) and (4) exclude from the sample the *ejidatarios* that decided to remain outside of the program and did not receive any payments. Columns (5) and (6) display the results using the total amount of payments received $psahtot_{ij}$ rather than average yearly payments respectively with the whole sample and excluding the ones that decided to remain outside of the program. Our variables of interest remain significant in all specifications, which confirm the robustness of our results.

As explained in Section 5.4, cattle ranchers clear large areas of forest with high returns. On the contrary, traditional producers clear moderate areas with lower return. Moreover, this farming system could be sustainable if fallow periods are long enough (Borrego and Skutsch, 2014). Mechanised producers are sedentary, at least on the short-run, and do not clear the forest anymore. In compensation logic, cattle ranchers should be the main beneficiaries of the PSA-H. These results confirm our hypothesis that the distribution of payments within the *ejido* does not follow the PES logic of compensation. On the contrary, the PSA-H appears to be perceived

by the *ejidatarios* as a reward for greener behaviour.

5.7 Concluding remarks

In this Chapter, we explore the distribution of the PSA-H payments at the *ejido* and household levels. We here oppose two conceptions of PES' efficiency. The first one regards PES as a compensation mechanisms for income loss attributable to conservation: it targets threatened forests in order to achieve maximum additionality at minimum costs. The second conception of PES pays more attention to local institutions and considers that, to be efficient on the long-run, PES allocation may reward existing conservation efforts. The PSA-H was designed as a compensation mechanism for income loss attributable to conservation: it targets threatened forests in order to achieve maximum additionality at minimum costs. Since most of the Mexican forests are commons, PES payments are allocated to the *ejidos*, and the assembly of each *ejido* divides payments among the *ejidatarios* according to their own rules and perception of fairness.

Based on *ejido* and household surveys in a sub-region of Yucatan State, we explore the interaction between the land-use type and internal payment distribution. In our study area, the cattle ranchers are the more likely to clear land in the near future and will obtain higher return from clearing than the other type of land-users. They are the main agents to compensate but if PES is seen as a reward, they should receive less payment. We estimate the impact of land use type on both the Gini coefficient of distribution at the *ejido*-level and the yearly payment amount received by each *ejidatario* at the household-level. Our econometric results suggest that the more prevalent cattle ranching is in the *ejido*, the more unequal the distribution tends to be. Moreover, within the same *ejido*, the *ejidatarios* that already conserve the forest receive higher payments whilst the cattle-ranchers, receive less remuneration than their peer-*ejidatarios*. The *ejidatarios* share the payments according to past behavior, the agents that deforested the most receives less payments either because it is considered that they already cleared their share of commons or because it is not considered as fair to remunerate more the land users that clears the forest. In no cases, the distribution follows the compensation logic that more payments should be allocated to the agents with higher OC. The *ejidatarios* appear to have reinterpreted this instrument conceived by federal authorities as a compensation as a reward for good practices.

As all compensation mechanisms, PES are complex exceptions to the polluter-pays principle (Pirard et al., 2010). The idea that payments must first be directed to the agents that deforest is far from being appropriated by all forest owners and the only agents willing to join might be the one with higher intrinsic motivation to conserve (Lapeyre et al., 2015). The institutional process of allocating compensation from the federal-level to the *ejidos* involves many levels of decision making, leaving room for reinterpretation of the program's objectives. PES might have been progressively transformed into a subsidy for the agents that do not clear the forest

Table 5.3: Determinant of the amount of payment received by the household
(Pseudo-panel estimation)

	(1)	(2)	(3)	(4)	(5)	(6)
	psahyr	psahyr	psahyr	psahyr	psahtot	psahtot
	FE	RE	FE	RE	FE	RE
mec05_hh	3.7685** (1.5625)	4.0199** (1.5897)	3.2428** (1.3301)	3.4172** (1.4209)	15.6547** (7.4804)	16.4676** (7.7884)
trad05_hh	2.9831** (1.0749)	2.7545** (1.0801)	3.1669** (1.1714)	2.8861** (1.1617)	15.2408** (6.3771)	14.8110** (6.4336)
ranch05_hh	-1.3585* (0.7622)	-1.5841** (0.6742)	-1.5768* (0.8756)	-1.7717** (0.8204)	-6.2461 (4.3225)	-6.6456* (3.9195)
off05	0.9919 (0.9932)	1.0519 (0.9693)	0.3901 (0.9270)	0.4677 (0.9064)	7.3725 (4.7309)	7.8755* (4.6554)
age	-0.0291 (0.0196)	-0.0304 (0.0187)	-0.0113 (0.0205)	-0.0119 (0.0195)	-0.0103 (0.1137)	-0.0148 (0.1115)
size05	-0.0444 (0.1893)	-0.0452 (0.1906)	0.1124 (0.1514)	0.0988 (0.1559)	-0.1982 (1.0701)	-0.1503 (1.0636)
write	0.5179 (0.9711)	0.3545 (0.9860)	0.9791 (0.9218)	0.8417 (0.9461)	3.4609 (5.1679)	2.9056 (5.2300)
assets05	0.7290 (3.1291)	1.2451 (3.0621)	1.2907 (2.0297)	1.6733 (2.0634)	8.2075 (15.8287)	9.1767 (15.8626)
partasemb_hh	1.4608 (1.7820)	1.4626 (1.7165)	-1.1758 (1.1317)	-1.1143 (1.1294)	7.0490 (6.4985)	7.1015 (6.4011)
orgejid	1.5611 (1.0862)	1.7396 (1.0725)	0.6013 (0.7597)	0.7934 (0.7650)	6.1104 (5.6804)	6.5513 (5.5953)
Constant	6.9080*** (2.1561)	8.7716*** (2.3138)	7.5950*** (2.2118)	9.5237*** (2.2593)	24.3260* (14.1033)	32.8560** (14.5378)
Observations	163	163	151	151	163	163
R-squared	0.2006	0.1991	0.1856	0.1838	0.1403	0.1399

Robust standard errors in parentheses. FE=Fixed effects, RE=Random effects

Standard errors clustered by *ejido*

*** p<0.01, ** p<0.05, * p<0.1

and explained as such to the *ejidatarios*.

Moreover, at the federal level, it is possible to discriminate between eligible areas in order to focus the program on areas with higher deforestation rates. However, within the *ejido*, remunerating only producers that are likely to clear the forest cover and not those who are already conserving it might prove impossible. Making the scheme acceptable requires taking into consideration local procedural justice and institutions (Adger et al., 2003; Corbera et al., 2007; Pascual et al., 2014) and the *ejido* may have reinterpreted the program's objectives according to their own conception of fairness.

Once confronted with reality, the implementation of the PES concept can result in unexpected outcomes. Compensation as an exception to the polluter-pays principle may not be well appropriated by the economic agents especially when dealing with commons. It also highlights the difficulty to involve the land users willing to deforest in the process. When dealing with commons, it seems ethically impossible to compensate income loss within a community without rewarding those already conserving the forest. Nevertheless, more effort is needed to include the deforesting agents in a process that they currently regard as a threat to their activity.

Can PES enhance Community Forestry?

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A version of this Chapter has been adapted as a working paper co-authored with Carlos Muñoz-Piña for future publication.

6.1 Introduction

During the last years, a wide variety of heterogeneous instruments including PES of various forms or incentives for sustainable management emerged. As these different instruments widespread, they eventually come to interact within the same areas. In recent researches, [Barton et al. \(2009\)](#) and [Ring and Schröter-Schlaack \(2011\)](#) drew attention on the concept of policy mix at landscape-level. As instruments interact, they may offset each other's impact or be complementary and create synergy. Therefore, they should not be considered or evaluated separately. In a search for relevant policy-mix, we here provide an example of positive interactions in Mexico between PES and Community Forestry.

The specificity of Mexican forests is that, as a result of one century of agrarian land reforms, 80% of these forests are owned today as commons by communities called *ejidos* ([Bray et al., 2003b](#); [Kaimowitz, 2005](#)). To counteract high deforestation rates, the Mexican government relies on a wide set of conservation instruments including the PSA-H ([Muñoz-Piña et al., 2008](#)). But since the 1980's, the timber value chain in Mexico has been characterized by the prominent role played by community forest enterprises (CFEs) ([Antinori, 2000](#); [Scheer et al., 2002](#)). These CFEs are managed directly by the *ejidatarios* and constitute a substantial source of income and an early stage of industrial development at the *ejido*-level. Moreover, many authors emphasized CFE development as sustainable options for forest conservation in Mexico ([Ellis and Porter-Bolland, 2008](#); [Bray, 2010](#); [Porter-Bolland et al., 2012](#)). As a matter of fact, in order to sell timber on the legal market, CFEs must comply with a management plan that ensures sustainability of logging activities.

How do the PSA-H and CFEs coexist and interact within the same landscape? Does paying for conservation discourage investment in CFEs? Or by contrast, can PES help communities to create and stabilise CFEs? We hypothesize that the PSA-H can contribute to CFE development for three reasons. First, because the PES can relax credit constraints. Extracting timber through CFEs requires investment that needs to be renewed regularly and *ejidos* may be unable to finance it without additional funding. Second, because PES reception improves *ejido*'s access to information. *Ejididos* are often unaware of the possibility of exploiting their timber resources through CFEs. Enrolling in the PSA-H enhances their interactions with CONAFOR's staff and other *ejidos* through meetings and workshops and increases their knowledge about CFEs. Third, because the PES can help *ejidos* create forest management institutions. To comply with PES' commitments, the *ejidatarios* must organize various tasks in the forest such as patrolling or building firebreaks. It creates institutions of forest management, thus likely fostering the emergence of additional CFEs

We propose an empirical analysis of the interactions between CFEs and the PSA-H. We use a national database of 223 *ejidos*. The results of our empirical analysis support our hypothesis.

6.2 PSA-H and CFE as a policy mix

6.2.1 Policy Mix in Mexico

The concept of policy mix derives from macroeconomic policy and can be defined as the art to combine and harmonize economic policies to achieve economic objectives. Following seminal works by Tinbergen (1952) or Mundell (1962), it often refers to the interdependencies between fiscal and monetary policies. In environmental policy, the concept of policy mix has been applied to the interactions between heterogeneous environmental policies at different scales. For instance, Sorrell and Sijm (2003) study interactions between cap-and-trade and quotas in the context of carbon trading. But the concept of policy mix has also been applied to interactions at micro-level (Barton et al., 2009; Ring and Schröter-Schlaack, 2011).

Ring and Schröter-Schlaack (2011) note that policy instruments in the context of biodiversity protection, are considered and evaluated independently even though they often interact in the same landscape. The authors define this policy mix as “*a combination of policy instruments which has evolved to influence the quantity and quality of biodiversity conservation and ecosystem service provision in public and private sectors*”. As emphasized by this definition, policy mix here emerge *de facto* and do not result from a coordinated process. Environmental policies also interact with other types of economic instruments including agricultural subsidies or social programmes. The outcome of the interactions between environmental policies and these programs is uncertain and potentially harmful to economic efficiency (Rodríguez et al., 2011). As highlighted by Barton (2014), the challenge is to think the policy mix, and resulting interactions, at landscape level. It includes a careful mapping of the instruments, and associated land uses, discussed with stakeholder and acknowledging the areas of higher environmental benefits and economic costs for the land users.

Many policy instruments interact in the rural Mexico. We add to the existing empirical evidence on this matter. Computing the multiplier effect of agricultural subsidies called PROCAMPO on household income, Sadoulet et al. (2001) note that the programme has the potential to relax a credit constraint. It can explain why this program together with cattle ranching subsidies has been found to increase deforestation in Mexico (Barbier and Burgess, 1996; Schmook and Vance, 2009). Using regression discontinuity design, Alix-Garcia et al. (2013) find that exposure to a social conditional cash transfer called *Oportunidades*¹ increases deforestation. The results show that, because of the credit constraint, additional income significantly increases consumption which increases deforestation. Recently, Sims et al. (2014) compared the additionality of protected areas and the PSA-H and interactions between both instruments. As expected, their results show that PSA-H’s additionality is low within protected areas which suggest that the protected areas were already well-enforced. We here empirically explore the interactions between two other environmental policies in Mexico: CFEs development and PES.

¹Formerly known as PROGRESA)

6.2.2 Community Forests Enterprises

6.2.2.1 Sustainable forestry as a conservation policy

CFEs emerged in Mexico in the early 1980's and expanded widely in the subsequent years. They are defined by Antinori and Bray (2005) as "*businesses based on collective ownership or secured access to a forest resource by a community, with governance derived from or influenced by local community traditions*". CFEs have become prominent actors of the Mexican timber value chain. It is difficult to know the number of *ejidos* with activities of timber extraction and transformation. Bray et al. (2003a) show that estimates can vary from one study to another. The most recent federal survey states that more than 1,700 communities had extraction activities in 2007 (Bray et al., 2007). More than forest or environmental policy, the main factor explaining the emergence of CFEs in Mexico lies in the land tenure system (Bray et al., 2006). In fact, most of the timber resources are owned by *ejidos* as commons. Moreover, the governance of CFEs relies on *ejidos*' already existing traditional governance institutions such as the assembly of *ejidatarios*.

CFEs are regulated by the General Law of Sustainable Forestry Development of 2006 (*Ley General de Desarrollo Forestal Sustentable*). This law strictly forbids the extraction of timber if the *ejido* is not complying with a forestry management plan (*Plan de Manejo Forestal*) ensuring that logging activities are implemented at a sustainable rate. The management plan defines the volume of timber that can be extracted annually for the subsequent ten or twenty years: this volume is called the annuity. The management plan also establishes the length of the rotation cycle, ie the time necessary for regeneration. An *ejido* cannot enroll the same area in a management plan before the end of the rotation cycle. The regeneration time depends on multiple characteristics such as, climatic conditions, tree and soil type and land-use history. At the end of the plan, the *ejido* can decide to pay for another plan and enroll a new area. To comply with their management plan, CFEs contract with private CONAFOR-qualified forest engineers. These engineers monitor and supervise extraction activities and ensure a good level of regeneration of the forest cover according to silviculture standards. The engineer's wages and the management plan are paid by the *ejido* but in some cases the timber buyer, a private sawmill for instance, may take over these costs.

Within the CFEs, day-to-day decisions are taken by a general manager (*gerente general* or *coordinador*) elected by the *ejido* (Antinori, 2000). The forest engineer is consulted to supervise the logging activities. More developed CFEs may also have a chief of sales (*jefe de ventas*) and/or a chief of finance (*jefe de finanzas*). Apart from the engineer, all the decision-makers are members of the *ejidos*. Antinori and Rausser (2007) studied decision-making in CFEs. Their findings suggest that more technical decisions are left to an external expert such as the forest engineer. Decisions concerning commercialization can be taken either by the assembly or delegated to the authorities of the *ejido* (such as the *comisariado* or elected managers) but key policy decisions such as profit distribution or the purchase of a sawmill are discussed at the assembly.

Various authors have studied the impact of CFEs on the forest cover or carbon mitigation. Their conclusions suggest that CFEs development, and community-based management are more generally associated with reduced deforestation. With the implementation of REDD+ mechanisms, some authors advocate for the inclusion of community-based management as carbon-reducing activities (Klooster and Masera, 2000; Bray et al., 2004; Ellis and Porter-Bolland, 2008; Bray, 2010; Porter-Bolland et al., 2012). Nevertheless, despite the fact that CFEs comply with most international standards of sustainable forestry, few of them apply for Forest Stewardship Council (FSC) certification. According to Gerez Fernandez and Alatorre-Guzman (2005), the premium for certification perceived by *ejidos* is too low in comparison to its cost and can be captured at a higher level of the timber value chain. Moreover, CFEs mainly sell on local markets that do not value the certification.

6.2.2.2 CFE and the timber value chain

In 1997, PROCYMAF (see Section 6.2.2.3) developed an ordered classification of CFEs presented in Table 6.1. We will use this classification in our econometric analysis to capture the development of CFEs

Table 6.1: PROCYMAF Classification of CFEs

Type I	Potential producers: Owners or possessors of forestlands with capacity for sustainable commercial production that currently do not carry out logging because they lack an authorized forest management plan or sufficient means to pay for its elaboration.
Type II	Producers who sell timber on the stump: Owners or possessors of parcels subject to timber exploitation where the activity is carried out by third parties through commercial contracts without the owner or possessor participating in any phase of the extraction process.
Type III	Producers of forest raw material: Owners and/or possessors of forest parcels that have authorized participate directly in some phase of the production chain.
Type IV	Producers with capacity for transformation and marketing: Producers of raw forest materials that have infrastructure for its primary transformation and directly carry out the marketing of their products.

Source:(Bray et al., 2003a)

This classification reflects early levels of industrial development. Type I are potential producers but do not carry extraction activities under a management plan. Type II producers only sell their annuities to private sawmills and are usually con-

sidered as rentiers (*rentistas*) (CONAFOR, 2012; Bray, 2005). The *ejidos* are not in charge of timber extraction, private sawmills use their own equipment and labor forces² to cut the trees and transform them into sawnwood. The *ejido* only receives a payment for the annuity allowed by the management plan. Type III and IV producers provide labor and capital to cut and transform the timber before selling it. Type III producers sell sawnwood and Type IV producers further transform it into final products such as boards.

All the *ejidos* with extracting activities, Types II to IV, must invest in a management plan. However, only Type III and IV producers are directly involved in timber transformation and management. According to the definition of Antinori and Bray (2005) presented in Section 6.2.2.1, CFEs correspond to these producers. Eventually, one should note that higher stages of development are associated with higher investment requirements and better organizational capacity.

6.2.2.3 Dependence on external supports

The main threat for CFE sustainability lies in their dependence on private and public support for financial and technical assistance.

At the federal-level, CFEs have benefited from two main programs: PROCYMAF (*Proyecto de Conservación y Manejo Sostenible de Recursos Forestales*), a World Bank-funded program, and PRODEFOR (*Programa de Desarrollo Forestal*). PROCYMAF was started in 1999 and ended in 2008. This program offered technical assistance in land-use planning and managerial capacities for *ejidos* willing to invest in a CFE or for *ejidos* that had already developed extraction activities (Scheer et al., 2002; Merino-Perez and Segura-Warnholtz, 2005). This program was only implemented in six states. PRODEFOR was started in 1997. Unlike PROCYMAF, it did not focus exclusively on CFE development but rather more generally on forest management. It offered support for road construction, timber extraction and certification.

In 2009, CONAFOR started a new program based on PROCYMAF's experience: the PDFC (*Programa de Desarrollo Forestal Comunitario*). The support to CFEs that originally flew through PRODEFOR was transferred to the PDFC. Nevertheless, PRODEFOR still finances studies and training in forestry activities, including elaboration of forestry management plan (CONAFOR, 2009). Like the PSA-H, both programs are now part of ProArbol. Note that the PDFC is now entirely financed by fiscal resources and no longer benefits from World Bank support. According to CONAFOR, more than 3,000 *ejidos* have received support from PDFC, including 215 CFEs between 2007 and 2012.

CFEs also rely on external support from timber buyers. Given the land tenure of Mexican forests, timber buyers, such as private sawmills, cannot integrate backwards without working with *ejidos* (Antinori, 2005). They provide assistance to the *ejidos* and finance small investments in order to secure their access to timber resources. However, the buyers do not assume large investments because, without long-term

²Some *ejidos* informally force the sawmill to employ some persons from the *ejido*

contracts with the *ejido*, they are unable to secure an investment for longer than the length of the management plan.

Despite federal and private support, CFEs remain fragile and their development is constrained by a lack of liquidity, the difficulty of organizing tasks within *ejidos* and the low absorption capacities of local markets. For these reasons, CFEs tend to extract less annually than the volume of timber authorized by their management plan (Antinori, 2005; Torres-Rojo et al., 2005) and struggle to sustain their activities.

6.2.3 Can PSA-H contribute to CFE development?

PSA-H coverage of Mexican forests has considerably increased during the last decade and interactions between the PSA-H and CFEs has become crucial for forest management. As feared by Bray (2005), paying for conservation may reduce the incentive to invest in a CFE and slow down their development. *Ejidors* may favor conservation over timber exploitation which is more costly and risky. We argue that the PSA-H can be combined with CFEs and contribute to their development for three reasons:

- **PES can relax a credit constraint:** Developing and sustaining CFEs requires investment that needs to be regularly renewed. *Ejidors* are often credit-constrained, which prevents them from financing investments. The PSA-H can relax these constraints.
- **PES can increase access to information:** *Ejidors* are often unaware of the possibility of valorizing their resources through CFEs. By enrolling in the PSA-H, *ejidos* become closer to CONAOR staff and participate in environmental workshops and meetings with other *ejidos*. This can improve their knowledge about federal programs and increase their willingness to invest in a CFE.
- **PES can help to create and reinforce institutions for forest management:** Collective action is a crucial determinant of CFE development and Yanez-Pagans (2013) shows that the PSA-H tends to reinforce cooperation in collective activities within the *ejidos*. When enrolling land in the PSA-H, the *ejidatarios* commit themselves to implement different tasks such as patrolling in the forest or building firebreaks. The PSA-H can increase the involvement of *ejidatarios* in forest-related activities and can help to create and reinforce CFEs.

Our hypothesis is that PSA-H can help the CFEs to develop and stabilise over time. We test this hypothesis using a database of 223 *ejidos*.

6.3 Database

We test our hypothesis on the representative sample of *ejidos* surveyed in 2002 and 2010 for the ENNAF survey presented in Chapter 2. Our sample is composed of 223

ejidos. There are on average 190 *ejidatarios* in an *ejido* but this number varies from 10 to 3,500. The area of *ejidos* also varies from less than 200 ha to more than 127,000 ha. The mean area of an *ejido* in our database is 10,000 ha. Of our 223 *ejidos*, 49 received the PSA-H between 2004 and 2010. The distribution of beneficiary *ejidos* according to the year of reception is presented in Table 6.2

Table 6.2: First year of enrollment in the PSA-H by ENNAF *ejidos*

First year of reception	2003	2004	2005	2006	2007	2008	2009	2010	Total
Number of <i>ejidos</i>	2	11	6	2	14	7	4	3	49

Note that 10 out of 49 *ejidos* subscribed to more than one PSA-H contract between 2003 and 2010. These *ejidos* either enrolled different parcels of forest at different times or renewed their contract after the initial five year period.

We do not look only at PES reception but also at the heterogeneity regarding the time spent in the program ($tpsah_j$) and the total amount of payments spent in the program ($psahval_j$). As a matter of fact, we suspect that the impact of PSA-H on CFE development increases with increasing exposure to the treatment. Figure 6.1 shows the distribution of our interest variables for the beneficiaries of the scheme. The absolute payment varies from 170,000 pesos (approximately 13,000 USD in 2010) to more than 6,300,000 pesos (approximately 484,600 USD in 2010).

We will now look conjointly at PES reception and CFEs. Table 6.3 shows the distribution of PSA-H beneficiaries and non-beneficiaries according to CFE type as presented in Table 6.1. The higher percentage of PSA-H beneficiaries is among the more developed CFEs. While only 21,97% of our sample benefited from the PSA-H, more than half of the *ejidos* that owned a sawmill received the PSA-H.

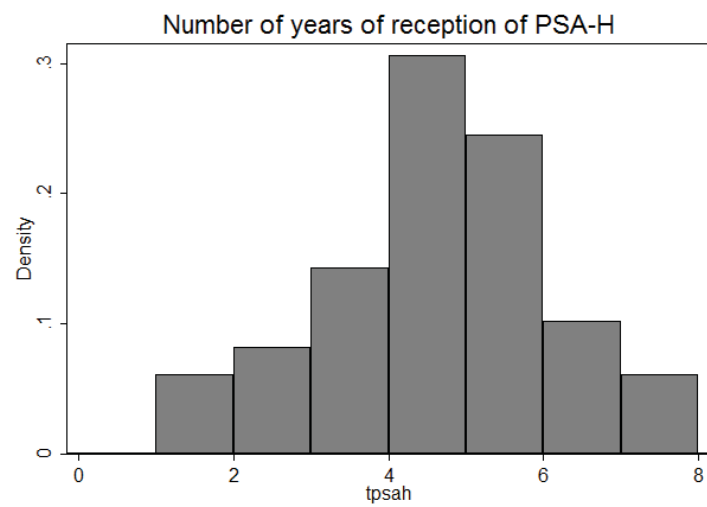
Table 6.3: Type of CFE and PSA-H reception

CFEs type 2010	Non PSA-H beneficiaries	PSA-H beneficiaries	Total	% of PSA-H beneficiaries
1: Potential producers	144	32	176	18,18%
2: Producers who sell timber on the stump	10	1	11	9,09%
3: Producers of forest raw material	15	4	19	21,05%
4: Producers with capacity for transformation and marketing	5	12	17	70,59%
Total	174	49	223	21,97%

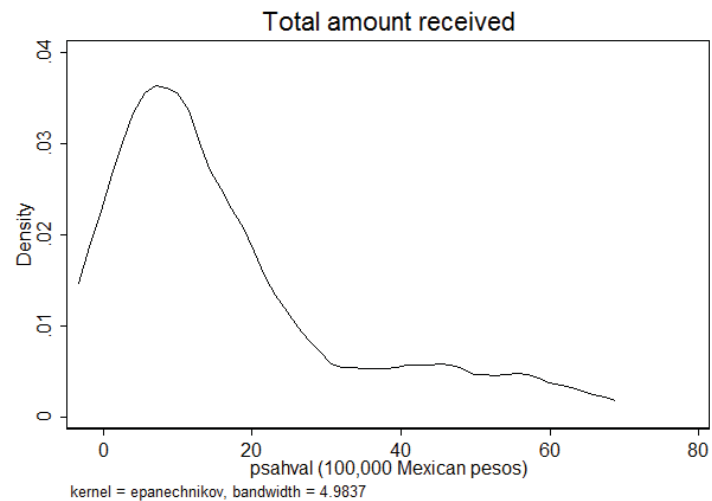
Table 6.4 presents the percentage of PES beneficiaries according to the evolu-

Figure 6.1: Number of year of PSA-H reception and amount received

(a) Time spent in the program



(b) Amount received in hundreds of thousands Mexican pesos



tion of the CFEs. We distinguish three groups: the first group ($cfe_j < cfe02_j$) corresponds to CFEs that regressed between 2003 and 2010 according to the typology presented in Table 6.1. The second group corresponds to CFEs that stabilized ($cfe_j = cfe02_j$) and the third group gathers CFEs that expanded ($cfe_j > cfe02_j$) i.e. according to the typology, they are more developed in 2010 than in 2002. We note that higher percentage of beneficiaries are found in the last two groups.

Table 6.4: Evolution of the CFEs' level of development and PSA-H reception

	Non PSA-H beneficiaries		PSA-H beneficiaries	
$cfe02 > cfe$	19	90,48%	2	9,52%
$cfe02 = cfe$	14	56,00%	11	44,00%
$cfe02 < cfe$	15	71,43%	6	28,57%

Figure 6.2 presents the distribution of our two interest variables for PSA-H beneficiaries according to the evolution of the CFE. Looking at Figure 6.2, we note that the *ejidos* that increased their activities between 2002 and 2010 received higher amounts and had been enrolled longer than the others. This also supports our hypothesis.

6.4 Econometric estimation

6.4.1 Econometric model

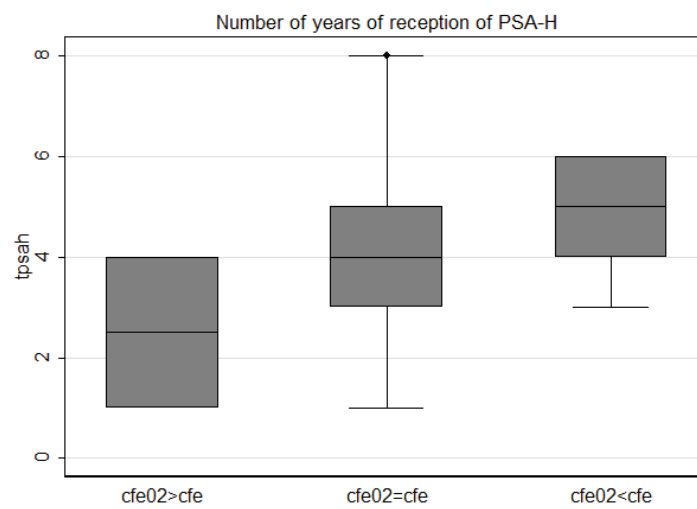
We are interested in estimating the impact of PSA-H reception on the level of CFE development. As other authors before (Antinori, 2000; Bray et al., 2003a; Antinori and Rausser, 2007), we use the PROCYMAF classification (see Table 6.1) in order to capture the level of development of the CFEs. This classification reflects an increasing involvement by the *ejidos* in the extraction and transformation process. Our variable cfe_j for *ejido* j is constructed as follows:

1. Potential producers
2. Producers who sell timber on the stump
3. Producers of raw materials (roundwood)
4. Producers with capacity for transformation and marketing (sawmill)

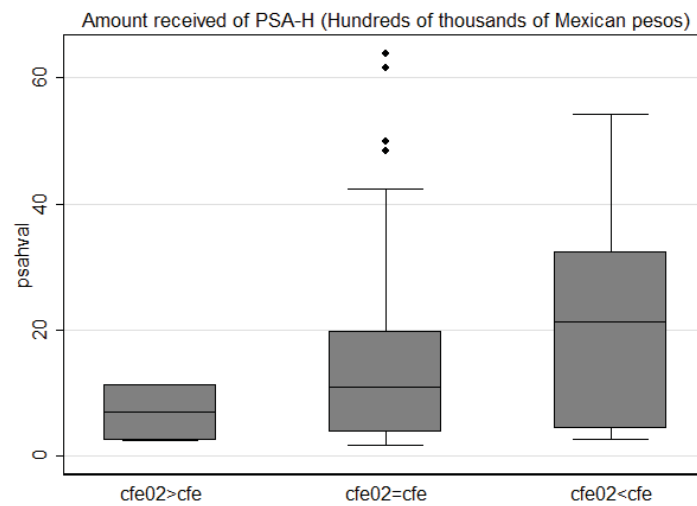
The impact of the PSA-H on CFE development is expected to be larger with increasing exposure to the treatment. We will consider here that exposure varies according to the time spent in the program and the amount of payments received. Therefore, as recommended by Miteva et al. (2012), we use continuous measures of PSA-H reception. Our variables of interest are defined as:

Figure 6.2: Time under PSA-H and amount received according to the evolution of the CFE

(a) Time spent in the program



(b) Amount received in the program



- $tpsah_j$: The number of year of reception of PSA-H by the *ejido* j between 2003 and 2010
- $psahval_j$: The sum of payments received by the *ejido* j between 2003 and 2010.

These variable have been computed thanks to CONAFOR's information.

Our explained variable cfe_j is multinomial and discrete. Therefore, we use an ordered probit to estimate the impact of PSA-H reception. We estimate the following models for two latent variables y^*_j and z^*_j :

$$y^*_j = \rho_1 tpsah_j + \lambda_1 X_j + \eta_1 \quad (6.1)$$

$$z^*_j = \rho_2 psahval_j + \lambda_2 X_j + \eta_2 \quad (6.2)$$

Given the threshold for each level of CFE, we will derive marginal effects of $tpsah_j$ and $psahval_j$ on each level of development of the CFE at average value of X_j .

In equation 6.1 and 6.2, X_j includes control variables such as the initial level of development of the CFE before PSA-H implementation ($cfe02_j$). We control for basic characteristics of the *ejido* including the number of *ejidatarios* ($ejidat10_j$), the size of the *ejido* in tens of thousands of hectares ($size_j$), the percentage of forest cover in 2002³ ($perfor02_j$), the mean slope ($meanslope_j$) and population density in 2010 ($density10_j$). We introduce proxies for remoteness and transactions costs using the distance to the closest road ($distroad_j$) and to the closest city of more than 2,500 habitants ($distcity_j$). We also control for the reception of technical assistance before 2002 ($at02_j$) and the illiteracy rates ($analph10_j$). Eventually, we control with dummy variable for three other economic policies that can possibly influence CFE development: PRODEFOR, PSA-CABSA⁴ and NPAs.

CFE development, reception of federal programs and demographic variables comes directly from the ENAFF survey. Data regarding PSA-H reception has been provided by CONAFOR. Illiteracy rates have been computed by CONAPO (National Population Council) at AGEB's level⁵ (*Area Geostatística Básica*). The other variables have been computed using GIS thanks to information from the Mexican Federal Statistical Institute (INEGI). More details about the definition and sources of each variable can be found in Table D.4 in the Appendix.

6.4.2 Checking for endogeneity

The main challenge to identifying the impact of PSA-H on CFE development is to deal with endogeneity of PSA-H reception. Endogeneity may arise for three reasons:

³The variable capturing the size of forests is computed using data from INEGI's Serie III with a resolution of 1:250000. It does not allow us to precisely estimate the forest cover at the *ejido*-level, but these data remain credible proxies for forest size.

⁴There are only 14 beneficiaries of PSA-CABSA in our sample

⁵In our sample, AGEB more or less overlap with municipalities.

- *Ejidors* with a CFE are closer to CONAFOR's staff, including technical advisors, than others. They have better access to information about the PSA-H, which increases their probability of enrolling in the program.
- *Ejidors* that have already developed a CFE are more inclined to favor environmental initiatives. Therefore, they are more likely to apply for the PSA-H.
- CONAFOR ranks applications for the PSA-H according to many selection criteria. Complying with a Management Plan is one of these criteria. At the margin, complying with a Management Plan can increase the probability that the PSA-H application will be accepted.

We introduce the lagged value of cfe_j in our estimations to control for most of the confounding factors generating endogeneity. Nevertheless, we test the presence of endogeneity using two-stage least squares (TSLS). The explained variable cfe_j being ordered and discrete, it would be better to run our estimations using an ordered probit but, to our knowledge, no instrumental variable estimators with an ordered probit as a second stage have been developed. The second stage of TSLS does not take into account the discrete nature of cfe_j but allows us to test the exogeneity of our interest variables.

The first step of the TSLS estimation must include instruments excluded from the second step. These instruments must be strong predictors of $tpsah_j$ and $psahval_j$ without directly impacting cfe_j . Based on PSA-H's operational rules, we identified two variables. The first is the area of mesophyll forests ($meso02_j$). This type of forest (often called cloud forest) is supposed to provide more environmental services and is remunerated with higher payments. The second variable is the number of years of eligibility of the *ejidos* ($telig_j$). As funds allocated to the PSA-H increased, more *ejidos* became eligible. We believe that the longer *ejidos* have been eligible, the more likely they are to apply and be accepted into the program. Nevertheless, it is unlikely that eligible zones have been defined based on a CFE's location.

We estimate the following models for the number of years spent in the program:

$$tpsah_j = \theta_1 + \rho_1 X_j + \gamma_1 Z_j + \mu_j \quad (6.3)$$

$$cfe_j = \alpha_1 + \beta_1 X_j + \sigma_1 \hat{tpsah}_j + \varepsilon_j \quad (6.4)$$

And the amount of payments received:

$$psahval_j = \theta_2 + \rho_2 X_j + \gamma_2 Z_j + \mu_j \quad (6.5)$$

$$cfe_j = \alpha_2 + \beta_2 X_j + \sigma_2 \hat{psahval}_j + \varepsilon_j \quad (6.6)$$

\hat{tpsah}_j and $\hat{psahval}_j$ respectively are predicted values of $tpsah_j$ and $psahval_j$, X_j is the vector of control variables and Z_j corresponds to the vector of instrumental variables ($meso02_j$ and $telig_j$).

The results of the estimations are presented in Table 6.5 and 6.6. Columns 1, 2 and 3, respectively, display the results of the model estimated using OLS and

Table 6.5: CFE and number of years of PSA-H reception between 2003 and 2010: Two-stage least square

VARIABLES	(1) cfe	(2) tpsah	(3) cfe
tpsah	0.0911*** (0.0330)		0.0985* (0.0566)
cfe02	0.4155*** (0.1380)	0.2067 (0.2553)	0.4139*** (0.1327)
size	0.0578* (0.0314)	0.0580 (0.0645)	0.0570* (0.0299)
perfor02	-0.3463 (0.2229)	0.4204 (0.5109)	-0.3528* (0.2108)
at02	0.4473 (0.2783)	-0.3575 (0.5306)	0.4480* (0.2662)
meanslope	0.0048 (0.0076)	0.0089 (0.0167)	0.0046 (0.0079)
analph10	0.0034 (0.0061)	-0.0076 (0.0141)	0.0034 (0.0060)
density10	-0.0030 (0.0589)	0.0689 (0.1481)	-0.0036 (0.0573)
distcity	-0.0139 (0.0520)	0.1411 (0.1485)	-0.0143 (0.0507)
distroad	-0.1135 (0.1347)	-0.1180 (0.2889)	-0.1123 (0.1294)
ejidat10	-0.0002** (0.0001)	0.0001 (0.0004)	-0.0002** (0.0001)
prodefor	0.1663 (0.1770)	0.0751 (0.2924)	0.1642 (0.1686)
cabsa	-0.1373 (0.2007)	-0.2740 (0.5282)	-0.1361 (0.1918)
npa	-0.0645 (0.1504)	0.9235** (0.4362)	-0.0754 (0.1771)
telig		0.2938*** (0.0535)	
meso02		0.0004*** (0.0001)	
Constant	0.7628*** (0.1901)	-0.8445** (0.3489)	0.7674*** (0.1888)
Observations	223	223	223
R-squared	0.4533	0.3449	0.4531

Notes: *=significant at the 1% level, **=significant at the 5% level, *=significant at the 10% level. Standard errors clustered at state-level. F-stat of excluded instrument=31.11(0.000). Sargan-Hansen statistic=0.244(0.6215). Wu-Hausman's statistics=0.010(0.9209)

Table 6.6: CFE and amount of PSA-H received between 2003 and 2010: Two-stage least square

VARIABLES	(4) cfe	(5) psahval	(6) cfe
psahval	0.0133** (0.0063)		0.0106* (0.0063)
cfe02	0.4568*** (0.1369)	-2.1255 (1.6467)	0.4525*** (0.1355)
size	0.0484 (0.0317)	1.2121* (0.6181)	0.0522* (0.0314)
perfor02	-0.3392 (0.2188)	1.9244 (2.5869)	-0.3243 (0.2143)
at02	0.3987 (0.2736)	2.7030 (3.5806)	0.4070 (0.2759)
meanslope	0.0046 (0.0077)	0.0662 (0.0976)	0.0052 (0.0080)
analph10	0.0029 (0.0060)	-0.0461 (0.0788)	0.0029 (0.0057)
density10	0.0052 (0.0611)	0.3434 (0.5650)	0.0052 (0.0591)
dist city	-0.0208 (0.0537)	1.6651 (1.0333)	-0.0184 (0.0513)
distroad	-0.1131 (0.1335)	-1.0779 (2.0439)	-0.1161 (0.1286)
ejidat10	-0.0002** (0.0001)	0.0041 (0.0037)	-0.0002** (0.0001)
prodefor	0.1794 (0.1749)	0.3979 (1.2478)	0.1820 (0.1679)
cabsa	-0.1574 (0.2031)	-0.1522 (2.7646)	-0.1563 (0.1989)
npa	0.0186 (0.1428)	2.3256 (2.1296)	0.0291 (0.1436)
telig		0.7873*** (0.2226)	
meso02		0.0053*** (0.0011)	
Constant	0.7631*** (0.1983)	-2.7458 (2.0750)	0.7518*** (0.1951)
Observations	223	223	223
R-squared	0.4427	0.4374	0.4420

Notes: * = significant at the 1% level, ** = significant at the 5% level, * = significant at the 10% level. Standard errors clustered at state-level. F-stat of excluded instrument = 21.37(0.000). Sargan-Hansen statistic = 1.485(0.2230). Wu-Hausman's statistics = 0.461(0.4972)

the first and second steps of TSLS both estimated using a linear functional form. In both cases, the instruments are significant and of expected signs. The F-test of joint significance is superior to 10 which allows us to reject the hypothesis that our instruments are weak. The over-identification test cannot reject the hypothesis that our instruments validate the exclusion restriction. Eventually, the exogeneity test confirms that the variables $psahval_j$ and $tpsah_j$ can be considered as exogeneous. Note that the coefficient of the variables $psahval_j$ and $tpsah_j$ remain significant and of similar magnitude as in the OLS estimation.

Since we cannot reject the hypothesis that our variables of interest $tpsah_j$ and $psahval_j$ are exogeneous, we now run estimations of the impact of the PSA-H on CFEs development using an ordered probit in order to correctly account for the discrete nature of cfe and be able to compute marginal effects.

6.4.3 Estimating the impact of PSA-H on CFE development

6.4.3.1 Results

We now turn to the estimation of equations 6.1 and 6.2. The results of the ordered probit estimations and associated marginal effects are presented in Table 6.7 and 6.8 which respectively estimate the impact of $tpsah_j$ and $psahval_j$ on CFEs.

According to the results presented in Table 6.7, enrolling in the PSA-H for five years decreases the probability that the *ejido* has no CFEs by 14.8% and increases the probability of being at stage 2, 3 and 4 by 3.05%, 5.25% and 6.5%, respectively. Note that the magnitude increases with the level of development of the CFEs. If, following Antinori and Bray (2005), we consider that CFEs are stage III and IV, a five-year contract increases by 11.75% the probability of having a CFEs.

Table 6.8 looks at the impact of the amount of payments received. An increase of one standard deviation of $psahval_j$ among beneficiaries (167 thousand pesos or about 128 thousand USD) decreases the probability of having no CFEs by about 8.5% and increases the probability at stage 2, 3 and 4 by 1.7%, 3% and 3.8%, respectively. Here again, the magnitude of the coefficient increases with the type of CFEs.

Moreover, technical assistance appears to be a strong determinant of CFEs development and the number of *ejidatarios* negatively impacts CFEs, which might be attributable to the difficulty of reaching an agreement in larger *ejidos*.

The variable $psahval_j$ captures the total amount of payments received by the *ejidos*. It implicitly captures both the impact of the time spent in the program (ie $tpsah_j$) and the impact of the amount of payments received every year. In order to disentangle the impact of the amount of payments from the impact of the time spent in the program, we introduce both variables in our estimations. The results are displayed in Table 6.9. These results should be taken with caution since multicollinearity is likely to arise when introducing both variables in the same estimation.

In table 6.9, the impact of $tpsah_j$ on CFEs remains positive, significant and

Table 6.7: CFE and number of years of PSA-H reception between 2003 and 2010: Ordered probit and marginal effects

VARIABLES	(1) cfe	(2) Pr(cfe=1)	(3) Pr(cfe=2)	(4) Pr(cfe=3)	(5) Pr(cfe=4)
tpsah	0.1599*** (0.0527)	-0.0296*** (0.0096)	0.0061** (0.0024)	0.0105*** (0.0038)	0.0130*** (0.0048)
cfe02	0.4438** (0.1963)	-0.0822** (0.0350)	0.0170* (0.0090)	0.0291** (0.0144)	0.0360** (0.0145)
size	0.1587** (0.0649)	-0.0294** (0.0124)	0.0061** (0.0030)	0.0104** (0.0047)	0.0129** (0.0059)
perfor02	-0.7647 (0.5286)	0.1416 (0.0974)	-0.0294 (0.0224)	-0.0502 (0.0372)	-0.0620 (0.0411)
at02	0.7568** (0.3526)	-0.1401** (0.0633)	0.0291** (0.0147)	0.0497** (0.0225)	0.0613** (0.0312)
meanslope	0.0108 (0.0179)	-0.0020 (0.0033)	0.0004 (0.0007)	0.0007 (0.0012)	0.0009 (0.0014)
analph10	-0.0019 (0.0144)	0.0004 (0.0027)	-0.0001 (0.0006)	-0.0001 (0.0009)	-0.0002 (0.0012)
density10	0.0565 (0.1291)	-0.0105 (0.0241)	0.0022 (0.0050)	0.0037 (0.0085)	0.0046 (0.0107)
distcity	-0.0378 (0.1069)	0.0070 (0.0198)	-0.0015 (0.0041)	-0.0025 (0.0070)	-0.0031 (0.0087)
distroad	-0.2814 (0.2255)	0.0521 (0.0425)	-0.0108 (0.0093)	-0.0185 (0.0152)	-0.0228 (0.0191)
ejidat10	-0.0019** (0.0008)	0.0003** (0.0002)	-0.0001* (0.0000)	-0.0001** (0.0001)	-0.0002** (0.0001)
prodefor	0.3111 (0.2777)	-0.0576 (0.0524)	0.0119 (0.0115)	0.0204 (0.0186)	0.0252 (0.0233)
cabsa	-0.3846 (0.4560)	0.0712 (0.0859)	-0.0148 (0.0184)	-0.0253 (0.0310)	-0.0312 (0.0375)
npa	-0.2958 (0.2737)	0.0547 (0.0517)	-0.0114 (0.0112)	-0.0194 (0.0182)	-0.0240 (0.0233)
Cut1	1.4475*** (0.4017)				
Cut2	1.7606*** (0.4143)				
Cut3	2.4779*** (0.4900)				
Observations	223	223	223	223	223

Notes: $Pseudo-R^2=0.2804$. *=*significant at the 1% level*, **=*significant at the 5% level*, *=*significant at the 10% level*. Standard errors clustered at state-level. Marginal effects are computed with dummy variables as balanced and at means of other variables.

Table 6.8: CFE and amount of PSA-H reception between 2003 and 2010: Ordered probit and marginal effects

VARIABLES	(1) cfe	(2) Pr(cfe=1)	(3) Pr(cfe=2)	(4) Pr(cfe=3)	(5) Pr(cfe=4)
psahval	0.0274** (0.0108)	-0.0051*** (0.0020)	0.0010** (0.0005)	0.0018** (0.0008)	0.0023** (0.0010)
cfe02	0.5575*** (0.1921)	-0.1042*** (0.0338)	0.0212** (0.0091)	0.0371** (0.0146)	0.0460*** (0.0150)
size	0.1431** (0.0607)	-0.0268** (0.0118)	0.0054** (0.0027)	0.0095** (0.0044)	0.0118** (0.0056)
perfor02	-0.7942 (0.5212)	0.1485 (0.0974)	-0.0302 (0.0220)	-0.0528 (0.0373)	-0.0655 (0.0417)
at02	0.5963* (0.3347)	-0.1115* (0.0611)	0.0227* (0.0137)	0.0397* (0.0219)	0.0492* (0.0289)
meanslope	0.0101 (0.0183)	-0.0019 (0.0034)	0.0004 (0.0007)	0.0007 (0.0012)	0.0008 (0.0015)
analph10	-0.0013 (0.0140)	0.0002 (0.0026)	-0.0000 (0.0005)	-0.0001 (0.0009)	-0.0001 (0.0012)
density10	0.0806 (0.1284)	-0.0151 (0.0242)	0.0031 (0.0049)	0.0054 (0.0086)	0.0066 (0.0108)
distcity	-0.0611 (0.1104)	0.0114 (0.0206)	-0.0023 (0.0042)	-0.0041 (0.0073)	-0.0050 (0.0092)
distroad	-0.2785 (0.2203)	0.0521 (0.0419)	-0.0106 (0.0090)	-0.0185 (0.0149)	-0.0230 (0.0191)
ejidat10	-0.0022*** (0.0009)	0.0004*** (0.0002)	-0.0001** (0.0000)	-0.0001** (0.0001)	-0.0002** (0.0001)
prodefor	0.3072 (0.2708)	-0.0574 (0.0515)	0.0117 (0.0112)	0.0204 (0.0183)	0.0253 (0.0231)
cabsa	-0.4148 (0.4664)	0.0776 (0.0885)	-0.0158 (0.0187)	-0.0276 (0.0321)	-0.0342 (0.0389)
npa	-0.1550 (0.2497)	0.0290 (0.0474)	-0.0059 (0.0098)	-0.0103 (0.0167)	-0.0128 (0.0212)
Cut 1	1.4387*** (0.3971)				
Cut 2	1.7471*** (0.4104)				
Cut 3	2.4576*** (0.4886)				
Observations	223	223	223	223	223

Notes: Pseudo- $R^2=0.2749$. *=significant at the 1% level, **=significant at the 5% level, *=significant at the 10% level. Standard errors clustered at state-level. Marginal effects are computed with dummy variables as balanced and at means of other variables.

Table 6.9: CFE, amount and number of years of PSA-H reception between 2003 and 2010: Ordered probit and marginal effects

VARIABLES	(1) cfe	(2) Pr(cfe=1)	(3) Pr(cfe=2)	(4) Pr(cfe=3)	(5) Pr(cfe=4)
tpsah	0.1220* (0.0691)	-0.0226* (0.0128)	0.0046 (0.0028)	0.0081* (0.0048)	0.0099* (0.0058)
psahval	0.0110 (0.0137)	-0.0020 (0.0025)	0.0004 (0.0005)	0.0007 (0.0009)	0.0009 (0.0011)
cfe02	0.4865** (0.1917)	-0.0900*** (0.0337)	0.0185** (0.0089)	0.0321** (0.0142)	0.0393*** (0.0143)
size	0.1529** (0.0630)	-0.0283** (0.0121)	0.0058** (0.0029)	0.0101** (0.0046)	0.0124** (0.0057)
perfor02	-0.8052 (0.5302)	0.1489 (0.0975)	-0.0306 (0.0224)	-0.0532 (0.0376)	-0.0651 (0.0412)
at02	0.6946** (0.3326)	-0.1285** (0.0597)	0.0264* (0.0138)	0.0459** (0.0216)	0.0562* (0.0289)
meanslope	0.0093 (0.0181)	-0.0017 (0.0033)	0.0004 (0.0007)	0.0006 (0.0012)	0.0008 (0.0014)
analph10	-0.0019 (0.0142)	0.0004 (0.0026)	-0.0001 (0.0005)	-0.0001 (0.0009)	-0.0002 (0.0012)
density10	0.0668 (0.1301)	-0.0124 (0.0243)	0.0025 (0.0050)	0.0044 (0.0087)	0.0054 (0.0107)
distcity	-0.0477 (0.1100)	0.0088 (0.0203)	-0.0018 (0.0042)	-0.0031 (0.0072)	-0.0039 (0.0089)
distroad	-0.2824 (0.2229)	0.0522 (0.0420)	-0.0107 (0.0091)	-0.0187 (0.0150)	-0.0228 (0.0189)
ejidat10	-0.0021** (0.0009)	0.0004** (0.0002)	-0.0001** (0.0000)	-0.0001** (0.0001)	-0.0002** (0.0001)
prodefor	0.3081 (0.2776)	-0.0570 (0.0524)	0.0117 (0.0114)	0.0203 (0.0187)	0.0249 (0.0233)
cabsa	-0.4167 (0.4565)	0.0771 (0.0860)	-0.0159 (0.0183)	-0.0275 (0.0313)	-0.0337 (0.0376)
npa	-0.2814 (0.2715)	0.0520 (0.0513)	-0.0107 (0.0110)	-0.0186 (0.0182)	-0.0227 (0.0231)
Cut 1	1.4220*** (0.3991)				
Cut 2	1.7349*** (0.4118)				
Cut 3	2.4581*** (0.4890)				
Observations	223	223	223	223	223

Notes: $Pseudo-R^2=0.2820$. *=*significant at the 1% level*, **=*significant at the 5% level*, *=*significant at the 10% level*. Standard errors clustered at state-level. Marginal effects are computed with dummy variables as balanced and at means of other variables.

of similar magnitude to that in Table 6.8 but the impact of $psahval_j$ is no longer significant. This result suggests that the time spent in the program matters more than the amount of payments received. In Section 6.2.3, we identified three transmission channels through which the PSA-H can positively impact the development of CFEs. Results from Table 6.9 suggest that the credit constraint may not be an obstacle to CFEs development or that the amount received by all beneficiaries of the PSA-H is sufficient to overcome it. Therefore, positive impact of the PSA-H on CFEs development can be attributed to one of the two other channels: the access to information and the development of institutions of forest-management.

6.4.3.2 Robustness tests

In Section 6.4.2, we tested the endogeneity of the variable of interest in our estimations. Since this issue is crucial to validate our identification strategy, we run three robustness tests. Results of the robustness tests are displayed in the appendix D.

First, we test our results on a sub-sample of eligible ejidos. Eligible ejidos share some common characteristics and non-eligible ejidos may not constitute a relevant control group. We restrict our sample to the ejidos that have been eligible in at least one year between 2004 and 2010. Our sample is now constituted of 159 ejidos: 110 non beneficiaries and 49 beneficiaries⁶. The results of the ordered probit presented in Table D.1 are very similar to those obtained using the whole sample.

The results may also be biased because of proximity between CONAFOR and the *ejidos* that already had a CFE before PSA-H implementation. We check the robustness of our results on a sub-sample composed of *ejidos* that already had a Management Plan in 2002 (Types II to IV). These *ejidos* are likely to share the same proximity with CONAFOR and have access to the same information. The results of the ordered probit estimations are reported in Table D.2. The impact of the PSA-H remains positive and significant which confirms our previous results⁷.

Eventually, we run a placebo regression by estimating the impact of PSA-H reception on the level of CFE before PSA-H implementation in 2002. If the PSA-H remains a significant predictor of the lagged value of CFEs, our results might be driven by unobservable confounding factors. The results are presented in Table D.3. The variables $tpsah$ and $psahval$ are not significant in this model which confirms the validity of our empirical strategy.

6.5 Conclusion

We explore the interactions between the PSA-H, a Mexican federal PES, and community forestry in Mexico. With the expansion of PSA-H coverage, the scheme has come to interact with existing forms of sustainable forest management, such as

⁶Note that there are no defiers (always taker) in our sample: all the beneficiaries were eligible.

⁷It would also be relevant to test the robustness of our results on the other sub-sample which is composed of the *ejidos* that did not have a CFE in 2002. Nevertheless, since most of these *ejidos* still do not have a CFE in 2010, the variable CFE would be highly censored.

CFEs, and one may wonder if paying for conservation can discourage investment into a CFE. Our results suggest that the PSA-H does not negatively impact CFEs and can contribute to their stabilization and development. After rejecting the endogeneity of PSA-H reception using TSLS, we run an ordered probit in order to estimate the PSA-H's impact on CFEs development. Our empirical analysis confirms that the PSA-H positively impacts the development of CFEs. Controlling for the initial development of the CFE and other covariates, we find evidence that the amount of payments received and the number of years of reception have a significant and positive impact on the level of development of the CFE.

According to our estimations, the number of years of reception matters more for a CFEs development than the amount of payments. This result suggests that the positive impact may not be due to credit constraints or at least that, given reception, the amount of payments received are sufficient to overcome this constraint. Other alternative transmission mechanisms include information access and organizational capacities. First, the PSA-H brings *ejidos* closer to CONAFOR and increases their knowledge about CFEs. Second, the PSA-H can help to create and reinforce forest management institutions at the *ejido*-level. In both cases, CONAFOR's technical advisors, who are the main agents in contact with the *ejidos*, play a crucial role in providing the information, helping the *ejidatarios* to organize and suggesting how PSA-H money can be invested into a CFE.

Permanence of PES impact after the end the contracts is questionable so one should wonder how to impulse sustainable changes in forest management (Pirard et al., 2010; Karsenty, 2011). Interactions between economic policies may have the potential to impulse that shift. In the influential "*PES: some nuts and bolts*", Wunder (2005) suggested that the PES could act as a temporary instrument allowing a "*desired shift toward sustainable forestry*" in profitable forests. We here provide an example of positive interactions between two instruments. If Community Forestry has the potential to generate long-term incentives for forest conservation (Bray, 2010; Porter-Bolland et al., 2012, among others), they struggle to emerge and stabilize over time for many reasons enounced in Section 6.2.2.1. PES alone cannot overcome all the constraints but has the potential to be a first step toward sustainable management. Nevertheless, these positive interactions of the PSA-H with Community Forestry emerged as a side-effect of the environmental policies and not from a coordinated policy process. Our study shows that, in order to promote this type of synergy, interactions must be monitored both at federal and landscape level through a policy mix able to enhance permanence of conservation projects.

General Conclusion

This dissertation examines the effectiveness of a Mexican federal PES program: the PSA-H. Answering the call by [Ferraro and Pattanayak \(2006\)](#) and [Miteva et al. \(2012\)](#) for more IE of conservation instruments, we propose three empirical essays based on primary survey data collected in a sub region of Yucatan State, the *Cono Sur*, and a representative database of forested *ejidos*.

Once the academic debates around PES design and effectiveness and the context of our study are presented, the dissertation discusses the various IE techniques based on the existing academic literature ([Arriagada et al., 2012](#); [Alix-Garcia et al., 2012](#); [Robalino and Pfaff, 2013](#), among others). We also show that applying a classic IE estimator to the case of PES scheme requires numerous adjustments.

The first empirical essay, presented in Chapter 4, proposes a new methodological approach to PES impact estimation and its application to the PSA-H in Mexico's *Cono Sur*. Our approach allows us to simultaneously estimate the program's impact on protected parcels and leakages using tools provided by spatial econometrics. We deal with selection bias using pre-matching. Our results confirm that leakages can undermine or even offset the additonicity of PES on protected parcels.

Chapter 5 looks at payment redistribution within Mexican *ejidos*. Based on household and *ejido* surveys, we study how the heterogeneity of types of land use within the *ejidos* in the *Cono Sur* has influenced inequality in payment redistribution. Our study shows that the type of land use is a strong determinant of inequality in redistribution and that lower payments are allocated to cattle ranchers who are the primary deforesting agents. Following the Coasean definition of PES, the Mexican authorities designed the PSA-H as compensation for the agents that would deforest in the absence of the program. However, the scheme is understood as a reward by the *ejidatarios* demonstrating that the polluter-paid principle is both difficult to appropriate and likely contrary to *ejidatarios'* conception of fairness.

Based on a nationally representative database of *ejidos*, Chapter 6 looks at the interactions between the PSA-H and Community Forest Enterprises. One might fear that paying for conservation could discourage investment in CFE. However, our empirical results suggest the contrary: the PSA-H has helped the CFE to develop and stabilize. This result may be attributable to various mechanisms. First, the PSA-H can relax credit constraints allowing investment in a CFE. Second, the scheme may increase interactions with CONAFOR's staff and improve access to information concerning the possibility to valorize timber resources through a CFE. Third, to receive PSA-H payments, the *ejidos* must implement a number of tasks related to forests management. The PSA-H has the potential to create forest management

institutions that are necessary for the emergence and stabilization of the CFEs.

Policy perspective

From a policy perspective, the dissertation highlights two main obstacles to PES effectiveness.

First, today, the PSA-H is highly flexible for the *ejidos*. As highlighted in Chapter 4, the PSA-H offers payments for a period of five years on areas of forests which are unlikely to generate additionality because of adverse selection within the *ejidos*. Moreover, the scheme does not include further restriction on unprotected forests. In essence, PES are voluntary schemes so one cannot oblige forest owners to put all their forest endowment under conservation. In such a situation, leakages are very likely to occur. Moreover, the scheme includes no guarantee that the areas will not be cleared at the end of the five years.

Nevertheless, as suggested by Chapter 6, PES schemes can be complementary with additional intervention and can be the first step toward forest cover sustainable management within *ejidos*. The need to combine PES with investment has also been emphasized by Pirard et al. (2010) and Karsenty (2011). Most *ejidos* that were eligible showed a willingness to join the program. For conservation policy, PES schemes can be the foundation of a sustainable transition. However, achieving such a transition requires investment in new income generating activities that would relax landowners' dependence on forest clearing.

Second, Chapter 5 demonstrates that more efforts are needed to involve deforesting agents in the process of forest conservation. In line with Wunder's definitions (Wunder, 2005, 2015), PES schemes are complex instruments based on polluter-paid principles. The forest owners and intermediaries between ES sellers and buyers may not accept and appropriate such an approach. This is especially problematic when dealing with commons because the appropriation of the program by the forest owners determine the final allocation. In the case of the PSA-H, the scheme is perceived as a reward and deforesting agents do not feel concerned by the program or are partially excluded from its benefits.

Modifying the form of the payments could be a way to involve more deforesting agents in the conservation process. Individual payments could be offered to all *ejidatarios* proportionally to the total share of commons owned, combined with a joint liability to conserve the forest cover. In this scheme, payments would be individualized but the conditionality would be collective.

In line with sustainable transition, CONAFOR could encourage the investment of the payments in alternative activities. The investment could be combined with other CONAFOR's sustainable forest management programs. However, the alternative activities would need to be adapted to the types of land-use found in the *ejido*. Land users, in our case cattle ranchers, may be less reluctant to enroll in the PSA-H and abandon a production mode they have been relying on for many years if they are offered alternatives for ecological intensification or sylvo-pastoralism.

Our conclusions makes it clear that PES schemes must be included in a larger

policy-mix (Ring and Schröter-Schlaack, 2011; Barton, 2014). State and NGO interventions must be coordinated at the *ejido* level through relevant land use planning that combines areas of forest conservation, sustainable forestry and the development of sustainable agricultural systems. As highlighted by Chapter 4, PES alone are likely to have a limited impact over the long term but may be the first step toward a larger sustainable transition.

Prospects for future research

Given the demand for more IE, more research is needed on the identification of additonicity and leakages. It is undeniable that using IE methodologies reduces the selection bias but most existing IE of PES impacts rely on contestable assumptions such as the selection on observable or the absence of diffusion effects (SUTVA). More importantly, as these IE techniques for the evaluation of environmental projects have become widely employed, a great deal of caution should be taken in their application. As emphasized in Chapter 3, each technique relies on important assumptions. Hence, to make the most of scarce resources, it is crucial to consider the assumptions of the estimator in order to build the best identification strategy at the very beginning of the evaluation process and especially before the sampling process.

Moreover, as emphasized by Ferraro (2009), IE requires an adequate theory of changes and rival explanations to explain a result. The heterogeneity of the impact over space and time may be more helpful than the ATT. Looking at other outcomes and particularly at the impact on the economic activities of beneficiary households might be relevant in building a theory of change and in assessing permanence and leakages. Moreover, in no case, should IE substitute for institutional approaches to scheme analysis (Corbera et al., 2009; Shapiro-Garza, 2013).

Another unexplored area of research concerns the cost side of conservation policies. According to Ferraro and Pattanayak (2006) and Vincent (2015), since IE methodologies have been applied to conservation issues, more attention has been given to the outputs through the measures of additonicity and heterogeneity over space. However, the costs of public policies are also likely to be very heterogeneous. A valuation of PES' benefits would also be helpful to compare with its costs (Pagiola et al., 2004b; Chevassus-au Louis et al., 2009). The higher cost-benefit ratio may not be found where the ATT is higher, which may dramatically change the priority of the program.

Finally, the term PES is used in many contexts and often refers to a wide variety of instruments. More research is needed to compare the varying designs of PES schemes according to their different allocation mechanisms (auctions vs selection with targeting criteria), the form of the payments (in-kind vs in-cash) and the timing of payments (proportional over time vs higher front-payments) (Jack, 2009; Ajayi et al., 2012; Clot and Stanton, 2014). Lab-in-field experiments or Randomized Controlled Trials (RCT) would be extremely helpful in such comparisons. Shaping PES schemes differently may help to involve deforesting agents in the process and increase additonicity.

Ecosystem services and PES schemes have been at the core of environmental policies for more than 15 years and continue to fuel academic debates. These debates reappear in the public sphere as highlighted by the controversy over the use of so-called market-based instruments and their effectiveness in reducing deforestation. This dissertation discusses the effectiveness of the Mexican PSA-H but its conclusions could be applied in many settings. Despite some pessimistic findings about leakages and permanence of the scheme, the dissertation also highlights the potential benefits of this PES instrument and its attractiveness to forest owners. The scheme alone is unlikely to have a long-term impact but synergies can be found with other instruments to begin a transition toward sustainable activities. We do not take a position against the use of PES instruments for conservation but advocate for their adaptation and integration into a coordinated policy mix.

Appendices

APPENDIX A

Appendix to Chapter 2

A.1 Allocation criteria of the PSA-H in 2010

PSA-H and PSA-CABSA common criteria

- Location inside a federal NPA
- Location within the sixty priority mountains defined by CONAFOR
- Located in a watershed whit other PSA-H
- Participation to a comity of environmental vigilance participatory
- Application grouped in order to form a biologic corridor
- Application sent with documentation showing the disposition to pay of environmental services users
- The location has land-use plan approved by CONAFOR
- The location is located in zones with higher risk of deforestation
- Located inside a municipal, state-owned or private NPA
- Higher density of biomass
- Located inside a promising area for environmental services defined by CONAFOR

PSA-H criteria

- Percentage of forest cover
- Location in an overexploited aquifer
- Location in a watershed with lower water-availability and location inside the watershed
- Degradation of the soil
- Predominance of evergreen high jungle
- Location inside strategic zones of restoration
- Location in a zone of low timber production

A.2 Ejido-level questionnaire

PESMIX - Cuestionario ejido Yucatán 2012

Nombre del ejido: _____ .ID: _____
 Nombre del encuestador: _____
 Fecha: ____/____/____. Hora en el comienzo de la entrevista: _____ Hora al terminar la entrevista: _____
 Contacto: Nombre _____ Tel: _____

A. Historia y población

1. Fecha de fundación: _____
2. Eventos importantes en la historia del ejido (crisis económica, inundación, huracanes, seca, enfermedades del ganado o plagas agrícolas, conflicto)? _____

3. Demografía: Ejidatarios: _____ Poseesionarios: _____ Vecindados: _____

4. Población total del ejido: _____ Población total en 2005? _____ Población total en 1999? _____

5. ¿Cuántos ejidatarios pertenecen a los siguientes grupos de edades?

0-30	30-40	40-50	50-60	Más de 60	TOTAL

6. ¿Cuántas personas de la comunidad no viven permanentemente en el ejido (no trabajan en el ejido) y viven en?

	Estados Unidos	México (País)
2012		
2005		
1999		

C. PSA-H

8.a. ¿Reciben el PSA-H? (1.Sí; 0.No) _____

	Año	Polígono
Contrato 1		
Contrato 2		
Contrato 3		
Solicitud en trámite 1		
Solicitud en trámite 2		

8.b. ¿Si no recibieron PSA-H, ya lo solicitaron? (1.Sí; 0.No) _____

Si sí, año: _____

Si sí, por qué no lo recibieron: _____

8.c. ¿Si no recibieron PSA-H, por qué no lo solicitaron? _____

9. ¿Cuando escucharon por primera vez hablar del PSA-H? _____

¿Cómo? _____

- T . Técnico;
- Ej. Otros ejidos;
- Of. Oficiales;
- M. Media;
- O . Otro especificar _____

10. ¿Cuál es la regla con respecto a la repartición de los pagos? _____

11. Con respecto de la remuneración:

¿Quien puede ser remunerado? _____

- 1: Ejidatarios;
- 2: Ejidatarios y poseionarios;
- 3: Todos

¿Qué tipo de trabajo? _____

12. Con respecto de la distribución:

¿Quien puede recibir? _____

- 1: Ejidatarios;
- 2: Ejidatarios y poseionarios;
- 3: Todos

¿Cuál es la regla de distribución? _____

- 1: Igualmente; especificar _____
- 2: Proporcionalmente especificar _____
- 3: Un solo grupo especificar _____
- 4: Otros especificar _____

13. Con respecto al técnico:

Nombre del técnico : _____

Empresa : _____

¿Cuántas veces venía el técnico al ejido en 2012? _____

14. ¿Cuántas veces participaron a pláticas sobre los programas de la CONAFOR en los últimos cinco años? _____

15. Repartición del PSA-H:

Año	# Ha	Valor total (+ técnico)	Inversión colectiva		Técnico.	Remuneración		Distribución	
			\$	Tipo*		\$	# pers.	\$	# pers.
2003									
2004									
2005									
2006									
2007									
2008									
2009									
2010									
2011									
2012									
Solicitud (%)									

*Inversión: 1. Actividad productiva; 2. Infraestructuras públicas; 3. Infraestructuras forestales; 4. Micro-crédito; 5. Otro (especificar _____)
La inversión no debe incluir los montos de remuneración!!!!

D. Tenencia

16. Superficie total del ejido: _____ Ha

17. Número de polígonos: _____

18. Dotación: _____ Ha

19. Ampliación: _____ Ha Fecha: _____ Ha Ampliación: _____ Ha Fecha: _____

20. ¿Cuándo terminaron el PROCEDE? _____

21. ¿Cuál es la regla de rotación del monte dedicado a la milpa? :

	PROCEDE*	PSA-H*
Antes		
Después		

*1. Parcelado; 2. Rotación por polígono; 3. Rotación libre en uso común; 4. Otra (especificar)

Descripción (si es un sistema mixto, especificar por polígono): _____

22. ¿Si hay tierra parcelada (PROCEDE o no), cuántas hectáreas corresponden a cada ejidatario?:

Año	1-10	11-20	21-30	31-40	Más de 40
2012					
2005					
1999					
Con PROCEDE					

23. ¿Se ha vendido tierra en el ejido? (1.Sí; 0.No) _____

Año	Superficie (ha)	Precio	Origen del comprador *

*Origen del comprador : 1.Externo; 2.De la comunidad

24.a. ¿ Cuántas personas del ejido alquilan tierras fuera en?: 2012: _____ 2005: _____ 1999: _____

24.b. ¿Cuántas personas exteriores alquilan tierras en el ejido en? : 2012: _____ 2005: _____ 1999: _____

24.c. ¿A qué precio se alquila un hectárea por año de pastos: _____ Tierra agrícola: _____

27.a. Agricultura mecanizada y/o con agroquímicos (7, 8 y 9)-Puede ser más de un polígono si la tecnología cambia

Políg.	PROCEDE/ Por acuerdo	Riego (1. Si; 0. No)	# Pers	Fecha de desmonte	Cult*	# ha cultivados				Si Milpa: rendimiento
						2012	2005	1999	Max en el pasado	

* 1. Milpa; 2. Arboles; 3. Horticultura

27.b.

	2012	2005	1999
Tractores			
# En sociedad			
# Individual			

27.c. Tecnología

	Evolución de la tecnología de cultivo de maíz mecanizado						Rendimiento promedio
	Preparación de tierra *	Siembra *	Fertilización *	Riego (Si/No)	Cosecha *	Control de malezas *	
2012							
2005							
1999							

* 0. Manual; 1.Mecanizado; 2.No hay

F. Actividades económicas

30. Tipología de actividades y repartición del PSA-H por contrato (repartición entre los diferente grupos como estaban el año de recepción del PSA-H)

Hogares de ejidatario y poseionarios	2012	2005	1999	PSA-H N°1 Año:			PSA-H N°2 Año:					
				% Pers	Min	Max	Prom	% Pers	Min	Max	Prom	
<i>Hogares de ejidatario y poseionarios cuyas tierras se trabajan</i>												
Trad												
Ganado												
Meca												
Trad+Ganado												
Trad + Meca												
Meca + Ganado												
Trad + Meca + Ganado												
<i>Hogares de ejidatario y poseionarios cuyas tierras no se trabajan</i>												
Off-farm solo (incl. migrante)												
No trabajan (enfermedad, edad...)												
Avecindados												
TOTAL												

Meca= Milpa mecanizado +cultivo comercial

31.a. ¿Cuántos productores venden maíz? _____

31.b. ¿A qué precio lo venden? _____

32. Evolución de colmenas :

Abejas	2012	2005	1999
# Ejidatarios con colmenas			
# Colmenas			

33. ¿Para bovinos, cuantas personas tienen? :

Año	1-10	11-20	21-30	Más de 30	Total bovinos
2012					
2005					
1999					

34. ¿Cuántos pequeños rumiantes (carneros o chivos) hay en el ejido ahora? _____ En 2005 _____ En 1999 _____

35. ¿Existen otras actividades colectivas que generan ingresos en el ejido (turismo etc.)? _____

G. Regla de utilización de la tierra

36.

Reglas		Polígono después PSA-H	Polígono antes de PSA-H	Descripción	L/Ej/PA/LPSA*	Supervisión (por año en 2012)		# Infracciones los últimos 3 años	Sanción***
						Quien**	Frecuencia		
Vender Madera	Se puede								
	No se puede								
Vender Leña	Se puede								
	No se puede								
Extraer de leña para auto-consumo	Se puede								
	No se puede								
Vender de Carbón	Se puede								
	No se puede								
Extraer material para construcción	Se puede								
	No se puede								
Cazar para venta	Se puede								
	No se puede								
Cazar para auto-consumo	Se puede								
	No se puede								
Acceso del ganado al monte de uso común	Se puede								
	No se puede								
Acceso de bovino después cosecha	Se puede								
	No se puede								
	Se puede								
	No se puede								
	Se puede								
	No se puede								

* L: Federal y Estado; Ej : Ejidal (escrita); PA: Informal (por acuerdo); LPSA: Reglamento del PSA-H

** S: Agente Publico; CV: Consejo de vigilancia; R: Persona remunerada por el ejido; PM: Peer Monitoring

*** 3. M: Multa; A: Advertencia; N: No se aplica

H. Acción colectiva

37.a. Mantenimiento de los bienes comunes

Faenas/ Mantiene infraestructuras	Frecuencia en los últimos 5 años	Cuántas personas se necesitan para hacer el trabajo	% de defección los últimos cinco años	Obligatorio (1:Si/0:No)	R/NR/NRV**
Cercos					
Rutas					
Guarda rayas					
Ronda del PSA-H					
Vigilancia					
Limpieza espacios comunes					

** R. Remuneración; NR. No remunerado; NRV: No remunerado pero de facto personas son remuneradas (faenas colectivas cuando un ejidatario paga a alguien para hacerla).

37.b. ¿Si hubo remuneración, cual es el salario por día de trabajo? _____ Pesos

I. Organización del ejido

38. ¿Cuánto veces se junto la asamblea en 2012? _____

39. ¿Quién puede participar? _____

- 1 : Todos
- 2 : Ejidatarios únicamente
- 3 : Ejidatarios + Posesionarios

40. ¿En promedio cuántas personas participan en 2012? _____

41. Lista los 3 últimos comisariado

Nombre	Fecha	Edad a la fecha	Número de candidatos	Resultado de la elección (%)

42. Lista las organizaciones que existen en el ejido:

Organización	Pers. del ejido	Tipo*

* 1. Organización de productores (asociación o cooperativa); 2. Grupo de actividad social (mujeres, jóvenes, deportiva, cultural)

43. ¿Los últimos 10 años, cuantos desacuerdos hubo entre los habitantes con respecto? :

Desacuerdos	I/E*	Describir
Límites de parcelas		
Uso de bosques		
Uso de pastos		
Límites del ejido		

* I. Interno ; E. Externo

I. Infraestructura

44. ¿Hay alguna escuela en el *ejido*? (0: No/1: Si) _____

Nivel máximo : _____

1 : Primaria;

2 : Secundaria;

3 :Preparatoria.

4 : Universidad

Si no hay: _____ km para ir a primaria

45. ¿Cuántos ejidatarios estudiaron hasta la Primaria: _____

Secundaria: _____

Preparatoria: _____

Estudios superiores: _____

46. ¿Hay servicios de salud en el *ejido*? (1.Sí; 0.No) _____

Si no hay: _____ km al centro de salud básico

47. ¿Cuántas personas tienen teléfonos en el *ejido*? _____ ¿Internet?: _____

48. ¿Cuál es la distancia al mercado? _____ km ¿Tiempo por vehículo? _____

49.a. ¿Hay organismo de crédito en el *ejido*? (1.Sí; 0.No) _____

49.b. ¿Cuántas personas del *ejido* recibieron un crédito los últimos diez años? _____

K. Otros programas federales

50. ¿Cuáles son los programas que conocen? (Escribir por orden de enumeración)

51. ¿Los últimos diez años, recibieron los siguientes programas (si programa anual último año solamente)? :

PROCOREF	Año	Ha	Año	Ha
	Año	Ha	Año	Ha
Brecha Corta Fuego (no PSA-H)	Año	Km de Brecha	Año	Km de Brecha
	Año	Km de Brecha	Año	Km de Brecha
PRODEFOR	Año	Tipo de apoyo	Año	Tipo de apoyo
Plan de Manejo para producción de carbón	Ha	Año	Ha	Año
UMA	Ha	Año	Ha	Año
70 y mas	# Pers.			
Oportunidades	N° de hogares			
PROGAN (en # de hogares)	Bovino	Abeja	Borrego	
Eco-certificación	Año	Obs :		
Otros programas:				

L. Perspectivas a futuro

A. Con respecto al PSA-H:

52. ¿Qué ha hecho la gente con el subsidio de PSA-H? _____

53.a. ¿Cree usted que el PSA-H : _____

- 1: No ha cambiado nada
- 2: Ha sido ayuda
- 3: ha traído problemas

53.b. ¿Por qué y cómo (actividad de producción, cohesión social, los recursos ambiente...)? _____

53.a. ¿Qué piensan hacer en los montes una vez que termine el PSA-H? _____

- 1. Otra solicitud
- 2. UMA
- 3. Milpa o pastos
- 4. Conservación sin programa
- 5. Otro: _____

53.b. ¿Por qué? _____

54. ¿Qué desearía cambiar en el sistema del PSA-H? _____

A.3 Ejido-level questionnaire

Proyecto PESMIX

Encuesta hogar 2013
Yucatán

Nombre del encuestador: _____
 1: Lucely; 2: Roberto; 3: Pedro; 4: Santos; 5: Luis; 6: Driss

Fecha: ____ / ____ / ____ (día/mes)

Hora en el comienzo de la entrevista: _____ Hora al terminar la entrevista _____

Nombre del entrevistado: _____

Clave:

Código del Ejido	Código del cuestionario	

I. Composición y características del hogar

clarificar la definición del hogar

1. Sexo del jefe de familia: _____
 1. Masculino; 2. Femenino.

2. Edad: _____

3. Estado Civil: _____
 1. Soltero; 2. Casado; 3. Divorciado; 4. Viudo; 5. Unión libre

4. ¿Cuál es su estatuto? _____
 1. Ejidatario; 2. Poseionario; 3. AVECINDADO / Poblador
 4: otro (especificar)

5. ¿Dónde vives? _____
 1: en el ejido; 2: en un pueblo (especificar)

6 ¿Cuántas personas viven en su casa en 2013?
 _____ niños (menores de 12 años)
 _____ jóvenes (entre 12 y 18 años)
 _____ adultos (entre 18 y 60 años)
 _____ ancianos (mayores de 60 años)

7. ¿Cuántas **personas/meses** participar a la siguientes actividades?

Año	Viven en su casa (personas)	Contribuyen al ingreso (personas)	Trabajo agrícola (meses)	Trabajo asalariado permanente* (meses)	Trabajo asalariado temporal* (meses)	Auto-empleo* (meses)	Migrantes temporales** (meses)	Migrantes permanentes** (personas)	Otra actividad* (meses)	Aportar remesas (personas)
2013										
2005										
1999										

*Especificar el tipo de actividad / ** Especificar la localización de los migrantes

8a. ¿Por cuánto tiempo ha vivido en la comunidad? _____ años 8b ¿Desde hace cuánto tiempo ha tenido su status actual? _____ años

9a. Nivel máximo de estudios del jefe de familia: _____

0. No sabe leer ni escribir; 1. Sabe leer y escribir; 2. Primaria 3. Secundaria; 4. Preparatoria; 5. Universidad

9b. ¿Cuántos de los integrantes de la familia que viven aquí actualmente (mayores de 12 años) van a la escuela (estudian secundaria, preparatoria o la universidad)? _____

9c. ¿Cuántos de todos los integrantes de la familia mayores estudiaron (preparatoria o la universidad)? _____

10. ¿Cuántas veces fue a la asamblea ejidal en el último año? _____

11. Número de personas afiliadas a organizaciones productivas

Tipo de organización	Número
Consejo ejidal (mesa directiva)	
Asociación ganadera	
Cooperativa apícola	
Cooperativa silvícola	
Asociaciones productiva de mujeres	
Otras cooperativas (precisar)	
Sindicato agrícola (precisar)	
...	

12a. ¿Cuál es la tipo de techo de la casa?

*1: material; 2: palma; 3: lamina galvanizada; 4: cartón

En 2013: _____

En 2005: _____

En 1999: _____

12b. ¿Cuál es tipo de material del piso?

*1: tierra; 2: cimento; 3: ladrillo

En 2013: _____

En 2005: _____

En 1999: _____

13. De los siguientes bienes, ¿Cuáles tiene y qué cantidad de cada uno de ellos?

	2013	2005	1999
Cuántos cuartos de mampostería hay en su casa?			
Cuántos cuartos de otro material hay en su casa?			
Camión de carga			
Automóvil o camioneta			
Motocicleta			
Bicicleta o triciclo			
Refrigerador			
Estufa de gas			
Televisión por satélite			
Televisión			
DVD			
Teléfono celular			
Cuántos día al mes consume carne o pollo?			

II. Uso de la tierra

*****MAPA *****

14. Lista de los parcelas que usaron **desde 1999** incluyendo los que rento (*debe ser dos códigos)

Número de identificación y nombre del parcela	Numero del polígono sobre el mapa del ejido	Superficie del parcela (ha)+	¿Desde cuándo adquirió el parcela? (años)	¿Cómo obtuvo sus parcelas?*	¿Cuál era el uso del parcela cuando lo obtuvo ?**	Forma de propiedad *** 2013	Forma de propiedad *** 2005	Forma de propiedad *** 1999
1								
2								
3								
4								
5								
6								
7								
TOTAL								

+ En caso de milpa tradicional, escribir la superficie total del monte necesario para cultivar la milpa. Si no sabe, calcular la superficie del monte en función de las hectáreas cultivadas, número de año cultivo y número de año de regresar. Ejemplo: si 1 ha de milpa se cultiva 2 años y regresar 10 años después: son 6 ha de monte necesarias.

*1: desde la fundación; 2: herencia; 3: comprado; 4: donación; 5: dotación ejidal; 6: otro (especificar)

**1 maíz criollo asociado; 2 maíz mejorado asociado; 3 maíz criollo monocultivo; 4 maíz mejorado monocultivo; 5: maíz para elote; 6: pastos; 7: pasto de corte; 8: hortaliza; 9: frutales; 10: sorgo; 11: soya; 12: reforestación; 13: monte bajo o huiche; 14: monte alto (más de 20 años) 15: monte alto con PSAH; 16: desmontada con maquinaria; Otros (especificar _____)

*** 1: parcelado por PROCEDE y lo trabajo yo; 2: parcelado por asamblea y lo trabajo yo; 3: uso común; 4: parcelado y lo doy rentado; 5: parcelado y lo presto; 6: arriendo el parcela; 7: no es mío pero lo trabajo sin pagar (gratis); 8: en ese entonces no era de él; 9: lo vendió; 10: lo cedió; 11: otros (especificar en el recuadro)

15. ¿Descansa el parcela? (colocar numero de parcela)

	¿Dentro el parcela?	¿Entre diferentes parcelas?	Tiempo del descanso?	¿Porque?
2013				
2005				
1999				

16. Caracterice el uso del suelo para cada parcela de uso personal desde el año 2000/1999. **Incluir las parcelas dadas en renta.**

Numero	2013				2005				1999			
	A1 (ha)	A2 (ha)	B1 (ha)	B4 (ha)	A1 (ha)	A2 (ha)	B1 (ha)	B4 (ha)	A1 (ha)	A2 (ha)	B1 (ha)	B4 (ha)
1												
2												
3												
4												
5												
6												
7												

A: Tipo de uso del suelo

- 1 maíz criollo asociado; 2 maíz mejorado asociado; 3 maíz criollo monocultivo; 4 maíz mejorado monocultivo; 5: maíz para elote; 6: pastos;
- 7: pasto de corte; 8: horticultura; 9: frutales; 10: sorgo; 11: soya; 12: reforestación; 13: monte bajo o hubche; 14: monte alto (más de 20 años) 15: monte alto con PSAH; 16: Otros (especificar _____)

B: # ha (suma de B's = superficie total)

III. Agricultura

17. ¿Cuánto usa de fertilizantes y herbicidas?

	Año	Fertilizantes (bultos / ha) *	Porque el cambio?	Herbicida (litros/ha)	Porque el cambio?
Maíz Criollo	2013				
	2005				
	1999				
Maíz híbrido	2013				
	2005				
	1999				
Otros cultivo	2013				
	2005				
	1999				

*El segundo año por el maíz criollo

18. De la agricultura tradicional (rustica)

Parcela #	2013			2005			1999		
	# Años de cultivo en el mismo lugar	Rendi. (Kg/Ha) del primer año	La lluvia*	# Años de cultivo en el mismo lugar	Rendi. (Kg/Ha) del primer año	La lluvia*	# Años de cultivo en el mismo lugar	Rendi. (Kg/Ha) del primer año	La lluvia*

*Como considero las lluvias en el año 1: buenas, 2: regular, 3: malas

19. De la agricultura mecanizada:

Años	# cosechas	¿Riega? (1=si; 0=no)	¿Quema? (1=si; 0=no)	Cultivo1 * (riego)	Rend. (kg/ha) Por cosecha	Cultivo2* (riego)	Rend. (kg/ha) por cosecha	Cultivo3* (temporal)	Rend. (kg/ha) por cosecha
parcela # _____									
2013									
2005									
1999									
parcela # _____									
2013									
2005									
1999									
parcela # _____									
2013									
2005									
1999									
parcela # _____									
2013									
2005									
1999									

*1 maíz criollo asociado; 2 maíz mejorado asociado; 3 maíz criollo monocultivo; 4 maíz mejorado monocultivo; 5: maíz para elote; 6: pastos;
 7: pasto de corte; 8: horticultura; 9: frutales; 10: sorgo; 11: soya; 12: reforestación; 13: monte bajo o hubche; 14: monte alto (más de 20 años) 15:
 monte alto con PSAH; 16: Otros (especificar _____)

20. Utilización de la mecanización

Año	Evolución de la tecnología de cultivo mecanizado							Maquinaria ¿Es propietario de la maquinaria agrícola?*
	Preparación de tierra*	Siembra*	Fertilización*	Cosecha*	Control de malezas*	Control de plagas*		
	Maíz : parcelas _____							
2012								
2005								
1999								
	Otros cultivos: parcelas _____							
2012								
2005								
1999								

* 0. Manual; 1.Mecanizado

**1: si solo mía, 2: con mi grupo 3:se renta, 4: otros (especificar _____)

IV. Ganadería y animales

21. ¿Cuántos de los siguientes animales tiene?

Tipo de animales		2013	2005	1999	1995
Bovinos	Becerras				
	Jóvenes (1 - 4 años) (novillos y vaquillas)				
	Adultos (> años) (sementales y vacas)				
Caballos	Adultos				
Burros	Adultos				
Ovinos	Adultos				
Caprinos	Adultos				
Porcinos	Adultos				
Aves de corral	Adultos				
Colmenas	Numero				

22. En caso de que tenga bovinos, ¿cuál es el sistema de producción? _____
 1: engorda; 2: cria y venta destetes; 3: ciclo completo

23 ¿Cuántos meses pasó el ganado en cada parcela? Verificar que el total por línea y periodo suma 12 meses.

		Parcela # ___	Parcela # ___	Parcela # ___	Parcela # ___	Parcela # ___	Pastos uso común # ___	Monte uso común Polígono: # ___	Monte uso común Polígono: # ___	Monte uso común Polígono: # ___	Otros* Polígono: # ___	Fuera del ejido	Total
Bovinos	2013												12
	2005												12
	1999												12
Colmenas	2013												12
	2005												12
	1999												12

*1: fundo legal, 2:pueblo; 3:UAIM; 4: la parcela escolar; 5: otros (especificar _____)

V. Cambios en sistemas de producción

24. ¿Qué cambios realizó en su forma de sistema agricultura y ganado en los siguientes periodos?

Tipo de cambios	Tipo cultivo / animales*	Parcela #	Diferencia en cantidad	¿Por qué?	Fuente de recursos**
Cambios número de animales					
2013-2005					
2005-1999					
Insumos de ganadería: ALIMENTACIÓN					
2013-2005					
2005-1999					
Cambios de agricultura y pastos (semillas, ..)					
2013-2005					
2005-1999					
Cambio en el equipo y otros					
2013-2005					
2005-1999					

*1 maíz criollo asociado; 2 maíz mejorado asociado; 3 maíz criollo monocultivo; 4 maíz mejorado monocultivo; 5: maíz para elote; 6: pastos; 7: pasto de corte; 8: horticultura; 9: frutales; 10: sorgo; 11: soya; 12: reforestación; 13: monte bajo o hubeche; 14: monte alto (más de 20 años) 15: monte alto con PSAH; 20: bovinos; 21: pequeños rumiantes; 22: colmenas; Otros (especificar _____)

** 1: PROGAN/PROCAMPO (especificar); 2: Crédito; 3: Ahorros/Beneficios del año; 4: Herencia; 5: Remesas; 6: PSAH; 7: Otro (especificar)

VI. Extracción de madera y otros productos forestales

25a. ¿Cuánto le duró un tercio de leña (días)?

En 2013: _____

En 2005: _____

En 1999: _____

25b. ¿De dónde la obtuvo?

1: de sus parcelas, 2: de otros parcelas privados del ejido (gratis), 3: comprada en el ejido, 4: comprada fuera del ejido, 5: de monte de uso común (especificar # polígono en la siguiente tabla)

En 2013: _____

En 2005: _____

En 1999: _____

26. Rellene la siguiente tabla para productos forestales por cada polígono de monte*

Tipo de producción	2013			2005			1999			
	Pol #	Pol #	Parcelas #	Pol #	Pol #	Parcelas #	Pol #	Pol #	Parcelas #	
Leña										
Madera										
Material de construcción										
Cazan										
Carbón										
Otros:										

*0: nada; 1: colectó, 2: vendió, 3: otros (especificar _____)

VII. Políticas de apoyo económico

27. Rellene la siguiente tabla para los diferentes programas que recibieron desde 1999.

	Superficie o número de animales	Numero de ano que participan entre 2005-2013	Numero de ano que participan entre 1999-2005	Monto o contenido del apoyo por año
Productiva programas				
PROGAN -Ganadería				
PROGAN -Apicultura				
PROCAMPO				
Otros *				
Social programas				
60/70 y más				
Oportunidades				
Otros **				

*1: diesel agrícola, 2: reforestación (procoref, prodefor), 4: apoyos insumos (especificar), 5 apoyos por pérdidas (cosechas o animales), 6: apoyo de semillas de soya; 7: otro (especificar)

** 1: un kilo de ayuada, 2: apoyos depues de isodoro, 3: otro (especificar)

28. ¿Tuvo capacitación en los últimos desde 1999?

Tipo de capacitación*	¿Qué institución ofreció la capacitación?	Años (fecha a fecha si fue continuo)

*1: Ganadería; 2: Agricultura; 3: Apicultura; 4: Manejo forestal; 5: Otro (Especificar _____)

29. ¿Cuánto ha recibido del PSA-H (pesos) y como se utilizó la primera año y los siguientes?

año	¿Cuánto para inversión en el ejido o un grupo de ejidatario? (especificar)	Para el hogar			Especificar
		¿Cuánto por año para hacer trabajos? (pesos)	¿Cuánto por año de la distribución? (pesos)	¿Cómo se utilizó?*	
2012					
2011					
2010					
2009					
2008					
2007					
2006					
2005					

*1: agricultura 2: ganadería, 3: hogar 4: pago la escuela de los hijos; 5: pago de deudas hogar 6: pago de deudas agricultura/ganadería; 7: otros (especificar _____)

30. ¿Sabe que compromisos tiene el ejido a cambio de PSAH?

31a. ¿Cuáles son los impactos positivos del PSA-H en la comunidad?

31b. ¿Cuáles son los impactos negativos del PSA-H en la comunidad?

32. ¿Cree que la distribución de los pagos por servicios ambientales fue justa? ¿Por qué?

Si no participar en PSAh:

33. Porque no participan de PSA-h?

34. Cree que participaría en los próximos años?

35. Que cambios ha realizado para participar en el programa?

VIII. Perspectivas

36. ¿Existen superficie susceptibles de ser mecanizadas que no lo son ahora de su parcelas o uso común? (1.Sí; 0.No) Si sí: _____

Parcela #	Ha	Porque no lo están

37. ¿Cómo ven la evolución del uso de sus parcelas y de sus actividades económicas en los próximos 5 años?

Tipo	Evolución de las superficies / tiempo de actividad (+,0,-)	Numero de parcela	¿Por qué?
Monte uso común del ejido			
Monte privado			
Pastos			
Ganado			
Milpa tradicional			
Agricultura mecanizada			
Abejas			
Otros empleos o migración			
Otros (especificar)			

Comentarios: _____

A.4 Satellite images

Figure A.1: SPOT Images 2012 (20m) classified

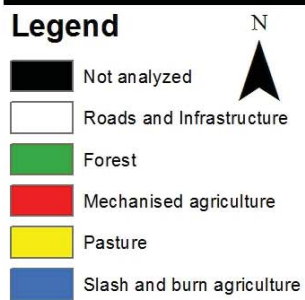


Figure A.2: SPOT Images 2005 (20m) classified

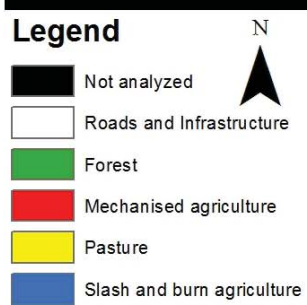


Figure A.3: SPOT Images 1999 (20m) classified

**Legend**

- Not analyzed
- Roads and Infrastructure
- Forest
- Mechanised agriculture
- Pasture
- Slash and burn agriculture

N



A.5 Pictures from the field work

Figure A.4: Pictures from the field work

(a) Implementation of the questionnaires



Participatory mapping



Example of participatory mapping



Material for the field work



End of the questionnaires



Sign indicating the program



APPENDIX B

Appendix to Chapter 4

B.1 Robustness tests

Table B.1: Robustness tests: Estimation using PSW

VARIABLES	(1) def	(2) def	(3) def	(4) def
psa	-0.0379*** (0.0032)			
tpsaa		-0.0047*** (0.0008)	-0.0060*** (0.0009)	-0.0060*** (0.0009)
wtpsaa1			0.0043*** (0.0014)	0.0046*** (0.0015)
wtpsaa2				0.0020 (0.0024)
forest05	-0.0021*** (0.0002)	-0.0021*** (0.0002)	-0.0020*** (0.0002)	-0.0020*** (0.0002)
slope	0.0015 (0.0023)	0.0019 (0.0023)	0.0019 (0.0023)	0.0020 (0.0023)
droad05	0.0001 (0.0005)	0.0003 (0.0006)	0.0002 (0.0006)	0.0002 (0.0006)
dagri05	-0.0154*** (0.0018)	-0.0154*** (0.0018)	-0.0147*** (0.0018)	-0.0144*** (0.0019)
dcity	-0.0005*** (0.0002)	-0.0005*** (0.0002)	-0.0005** (0.0002)	-0.0005** (0.0002)
telig	-0.0009 (0.0012)	-0.0003 (0.0012)	-0.0006 (0.0012)	-0.0010 (0.0014)
lagbuffer	0.6006*** (0.1238)	0.6023*** (0.1255)	0.6003*** (0.1256)	0.6004*** (0.1259)
areaejid	0.0003** (0.0001)	0.0002 (0.0001)	0.0004** (0.0002)	0.0004** (0.0002)
lagdefejid	-0.2800 (0.1977)	-0.3101 (0.2040)	-0.2792 (0.2054)	-0.2806 (0.2050)
ejiddens	0.2292 (0.1898)	0.0758 (0.2128)	0.3427 (0.2311)	0.3879 (0.2558)
margi05	-0.0011 (0.0022)	-0.0014 (0.0022)	-0.0014 (0.0022)	-0.0010 (0.0021)
defrisk	0.8333*** (0.2288)	0.7235*** (0.2300)	0.7985*** (0.2322)	0.8323*** (0.2402)
Constant	0.0601*** (0.0124)	0.0512*** (0.0125)	0.0351*** (0.0128)	0.0312** (0.0130)
Observations	10,352	10,352	10,352	10,352
R-squared	0.1785	0.1647	0.1659	0.1660

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table B.2: Robustness tests: Selection using covariate matching

VARIABLES	(1) def	(2) def	(3) def	(4) def
psa	-0.0456*** (0.0073)			
tps		-0.0036*** (0.0012)	-0.0054*** (0.0017)	-0.0056*** (0.0016)
wtpsa1			0.0075** (0.0032)	0.0079*** (0.0029)
wtpsa2				0.0077 (0.0051)
pscore	-0.5884*** (0.1925)	-0.5846*** (0.2100)	-0.5924*** (0.2135)	-0.6045*** (0.2157)
forest05	-0.0006 (0.0005)	-0.0008 (0.0006)	-0.0006 (0.0006)	-0.0005 (0.0006)
slope	-0.0019 (0.0018)	-0.0016 (0.0017)	-0.0017 (0.0017)	-0.0013 (0.0018)
droad05	0.0004 (0.0016)	0.0002 (0.0016)	0.0000 (0.0016)	0.0004 (0.0015)
dagri05	0.0226** (0.0109)	0.0209* (0.0118)	0.0225* (0.0121)	0.0246** (0.0122)
dcity	-0.0012** (0.0005)	-0.0011** (0.0005)	-0.0010* (0.0005)	-0.0011** (0.0005)
telig	0.0242*** (0.0085)	0.0238** (0.0091)	0.0231** (0.0091)	0.0225** (0.0094)
lagbuffer	-0.7764 (0.4856)	-0.7141 (0.5285)	-0.7441 (0.5378)	-0.7707 (0.5446)
areaejid	-0.0086*** (0.0028)	-0.0084*** (0.0030)	-0.0080** (0.0030)	-0.0085*** (0.0031)
lagdefejid	-2.0758*** (0.6844)	-2.0266*** (0.7274)	-2.0168*** (0.7187)	-2.0439*** (0.7139)
ejiddens	-4.3677*** (1.4613)	-4.3907*** (1.5459)	-4.0691** (1.5522)	-3.9832** (1.5721)
margi05	-0.0269*** (0.0088)	-0.0261*** (0.0092)	-0.0264*** (0.0089)	-0.0257*** (0.0093)
defrisk	-3.2272*** (1.1637)	-3.0911** (1.2431)	-2.8402** (1.2446)	-2.8576** (1.1946)
Constant	0.4262*** (0.1162)	0.4033*** (0.1237)	0.3779*** (0.1251)	0.3721*** (0.1242)
Observations	7,490	7,490	7,490	7,490
R-squared	0.1929	0.1740	0.1771	0.1788

Standard errors in parentheses adjusted for 62 clusters

*** p<0.01, ** p<0.05, * p<0.1

Table B.3: Robustness tests: Estimation without the larger ejido

VARIABLES	(1) def	(2) def	(3) def	(4) def
psa	-0.0482*** (0.0080)			
tps		-0.0042*** (0.0012)	-0.0058*** (0.0018)	-0.0059*** (0.0017)
wtps1			0.0053* (0.0029)	0.0056* (0.0029)
wtps2				0.0033 (0.0054)
pscore	-0.6828*** (0.2084)	-0.7080*** (0.2246)	-0.7108*** (0.2260)	-0.7188*** (0.2251)
forest05	-0.0001 (0.0006)	-0.0001 (0.0007)	-0.0000 (0.0007)	0.0000 (0.0007)
slope	-0.0026 (0.0018)	-0.0024 (0.0018)	-0.0023 (0.0018)	-0.0021 (0.0019)
droad05	0.0010 (0.0016)	0.0011 (0.0016)	0.0009 (0.0016)	0.0010 (0.0016)
dagri05	0.0299** (0.0123)	0.0293** (0.0131)	0.0302** (0.0131)	0.0313** (0.0130)
dcity	-0.0022*** (0.0007)	-0.0023*** (0.0007)	-0.0022*** (0.0007)	-0.0022*** (0.0006)
telig	0.0285*** (0.0090)	0.0291*** (0.0095)	0.0286*** (0.0095)	0.0283*** (0.0097)
lagbuffer	-0.9805* (0.5542)	-0.9851 (0.5916)	-0.9983* (0.5957)	-1.0160* (0.5954)
areaejid	-0.0065** (0.0031)	-0.0071** (0.0033)	-0.0069** (0.0034)	-0.0070* (0.0035)
lagdefejid	-2.3007*** (0.7295)	-2.3395*** (0.7612)	-2.3196*** (0.7580)	-2.3391*** (0.7526)
ejiddens	-4.9800*** (1.6462)	-5.1534*** (1.6937)	-4.8807*** (1.7279)	-4.8695*** (1.7408)
margi05	-0.0316*** (0.0091)	-0.0315*** (0.0095)	-0.0315*** (0.0094)	-0.0312*** (0.0096)
defrisk	-2.8966** (1.2792)	-2.9924** (1.3327)	-2.8695** (1.3460)	-2.8634** (1.3269)
Constant	0.4592*** (0.1256)	0.4585*** (0.1329)	0.4416*** (0.1354)	0.4407*** (0.1359)
Observations	7,879	7,879	7,879	7,879
R-squared	0.1932	0.1731	0.1746	0.1749

Standard errors in parentheses adjusted for 61 clusters

*** p<0.01, ** p<0.05, * p<0.1

Table B.4: Robustness tests: Sample selection and leakages

VARIABLES	(1) def	(2) def	(3) def
tpsa	-0.0062*** (0.0008)	-0.0061*** (0.0008)	-0.0132*** (0.0009)
wtpsa1	0.0045*** (0.0015)	0.0045*** (0.0015)	0.0112*** (0.0013)
wtpsa2		-0.0005 (0.0023)	-0.0147*** (0.0016)
forest05	-0.0021*** (0.0002)	-0.0021*** (0.0002)	
slope	-0.0007 (0.0012)	-0.0007 (0.0012)	
droad05	-0.0012*** (0.0004)	-0.0012*** (0.0004)	
dagri05	-0.0158*** (0.0014)	-0.0158*** (0.0014)	
dcity	-0.0003 (0.0002)	-0.0003 (0.0002)	
telig	-0.0002 (0.0012)	-0.0001 (0.0013)	
lagbuffer	0.7067*** (0.0525)	0.7067*** (0.0525)	
areaejid	0.0007*** (0.0001)	0.0007*** (0.0002)	
lagdefejid	0.0289 (0.0752)	0.0284 (0.0753)	
ejiddens	0.8155*** (0.1945)	0.8046*** (0.2029)	
margi05	-0.0056*** (0.0020)	-0.0057*** (0.0020)	
defrisk	1.4226*** (0.2771)	1.4173*** (0.2777)	
Constant	0.0183 (0.0146)	0.0189 (0.0148)	0.0909*** (0.0045)
Observations	10,352	10,352	10,352
R-squared	0.1893	0.1893	0.0369

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

B.2 Variable description and sources

Table B.5: Variable description

Variable	Description	Source
def	Percentage of forest cover loss in the polygon between 2005 and 2012	SPOT images (20m)
psa	Polygons received the PSA-H between 2004 and 2012	CONAFOR and PESMIX surveys
tpsa	Time spent in the program by the polygon between 2005 and 2012	CONAFOR and PESMIX surveys
wtpsa1	Average number of years spent under PSA-H by one hectare of forest in the <i>ejido</i> between 2005 and 2012	CONAFOR and PESMIX surveys
wtpsa2	Average number of years spent under PSA-H by one hectare of forest in the neighbouring <i>ejidos</i> between 2005 and 2012	CONAFOR and PESMIX surveys
pscore	Predicted probability that the polygons receive the PSA-H	Computed by the authors
forest05	Size of the polygon of forest in 2005	Computed by the authors
slope	Average slope of the polygon of forest	Nasa's Shuttle Radar Topography Mission
droad05	Distance of the polygon to nearest road in the <i>ejido</i> in 2005	SPOT images (20m)
dagri05	Distance of the polygon to nearest agricultural road in the <i>ejido</i> in 2005	SPOT images (20m)
dcity	Distance of the polygon to nearest city of more than 2,500 inhabitants	INEGI
telig	Time since the polygon is eligible for PSA-H reception	CONAFOR
lagbuffer	Percentage of forest cover loss between 1999 and 2005 in a buffer of 1km around the polygon	SPOT images (20m)
areaejid	Size of the <i>ejido</i>	INEGI
lagdefejid	Percentage of forest cover loss between 1999 and 2005 in the <i>ejido</i>	SPOT images (20m)
ejiddens	Number of <i>ejidatarios</i> per hectare of the <i>ejido</i>	INEGI and PESMIX surveys
margi05	Marginality index of the <i>ejido</i>	CONAPO
defrisk	Deforestation risk index of the <i>ejido</i>	INECC

B.3 Descriptives statistics before and after matching

Table B.6: Descriptives statistics before and after matching

Variable	Before pre-matching					After pre-matching				
	Mean	Stand. dev.	Skewness	Min	Max	Mean	Stand. dev.	Skewness	Min	Max
def	0.0573	0.1487	3.4690	-6.78e-06	0.9999	0.0499	0.1405	3.7675	-6.78e-06	0.9999
psa	0.4794	0.4996	0.0824	0	1	0.5684	0.4953	-0.2761	0	1
tpsa	1.6748	2.2597	0.8665	0	7	1.9856	2.3317	0.6016	0	7
wtpsa1	1.8588	1.5415	0.6683	0	6.4504	2.0445	1.5408	0.5408	0	6.4504
wtpsa2	2.1993	1.0207	-0.6431	0	4.6446	2.2146	0.9552	-0.5372	0	4.6446
pscore	0.4798	0.2229	-0.2982	0.0003	0.9573	0.5308	0.1964	-0.4813	0.0151	0.9573
forest05	15.6355	8.2613	-0.2239	0.5022	25	15.4657	8.2195	-0.1765	0.5022	25
slope	2.0644	1.2433	1.3645	0.1055	11.3654	2.0496	1.1919	1.2443	0.10552	10.074
droad05	2.1879	3.2019	2.5430	0	22.9556	2.0484	2.8841	2.3843	0	22.9556
dagri05	0.4495	0.6754	2.1683	0	5.4260	0.4881	0.6972	2.0690	0	5.4260
dcty	26.9323	9.1147	-2.347	1.5931	48.4144	27.8193	8.7454	-0.1801	1.5931	48.4144
telig	8.0640	2.0066	-2.4557	0	9	8.3076	1.6957	-3.0013	0	9
lagbuffer	0.0398	0.0602	2.6030	-2.11e-07	0.5042	0.0337	0.0498	2.4925	-2.11e-07	0.4941
areaejid	8.3539	11.3183	1.7560	.5263	34.4718	6.6991	9.5091	2.3666	0.5263	34.4718
lagdefejid	-0.0375	0.0399	-2.2087	-0.2083	-0.0005	-0.0374	0.0393	-2.3366	-0.2083	-0.0005
ejiddens	0.0188	0.0132	1.6419	0.0060	0.0641	0.0179	0.0121	1.7059	0.0060	0.0641
margi05	0.4396	0.7435	0.4811	-0.9292	2.2204	0.4113	0.7438	0.6454	-0.9292	2.2204
defrisk	0.03419	0.0057	1.4125	0.024	0.0553	0.0344	0.0059	1.2857	0.024	0.0553

APPENDIX C

Appendix to Chapter 5

C.1 Variable description at *ejido* levelTable C.1: Variable description at *ejido* level

Variable	Description	Source	Mean	Stand. dev.	Skewness	Min	Max
psa_gini	Gini of payments distribution at <i>ejido</i> level	PESMIX Surveys	0.3663	0.2530	0.1927	0	0.9730
mec05_ejid	Presence of mechanised agriculture in the <i>ejido</i> in 2005 (Dummy variable)	PESMIX Surveys	0.7447	0.4408	-1.1223	0	1
trad05_ejid	Presence of traditional agriculture in the <i>ejido</i> in 2005 (Dummy variable)	PESMIX Surveys	0.5745	0.4998	-0.3012	0	1
ranch05_ejid	Presence of cattle-ranching in the <i>ejido</i> in 2005 (Dummy variable)	PESMIX Surveys	0.7872	0.4137	-1.4037	0	1
per_mec05	Percentage of <i>ejidatarios</i> with mechanised agriculture in the <i>ejido</i> in 2005	PESMIX Surveys	0.4183	0.3484	0.1703	0	1
per_trad05	Percentage of <i>ejidatarios</i> with traditional agriculture in the <i>ejido</i> in 2005	PESMIX Surveys	0.2266	0.3108	1.3568	0	1.0000
per_ranch05	Percentage of <i>ejidatarios</i> with cattle ranching in the <i>ejido</i> in 2005	PESMIX Surveys	0.2180	0.2215	1.2540	0	1
ejidat	Number of <i>ejidatarios</i>	PESMIX Surveys	43.7447	46.1324	3.1312	11	244
age	Average age of the <i>ejidatarios</i>	PESMIX Surveys	50.5718	4.4163	-0.5558	40.2941	58.2143
age_sd	Standard deviation of the <i>ejidatarios'</i> age	PESMIX Surveys	10.1551	2.6069	0.5739	5.5572	17.2711
labejid	Labour- <i>ejido</i> (dummy variable)	PESMIX Surveys	0.3191	0.4712	0.7759	0	1
partasemb	Average participation rate at the assembly	PESMIX Surveys	0.7829	0.1949	-0.3865	0.4000	1
forest05	Total superficies of common forest in the <i>ejido</i> in 2005 (20m)	SPOOT images	1672.9407	1636.4204	1.7820	0	8254.8799
per_forcom	Percentage of common forest in 2005	PESMIX Surveys	0.6421	0.3812	-0.4841	0	1.3935
psaejid_yr	Average PSA-H payments received by the <i>ejido</i> during reception years	CONAFOR and PESMIX Surveys	39.4345	21.7216	0.5776	3.5041	93.8586

C.2 Variable description at household level

Table C.2: Variable description at household-level

Variable	Description	Source	Mean	Stand. dev.	Skewness	Min	Max
psahval_an_hh	Average yearly PSA-H payments received by the households during years of reception by the <i>ejido</i> (Thousands of pesos)	PESMIX Surveys	8.3376	7.4880	1.1183	0	34
psahval_hh	Total PSA-H payments received by the households between 2005 and 2012 (Thousands of pesos)	PESMIX Surveys	38.4248	42.4930	1.4485	0.0000	180
mec05_hh	<i>Ejidatarios</i> with mechanised agriculture in 2005 (Dummy variable)	PESMIX Surveys	0.4564	0.4994	0.1750	0	1.0000
trad05_hh	<i>Ejidatarios</i> with traditional agriculture in 2005 (Dummy variable)	PESMIX Surveys	0.3385	0.4744	0.6828	0	1
ranch05_hh	<i>Ejidatarios</i> with cattle ranching in 2005 (Dummy variable)	PESMIX Surveys	0.1590	0.3666	1.8653	0	1
off05	<i>Ejidatarios</i> with permanent off-farm activities in 2005 (Dummy variable)	PESMIX Surveys	0.3179	0.4669	0.7819	0	1
write	Writing and reading abilities of the household's head (Dummy variable)	PESMIX Surveys	0.7744	0.4191	-1.3127	0	1
age	Age of the household's head	PESMIX Surveys	54.5128	14.0688	0.3923	24	89
size05	Size of the household in 2005	PESMIX Surveys	4.8256	2.1919	0.2231	0	11
assets05	Assets of the household in 2005	PESMIX Surveys	0.1734	0.1470	1.7968	0.0053	1
orgejid	Involvement in the <i>ejidos'</i> authorities (Dummy variable)	PESMIX Surveys	0.2205	0.4157	1.3483	0.0000	1.0000
partasemb_hh	Average participation rate at the assembly	PESMIX Surveys	0.5893	0.3318	-0.0272	0	1

APPENDIX D

Appendix to Chapter 6

D.1 Robustness test

Table D.1: Robustness test: Eligible ejidos

VARIABLES	(1) cfe	(2) cfe	(3) cfe
tpsah	0.1588*** (0.0556)		0.1165* (0.0702)
psahval		0.0285** (0.0121)	0.0126 (0.0147)
cfe02	0.4995** (0.2434)	0.6639*** (0.2349)	0.5705** (0.2395)
size	0.2309** (0.1078)	0.1920* (0.0980)	0.2141** (0.1036)
perfor02	-0.6065 (0.6293)	-0.6958 (0.6290)	-0.6749 (0.6328)
at02	0.5994 (0.4479)	0.3546 (0.4172)	0.4936 (0.4204)
meanslope	-0.0031 (0.0229)	-0.0050 (0.0234)	-0.0053 (0.0232)
analph10	0.0026 (0.0159)	0.0021 (0.0156)	0.0023 (0.0159)
density10	-0.0210 (0.1410)	-0.0155 (0.1414)	-0.0199 (0.1408)
distcity	-0.1581 (0.1463)	-0.1820 (0.1505)	-0.1693 (0.1508)
distroad	-0.2571 (0.2675)	-0.2748 (0.2612)	-0.2679 (0.2639)
ejidat10	-0.0026** (0.0012)	-0.0028** (0.0012)	-0.0027** (0.0012)
prodefor	0.3962 (0.3206)	0.3721 (0.3140)	0.3871 (0.3213)
cabsa	-0.4162 (0.4991)	-0.4657 (0.5142)	-0.4571 (0.4996)
npa	-0.2428 (0.2705)	-0.1210 (0.2538)	-0.2266 (0.2687)
Cut 1	1.2773** (0.5272)	1.2244** (0.5178)	1.2427** (0.5227)
Cut 2	1.6261*** (0.5401)	1.5664*** (0.5326)	1.5912*** (0.5354)
Cut 3	2.2567*** (0.6027)	2.1938*** (0.5982)	2.2304*** (0.6008)
R-squared	0.3007	0.2952	0.3030
Observations	159	159	159

Notes: * = significant at the 1% level, ** = significant at the 5% level, * = significant at the 10% level. Standard errors clustered at state-level. Marginal effects are computed with dummy variables as balanced and at means of other variables.

Table D.2: Robustness test: Ejidos with a CFE in 2002

VARIABLES	(1) cfe	(2) cfe	(3) cfe
tpsah	0.4170*** (0.0900)		0.2259** (0.1128)
psahval		0.1032** (0.0427)	0.0597 (0.0425)
cfe02	1.0110*** (0.3219)	1.2868*** (0.3346)	1.1898*** (0.3505)
size	0.1273 (0.1048)	0.0828 (0.1103)	0.1050 (0.1089)
perfor02	-0.7997 (0.8137)	-1.0065 (0.8478)	-0.9988 (0.8395)
at02	1.5446** (0.6618)	1.2045* (0.6479)	1.3320** (0.6606)
meanslope	0.0894** (0.0441)	0.0763* (0.0441)	0.0788* (0.0452)
analph10	-0.0241 (0.0398)	0.0264 (0.0394)	0.0028 (0.0424)
density10	0.0504 (0.1845)	0.2193 (0.1844)	0.1412 (0.1922)
distcity	0.0999 (0.1638)	0.0800 (0.1674)	0.1023 (0.1679)
distroad	-0.1492 (0.3811)	-0.0883 (0.4146)	-0.1423 (0.4028)
ejidat10	-0.0023 (0.0023)	-0.0040* (0.0023)	-0.0033 (0.0024)
prodefor	-0.0797 (0.3648)	-0.1261 (0.3539)	-0.1410 (0.3523)
cabsa	0.4773 (0.7986)	-0.3872 (0.8271)	-0.0249 (0.8414)
npa	-0.3298 (0.4655)	0.2018 (0.4265)	-0.0838 (0.4210)
Cut 1	4.2600*** (1.3457)	4.7628*** (1.3401)	4.5003*** (1.3764)
Cut 2	4.7237*** (1.2944)	5.2331*** (1.2808)	4.9748*** (1.3190)
Cut 3	6.3632*** (1.4618)	6.9046*** (1.4527)	6.6988*** (1.4908)
R-squared	0.3788	0.3821	0.3946
Observations	51	51	51

Notes: *=*significant at the 1% level*, **=*significant at the 5% level*, *=*significant at the 10% level*. Standard errors clustered at state-level. Marginal effects are computed with dummy variables as balanced and at means of other variables.

Table D.3: Robustness test: Placebo regression

VARIABLES	(1) cfe02	(2) cfe02	(3) cfe02
tpsah	0.0458 (0.0505)		0.1172 (0.0769)
psahval		-0.0021 (0.0094)	-0.0181 (0.0160)
cfe90	0.9790*** (0.2044)	0.9753*** (0.2074)	0.9557*** (0.2062)
size	0.1093 (0.0962)	0.1132 (0.0982)	0.1173 (0.0988)
perfor02	0.9980** (0.4928)	1.0255** (0.4984)	1.0192** (0.5005)
at02	2.4817*** (0.3473)	2.5019*** (0.3629)	2.5443*** (0.3676)
meanslope	0.0298 (0.0237)	0.0332 (0.0239)	0.0343 (0.0244)
analph10	0.0052 (0.0190)	0.0067 (0.0187)	0.0034 (0.0201)
density10	0.2993 (0.2001)	0.3027 (0.1968)	0.2720 (0.2044)
distcity	0.0272 (0.1075)	0.0205 (0.1099)	0.0292 (0.1090)
distroad	0.0934 (0.1965)	0.1066 (0.2007)	0.1193 (0.2013)
ejidat10	-0.0024 (0.0017)	-0.0023 (0.0017)	-0.0022 (0.0018)
prodefor	0.5683* (0.2927)	0.6022** (0.2992)	0.5663* (0.2899)
cabsa	0.9166** (0.4180)	0.9238** (0.4214)	0.9670** (0.4153)
npa	-0.6398* (0.3518)	-0.5684 (0.3635)	-0.6822** (0.3406)
Cut 1	4.1694*** (0.7095)	4.2244*** (0.7257)	4.2333*** (0.7312)
Cut 2	5.3490*** (0.8185)	5.4055*** (0.8357)	5.4170*** (0.8449)
Cut 3	7.4338*** (1.0088)	7.4713*** (1.0196)	7.5215*** (1.0306)
R-squared	0.6154	0.6142	0.6180
Observations	223	223	223

Notes: * = significant at the 1% level, ** = significant at the 5% level, * = significant at the 10% level. Standard errors clustered at state-level. Marginal effects are computed with dummy variables as balanced and at means of other variables.

D.2 Variable description and sources

Table D.4: Variable description

Variable	Description	Source	Mean	Stand. dev.	Skewness	Min	Max
cfé	Type of products produced by the CFE's in 2010 following PROCYMAF classification (discrete variable)	ENNAF	1.4484	0.9376	1.8588	1	4
cfé02	Lagged value of CFE's in 2002	ENNAF	1.4260	.8556	1.8309	1	4
psah	Reception of PSA-H between 2003 and 2010 (dummy)	CONAFOR	0.9148	1.8712	1.8312	0	8
psahval	Amount of payments for PSA-H received between 2003 and 2010 (thousand of Mexican pesos)	CONAFOR	374.8398	1049.736	3.6676	0	6382.083
size	Total size of the <i>ejido</i> (tens thousands of hectares)	INEGI	1.0482	2.0176	3.8206	0.0190	12.7734
perpor02	Share of forest cover in 2002 in percentage of total size of the <i>ejido</i> (Hectares)	Serie III / INEGI	0.4603	0.2788	0.4460	0.0001	1
at02	Reception of technical assistance to develop timber extraction before 2002 (Dummy)	ENNAF	0.2108	0.4088	1.4183	0	1
meanslope	Mean slope in the <i>ejido</i> in percentage	Nasa's Shuttle Radar Topography Mission	11.3511	7.3014	0.2741	0	29.6752
analph10	Illiteracy rate 2010 (AGEB level)	CONAPO	13.3314	8.1830	1.4220	2.1658	52.0571
density10	Population density in 2010	ENNAF	0.5676	0.8207	2.6985	0	5.2395
distcity	Linear distance to the closest city of more than 2,500 inhabitants ((Tens of Km)	INEGI	1.4045	1.2101	1.7044	0.01315	7.1168
distroad	Linear distance to the closest road (Tens of Km)	INEGI	0.4170	0.4750	2.2828	0.0012	2.877
ejidat10	Number of ejidatarios in 2010	ENNAF	189.8386	344.3888	6.8802	10	3500
prodefor	Reception of PRODEFOR between 2003 and 2010 (dummy)	ENNAF	0.2242	0.4180	1.3225	0	1
cabsa	Reception of PSA-CABSAs between 2003 and 2010 (dummy)	CONAFOR	0.0628	0.2431	3.605	0	1
npa	Location of the <i>ejido</i> inside a Natural Protected Areas (dummy)	INEGI	0.1390	0.3467	2.0869	0	1
telig	Number of years spent by the <i>ejido</i> inside the eligibility zones since 2003	CONAFOR	2.9462	2.6126	0.2214	0	7
meso02	Area of Mesophyll forests (Ha)	Serie III / INEGI	205.0195	924.0211	6.1954	0	8730.484

Bibliography

- Abadie, A. and Imbens, G. W. (2006). Large sample properties of matching estimators for average treatment effects. *Econometrica*, 74(1):235–267.
- Abizaid, C. and Coomes, O. T. (2004). Land use and forest following dynamics in seasonally dry tropical forests of the southern yucatan peninsula, mexico. *Land Use Policy*, 21(1):71–84.
- Adger, W. N., Brown, K., Fairbrass, J., Jordan, A., Paavola, J., Rosendo, S., and Seyfang, G. (2003). Governance for sustainability: towards a thick analysis of environmental decisionmaking. *Environment and Planning A*, 35(6):1095–1110.
- Ajayi, O. C., Jack, B. K., and Leimona, B. (2012). Auction design for the private provision of public goods in developing countries: lessons from payments for environmental services in malawi and indonesia. *World development*, 40(6):1213–1223.
- Alix-Garcia, J. (2007). A spatial analysis of common property deforestation. *Journal of Environmental Economics and Management*, 53(2):141–157.
- Alix-Garcia, J. (2008). An exploration of the positive effect of inequality on common property forests. *Journal of Development Economics*, 87(1):92–105.
- Alix-Garcia, J., De Janvry, A., and Sadoulet, E. (2008). The role of deforestation risk and calibrated compensation in designing payments for environmental services. *Environment and Development Economics*, 13(03):375–394.
- Alix-Garcia, J., McIntosh, C., Sims, K. R., and Welch, J. R. (2013). The ecological footprint of poverty alleviation: evidence from mexico’s oportunidades program. *Review of Economics and Statistics*, 95(2):417–435.
- Alix-Garcia, J., Shapiro, E., and Sims, K. (2010). Forest conservation and slippage: Evidence from mexico’s national payments for ecosystem services program. Technical report, Working Paper, University of Wisconsin, Madison.
- Alix-Garcia, J., Sims, K. R., Yanez-Pagans, P., Radeloff, V. C., and Shapiro, E. (2014). Only one tree from each seed? environmental effectiveness and poverty alleviation in programs of payments for ecosystem services. *American Economic Journal - Economic Policy*.
- Alix-Garcia, J. and Wolff, H. (2014). Payment for ecosystem services from forests.
- Alix-Garcia, J. M., Shapiro, E. N., and Sims, K. R. (2012). Forest conservation and slippage: Evidence from mexico’s national payments for ecosystem services program. *Land Economics*, 88(4):613–638.

- Amin, A., Choumert, J., Combes-Motel, P., Combes, J. L., Kere, E. N., Ongono-Olinga, J. G., and Schwartz, S. (2014). A spatial econometric approach to spillover effects between protected areas and deforestation in the brazilian amazon. *Etudes et Documents*, 6:2–27.
- Andam, K. S., Ferraro, P. J., Pfaff, A., Sanchez-Azofeifa, G. A., and Robalino, J. A. (2008). Measuring the effectiveness of protected area networks in reducing deforestation. *Proceedings of the National Academy of Sciences*, 105(42):16089–16094.
- Andam, K. S., Ferraro, P. J., Sims, K. R., Healy, A., and Holland, M. B. (2010). Protected areas reduced poverty in costa rica and thailand. *Proceedings of the National Academy of Sciences*, 107(22):9996–10001.
- Angelsen, A. and Kaimowitz, D. (1999). Rethinking the causes of deforestation: lessons from economic models. *The world bank research observer*, 14(1):73–98.
- Angrist, J. D. (1990). Lifetime earnings and the vietnam era draft lottery: evidence from social security administrative records. *The American Economic Review*, pages 313–336.
- Angrist, J. D., Imbens, G. W., and Rubin, D. B. (1996). Identification of causal effects using instrumental variables. *Journal of the American statistical Association*, 91(434):444–455.
- Anthon, S., Garcia, S., and Stenger, A. (2010). Incentive contracts for natura 2000 implementation in forest areas. *Environmental and Resource Economics*, 46(3):281–302.
- Antinori, C. (2000). *Vertical Integration in Mexican Common Property Forests*. PhD thesis, Agriculture and Ressources Economics, University of California, Berkeley.
- Antinori, C. (2005). Vertical integration in the community forestry enterprises of oaxaca. *The community forestry of Mexico: managing for sustainable landscapes*. University of Texas Press, Austin, TX, EEUU.
- Antinori, C. and Bray, D. (2005). Community forest enterprises as entrepreneurial firms: Economic and institutional perspectives from mexico. *World Development*, 33(9):1529–1543.
- Antinori, C. and Rausser, G. (2007). Collective choice and community forestry management in mexico: An empirical analysis. *Journal of Development Studies*, 43(3):512–536.
- Araujo, C., Bonjean, C. A., Combes, J.-L., Motel, P. C., and Reis, E. J. (2009). Property rights and deforestation in the brazilian amazon. *Ecological Economics*, 68(8):2461–2468.
- Araujo, C., Brun, J.-F., and Combes, J.-L. (2004). *Econométrie*. Bréal éd.

- Arriagada, R. A. (2008). *Private provision of public goods: applying matching methods to evaluate payments for ecosystem services in Costa Rica*. ProQuest.
- Arriagada, R. A., Ferraro, P., Sills, E., Pattanayak, S., and Cordero-Sancho, S. (2012). Do payments for environmental services affect forest cover? a farm-level evaluation from costa rica. *Land Economics*, 88(2):382–399.
- Ashenfelter, O. (1978). Estimating the effect of training programs on earnings. *The Review of Economics and Statistics*, 60(1):47–57.
- Assies, W. (2008). Land tenure and tenure regimes in mexico: an overview. *Journal of Agrarian Change*, 8(1):33–63.
- Aukland, L., Costa, P. M., and Brown, S. (2003). A conceptual framework and its application for addressing leakage: the case of avoided deforestation. *Climate Policy*, 3(2):123–136.
- Austin, P. C. (2011). An introduction to propensity score methods for reducing the effects of confounding in observational studies. *Multivariate Behavioral Research*, 46(3):399–424.
- Barbier, E. B. and Burgess, J. C. (1996). Economic analysis of deforestation in mexico.
- Barton, D. N., Rusch, G., May, P., Ring, I., Unnerstall, H., Santos, R., Antunes, P., Brouwer, R., Grieg-Gran, M., Similä, J., et al. (2009). Assessing the role of economic instruments in a policy mix for biodiversity conservation and ecosystem services provision: a review of some methodological challenges.
- Barton, D. N.; Ring, I. R. G. (2014). Policyscapes. nature-based policy mixes for biodiversity conservation and ecosystem services provision. Policy Brief 2, Policy Mix.
- Bizberg, I. (2003). Auge y decadencia del corporativismo. *Una historia contemporánea de México*, 1:313–66.
- Blackman, A. (2013). Evaluating forest conservation policies in developing countries using remote sensing data: An introduction and practical guide. *Forest Policy and Economics*, 34:1–16.
- Borrego, A. and Skutsch, M. (2014). Estimating the opportunity costs of activities that cause degradation in tropical dry forest: Implications for redd+. *Ecological economics*, 101:1–9.
- Bouquet, E. (2009). State-led land reform and local institutional change: Land titles, land markets and tenure security in mexican communities. *World Development*, 37(8):1390–1399.

- Bray, D. (2005). Community forestry in Mexico: twenty lessons learned and four future pathways. *The community forests of Mexico: managing for sustainable landscapes*, 14:335–349.
- Bray, D. (2010). Toward post-redd+ landscapes. Mexico community forest enterprises provide a proven pathway to reduce emissions from deforestation and forest degradation. Technical report, CIFOR Infobrief 30.
- Bray, D., Antinori, C., and Torres-Rojo, J. (2006). The Mexican model of community forest management: The role of agrarian policy, forest policy and entrepreneurial organization. *Forest Policy and Economics*, 8(4):470–484.
- Bray, D., Durán Medina, E., Merino Pérez, L., Torres Rojo, J., and Velázquez Montes, A. (2007). Nueva evidencia: los bosques comunitarios de México protegen el ambiente, disminuyen la pobreza y promueven la paz social. Technical report, Agrupación Sierra Madre/Consejo Civil Mexicano para la Silvicultura Sostenible, Mexico City, Mexico.
- Bray, D. B., Ellis, E. A., Armijo-Canto, N., and Beck, C. T. (2004). The institutional drivers of sustainable landscapes: a case study of the Šmayan zoneŠin Quintana Roo, Mexico. *Land Use Policy*, 21(4):333–346.
- Bray, D. B., Merino-Pérez, L., and Barry, D. (2003a). Community-managed in the strong sense of the phrase: Community forests enterprises. the community forests of Mexico. In D. Barton Bray, L. M. P. and Austin, D. B., editors, *Managing for Sustainable Landscapes*. University of Texas Press.
- Bray, D. B., Merino-Pérez, L., Negreros-Castillo, P., Segura-Warnholtz, G., Torres-Rojo, J. M., and Vester, H. F. M. (2003b). Mexico’s community-managed forests as a global model for sustainable landscapes. *Conservation Biology*, 17(3):672–677.
- Brimont, L., Ezzine-de Blas, D., Karsenty, A., and Toulon, A. (2015). Achieving conservation and equity amidst extreme poverty and climate risk: The Makira redd+ project in Madagascar. *Forests*, 6(3):748–768.
- Brown, J. (2004). Ejido and comunidades in Oaxaca, Mexico: Impact of the 1992 reforms. Technical report, Rural Development Institute.
- Caliendo, M. and Kopeinig, S. (2008). Some practical guidance for the implementation of propensity score matching. *Journal of Economic Surveys*, 22(1):31–72.
- Cameron, A. C. and Trivedi, P. K. (2005). *Microeconometrics: methods and applications*. Cambridge University Press.
- Canavire-Bacarreza, G. and Hanauer, M. M. (2013). Estimating the impacts of Bolivia’s protected areas on poverty. *World Development*, 41:265–285.

- Chabe-Ferret, S. (2008). *L'évaluation de l'impact des politiques publiques: caractérisation des enjeux et exemples de politiques agricoles et forestières*. PhD thesis, Université d'Auvergne-Clermont-Ferrand I.
- Chabé-Ferret, S. and Subervie, J. (2009). Evaluation de l'effet propre des mesures agro-environnementales du pdrn 2000-2006 sur les pratiques des agriculteurs. *Rapport d'évaluation, Cemagref, <http://agriculture.gouv.fr/sections/publications/evaluation-politiques/evaluations/estimation-effets>*.
- Chabé-Ferret, S. and Subervie, J. (2013). How much green for the buck? estimating additional and windfall effects of french agro-environmental schemes by did-matching. *Journal of Environmental Economics and Management*, 65:12 – 27.
- Chevassus-au Louis, B., Salles, J.-M., Pujol, J.-L., Bielsa, S., Martin, G., and Richard, D. (2009). Approche économique de la biodiversité et des services liés aux écosystèmes: contribution à la décision publique.
- Chomitz, K. M. (2002). Baseline, leakage and measurement issues: how do forestry and energy projects compare? *Climate Policy*, 2(1):35–49.
- Clot, S. and Stanton, C. Y. (2014). Present bias predicts participation in payments for environmental services: Evidence from a behavioral experiment in uganda. *Ecological Economics*, 108:162–170.
- Coase, R. H. (1960). Problem of social cost, the. *JL & econ.*, 3:1.
- Comerford, E. (2014). Understanding why landholders choose to participate or withdraw from conservation programs: A case study from a queensland conservation auction. *Journal of Environmental Management*, 141(0):169–176.
- CONAFOR (2009). Réglas de operacion del programa proarbol 2010. Technical report, Diario oficial 31 de Diciembre de 2009.
- CONAFOR (2012). Logros y perspectivas del desarrollo forestal en mexico 2007-2012. Technical report.
- CONANP (2015). Que hacemos?
- Corbera, E., Brown, K., and Adger, W. N. (2007). The equity and legitimacy of markets for ecosystem services. *Development and change*, 38(4):587–613.
- Corbera, E., González Soberanis, C., and Brown, K. (2009). Institutional dimensions of payments for ecosystem services: An analysis of mexico's carbon forestry programme. *Ecological Economics*, 68(3):743 – 761.
- Costanza, R., d'Arge, R., Groot, R. d., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R. V., Paruelo, J., et al. (1998). The value of the world's ecosystem services and natural capital.

- Costanza, R., Wilson, M. A., Troy, A., Voinov, A., Liu, S., and D'Agostino, J. (2006). The value of new jersey's ecosystem services and natural capital.
- Costedoat, S., Corbera, E., Ezzine-de Blas, D., Honey-Rosés, J., Baylis, K., and Castillo-Santiago, M. (2015). How effective are biodiversity conservation payments in mexico? *PloS one*, 10(3):e0119881.
- Daily, G. (1997). *Nature's services: societal dependence on natural ecosystems*. Island Press.
- De Groot, R. S., Wilson, M. A., and Boumans, R. M. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological economics*, 41(3):393–408.
- De Janvry, A., Dutilly, C., Muñoz-Piña, C., and Sadoulet, E. (2001). Liberal reforms and community responses in mexico. *Communities and markets in economic development*, pages 318–44.
- De Janvry, A., Gonzalez-Navarro, M., and Sadoulet, E. (2014). Are land reforms granting complete property rights politically risky? electoral outcomes of mexico's certification program. *Journal of Development Economics*, 110:216–225.
- De Janvry, A., Gordillo, G., Sadoulet, E., et al. (1997). *Mexico's second agrarian reform: household and community responses, 1990-1994*.
- Deaton, A. S. (2009). Instruments of development: Randomization in the tropics, and the search for the elusive keys to economic development. Technical report, National Bureau of Economic Research.
- Deininger, K. and Bresciani, F. (2001). Mexico's second agrarian reform: implementation and impact. *Washington DC: World Bank*.
- Deininger, K. and Minten, B. (2002). Determinants of deforestation and the economics of protection: An application to mexico. *American Journal of Agricultural Economics*, 84(4):943–960.
- Deininger, K. W. et al. (2003). *Land policies for growth and poverty reduction*. World Bank Publications.
- Deininger, K. W. and Minten, B. (1999). Poverty, policies, and deforestation: the case of mexico. *Economic Development and Cultural Change*, 47(2):313–344.
- Delacote, P., Robinson, E. J., Roussel, S., et al. (2015). Deforestation, leakage and avoided deforestation policies: A spatial analysis. Technical report.
- Diamond, A. and Sekhon, J. S. (2013). Genetic matching for estimating causal effects: A general multivariate matching method for achieving balance in observational studies. *Review of Economics and Statistics*, 95(3):932–945.

- Dudley, N. (2008). *Guidelines for applying protected area management categories*. IUCN.
- Dutilly, C. (2001). *Action Collective et Coopération Partielle dans la Gestion des Ressources Communes: Le Cas des Ejidos Mexicains*. PhD thesis, Université d'Auvergne, Clermont-Ferrand I.
- Ellis, E. A. and Porter-Bolland, L. (2008). Is community-based forest management more effective than protected areas?: A comparison of land use/land cover change in two neighboring study areas of the central yucatan peninsula, mexico. *Forest ecology and management*, 256(11):1971–1983.
- Engel, S., Pagiola, S., and Wunder, S. (2008). Designing payments for environmental services in theory and practice: An overview of the issues. *Ecological economics*, 65(4):663–674.
- Ewers, R. M. and Rodrigues, A. S. (2008). Estimates of reserve effectiveness are confounded by leakage. *Trends in Ecology & Evolution*, 23(3):113–116.
- FAO (2011). *State of the world's forests 2011*. FAO, Rome.
- Farber, S. C., Costanza, R., and Wilson, M. A. (2002). Economic and ecological concepts for valuing ecosystem services. *Ecological economics*, 41(3):375–392.
- Farley, J. and Costanza, R. (2010). Payments for ecosystem services: from local to global. *Ecological Economics*, 69(11):2060–2068.
- Ferraro, P. J. (2008). Asymmetric information and contract design for payments for environmental services. *Ecological Economics*, 65(4):810–821.
- Ferraro, P. J. (2009). Counterfactual thinking and impact evaluation in environmental policy. *New Directions for Evaluation*, 2009(122):75–84.
- Ferraro, P. J. (2011). The future of payments for environmental services. *Conservation Biology*, 25(6):1134–1138.
- Ferraro, P. J., Hanauer, M. M., Miteva, D. A., Canavire-Bacarreza, G. J., Patanayak, S. K., and Sims, K. R. (2013). More strictly protected areas are not necessarily more protective: evidence from bolivia, costa rica, indonesia, and thailand. *Environmental Research Letters*, 8(2):025011.
- Ferraro, P. J., Hanauer, M. M., and Sims, K. R. (2011). Conditions associated with protected area success in conservation and poverty reduction. *Proceedings of the National Academy of Sciences*, 108(34):13913–13918.
- Ferraro, P. J. and Kiss, A. (2002). Direct payments to conserve biodiversity. *Science*, 298(5599):1718–1719.

- Ferraro, P. J. and Miranda, J. J. (2013). Heterogeneous treatment effects and mechanisms in information-based environmental policies: Evidence from a large-scale field experiment. *Resource and Energy Economics*, 35(3):356–379.
- Ferraro, P. J. and Pattanayak, S. K. (2006). Money for nothing? a call for empirical evaluation of biodiversity conservation investments. *PLoS biology*, 4(4).
- Fiquepron, J., Garcia, S., and Stenger, A. (2013). Land use impact on water quality: valuing forest services in terms of the water supply sector. *Journal of Environmental Management*, 126:113–121.
- Gan, J. and McCarl, B. A. (2007). Measuring transnational leakage of forest conservation. *Ecological Economics*, 64(2):423–432.
- García-Amado, L. R., Ruiz Pérez, M., Reyes Escutia, F., Barrasa García, S., and Contreras Mejía, E. (2011). Efficiency of payments for environmental services: Equity and additionality in a case study from a biosphere reserve in chiapas, mexico. *Ecological Economics*, 70(12):2361 – 2368.
- Geres, R. and Michaelowa, A. (2002). A qualitative method to consider leakage effects from cdm and ji projects. *Energy Policy*, 30(6):461–463.
- Gerez Fernandez, P. and Alatorre-Guzman, E. (2005). Challenges for forest certification and community forestry in mexico. *The community-managed forests of Mexico: Managing for sustainable landscapes*, pages 71–87.
- Gómez-Baggethun, E., De Groot, R., Lomas, P. L., and Montes, C. (2010). The history of ecosystem services in economic theory and practice: from early notions to markets and payment schemes. *Ecological Economics*, 69(6):1209–1218.
- Gómez-Baggethun, E. and Muradian, R. (2015). In markets we trust? setting the boundaries of market-based instruments in ecosystem services governance. *Ecological Economics*.
- Gordillo de Anda, G., Janvry, A. d., and Sadoulet, E. (1998). Between political control and efficiency gains: the evolution of agrarian property rights in mexico. *Cepal Review*.
- Grieg-Gran, M., Porras, I., and Wunder, S. (2005). How can market mechanisms for forest environmental services help the poor? preliminary lessons from latin america. *World Development*, 33(9):1511–1527.
- Guevara-Sanginés, A. and Lara-Pulido, J. (2012). Evolución de los programas de conafor: origen, desarrollo y perspectivas a futuro. In *CONAFOR en la historia y futuro de Mexico*. CONAFOR.
- Haenn, N. (2006). The changing and enduring ejido: a state and regional examination of mexico’s land tenure counter-reforms. *Land Use Policy*, 23(2):136–146.

- Heath, J. R. (1992). Evaluating the impact of mexico's land reform on agricultural productivity. *World development*, 20(5):695–711.
- Heckman, J. and Navarro-Lozano, S. (2004). Using matching, instrumental variables, and control functions to estimate economic choice models. *The Review of Economics and Statistics*, 86(1):30–57.
- Heckman, J. J. and Urzua, S. (2010). Comparing iv with structural models: What simple iv can and cannot identify. *Journal of Econometrics*, 156(1):27–37.
- Hendrickson, C. Y. and Corbera, E. (2015). Participation dynamics and institutional change in the scolel té carbon forestry project, chiapas, mexico. *Geoforum*, 59:63–72.
- Hirano, K. and Imbens, G. W. (2001). Estimation of causal effects using propensity score weighting: An application to data on right heart catheterization. *Health Services and Outcomes research methodology*, 2(3-4):259–278.
- Hirano, K. and Imbens, G. W. (2004). The propensity score with continuous treatments. *Applied Bayesian modeling and causal inference from incomplete-data perspectives*, pages 73–84.
- Hirano, K., Imbens, G. W., and Ridder, G. (2003). Efficient estimation of average treatment effects using the estimated propensity score. *Econometrica*, 71(4):1161–1189.
- Ho, D. E., Imai, K., King, G., and Stuart, E. A. (2007). Matching as nonparametric preprocessing for reducing model dependence in parametric causal inference. *Political analysis*, 15(3):199–236.
- Honey-roses, J., Baylis, K., and Ramirez, M. I. (2011). A spatially explicit estimate of avoided forest loss. *Conservation Biology*, 25(5):1032–1043.
- Imbens, G. and Wooldridge, J. (2007). Control function and related methods. *What's new in Econometrics*.
- Imbens, G. W. (2009). Better late than nothing: Some comments on deaton (2009) and heckman and urzua (2009). Technical report, National Bureau of Economic Research.
- Jack, B. K. (2009). Upstream–downstream transactions and watershed externalities: Experimental evidence from kenya. *Ecological economics*, 68(6):1813–1824.
- Jack, B. K., Kousky, C., and Sims, K. R. (2008). Designing payments for ecosystem services: Lessons from previous experience with incentive-based mechanisms. *Proceedings of the National Academy of Sciences*, 105(28):9465–9470.
- Jayachandran, S. (2013). Liquidity constraints and deforestation: The limitations of payments for ecosystem services. *American Economic Review*, 103(3):309–13.

- Joppa, L. and Pfaff, A. (2010). Reassessing the forest impacts of protection. *Annals of the New York Academy of Sciences*, 1185(1):135–149.
- Joppa, L. N. and Pfaff, A. (2009). High and far: biases in the location of protected areas. *PLoS One*, 4(12):8273.
- Kaimowitz, T. (2005). Mexico: Market options and barriers for timber and sawnwood from michoacan, oaxaca, guerrero, campeche adn quintana roo. a summary. Technical report, Forest Trends.
- Karsenty, A. (2004). Des rentes contre le développement? les nouveaux instruments d'acquisition mondiale de la biodiversité et l'utilisation des terres dans les pays tropicaux. *Mondes en développement*, (3):61–74.
- Karsenty, A. (2011). Combining conservation incentives with investment. *Perspective, Environmental Policies*, 7.
- Karsenty, A. and Ezzine de Blas, D. (2014). Du mésusage des métaphores - les paiements pour services environnementaux sont-ils des instruments de marchandisation de la nature ? In Halpern P. Lascoumes, P. L. G., editor, *L'instrumentation de l'action publique - Controverses, résistances, effets*, pages 161–189. Presses de Sciences Po.
- Key, N., Munoz-Pina, C., de Janvry, A., and Sadoulet, E. (1998). Social and environmental consequences of the mexican reforms: Common pool resources in the ejido sector. University of California at Berkeley, Department of Agricultural and Resource Economics.
- Khandker, S. R., Koolwal, G. B., and Samad, H. A. (2010). *Handbook on impact evaluation: quantitative methods and practices*. World Bank Publications.
- Klepeis, P. and Turner Ii, B. (2001). Integrated land history and global change science:: the example of the southern yucatán peninsular region project. *Land Use Policy*, 18(1):27–39.
- Klooster, D. and Masera, O. (2000). Community forest management in mexico: carbon mitigation and biodiversity conservation through rural development. *Global Environmental Change*, 10(4):259 – 272.
- Kolinjivadi, V., Grant, A., Adamowski, J., and Kosoy, N. (2015). Juggling multiple dimensions in a complex socio-ecosystem: The issue of targeting in payments for ecosystem services. *Geoforum*, 58:1–13.
- Kosoy, N. and Corbera, E. (2010). Payments for ecosystem services as commodity fetishism. *Ecological Economics*, 69(6):1228–1236.
- Kull, C. A., de Sartre, X. A., and Castro-Larrañaga, M. (2015). The political ecology of ecosystem services. *Geoforum*, 61:122–134.

- Lapeyre, R. and Pirard, R. (2013). Payments for environmental services and market-based instruments: next of kin or false friends. Technical report, IDDRI Working Paper.
- Lapeyre, R., Pirard, R., and Leimona, B. (2015). Payments for environmental services in indonesia: What if economic signals were lost in translation? *Land Use Policy*, 46:283–291.
- Le Coq, J.-F., Froger, G., Legrand, T., Pesche, D., and Saenz-Segura, F. (2013). The governance of costa rica’s programme of payments for environmental services: A stakeholder’s perspective. In *Governing the provision of ecosystem services*, pages 235–255. Springer.
- Le Gallo, J. (2002). Économétrie spatiale: l’autocorrélation spatiale dans les modèles de régression linéaire. *Economie & prévision*, (4):139–157.
- LeSage, J. and Pace, R. K. (2009). *Introduction to Spatial Econometrics (Statistics: A Series of Textbooks and Monographs)*. Chapman and Hall/CRC, 1 edition.
- Lunceford, J. K. and Davidian, M. (2004). Stratification and weighting via the propensity score in estimation of causal treatment effects: a comparative study. *Statistics in medicine*, 23(19):2937–2960.
- Martin Persson, U. and Alpízar, F. (2012). Conditional cash transfers and payments for environmental services - a conceptual framework for explaining and judging differences in outcomes. *World Development*, 43:124–137.
- Mas, J.-F. (2005). Assessing protected area effectiveness using surrounding (buffer) areas environmentally similar to the target area. *Environmental monitoring and assessment*, 105(1-3):69–80.
- McAfee, K. and Shapiro, E. N. (2010). Payments for ecosystem services in mexico: Nature, neoliberalism, social movements, and the state. *Annals of the Association of American Geographers*, 100(3):579–599.
- Merino-Perez, L. and Segura-Warnholtz, G. (2005). Forest and conservation policies and their impact on forest communities in mexico. *The community forests of Mexico: managing for sustainable landscapes*, pages 49–70.
- Mickwitz, P. and Birnbaum, M. (2009). Key insights for the design of environmental evaluations. *New Directions for Evaluation*, 2009(122):105–112.
- Miteva, D. A., Pattanayak, S. K., and Ferraro, P. J. (2012). Evaluation of biodiversity policy instruments: what works and what doesn’t? *Oxford Review of Economic Policy*, 28(1):69–92.
- Mundell, R. A. (1962). The appropriate use of monetary and fiscal policy for internal and external stability. *Staff Papers-International Monetary Fund*, pages 70–79.

- Muñoz-Piña, C., Fernández, J., Jaramillo, L., and Esteva, G. (2004). Pixel patterns of deforestation in Mexico: 1993–2000. Technical report, INE Working Paper Series.
- Muñoz Piña, C., Rivera, M., Cisneros, A., García, H., et al. (2011). Payment for environmental services in Mexico: Targeting challenges. *Revista Española de Estudios Agrosociales y Pesqueros*.
- Muñoz-Piña, C., Guevara, A., Torres, J. M., and Braña, J. (2008). Paying for the hydrological services of Mexico's forests: Analysis, negotiations and results. *Ecological Economics*, 65(4):725–736.
- Muradian, R. (2013). Payments for ecosystem services as incentives for collective action. *Society & Natural Resources*, 26(10):1155–1169.
- Muradian, R., Arsel, M., Pellegrini, L., Adaman, F., Aguilar, B., Agarwal, B., Corbera, E., Ezzine de Blas, D., Farley, J., Froger, G., et al. (2013). Payments for ecosystem services and the fatal attraction of win-win solutions. *Conservation Letters*, 6(4):274–279.
- Muradian, R., Corbera, E., Pascual, U., Kosoy, N., and May, P. H. (2010). Reconciling theory and practice: An alternative conceptual framework for understanding payments for environmental services. *Ecological Economics*, 69(6):1202–1208.
- Muradian, R. and Rival, L. (2012). Between markets and hierarchies: the challenge of governing ecosystem services. *Ecosystem Services*, 1(1):93–100.
- Murray, B. C., McCarl, B. A., and Lee, H.-C. (2004). Estimating leakage from forest carbon sequestration programs. *Land Economics*, 80(1):109–124.
- Nakamura, A. and Nakamura, M. (1981). On the relationships among several specification error tests presented by Durbin, Wu, and Hausman. *Econometrica: Journal of the Econometric Society*, pages 1583–1588.
- Near, D. G., Ice, G. G., and Jackson, C. R. (2009). Linkages between forest soils and water quality and quantity. *Forest Ecology and Management*, 258(10):2269–2281.
- Norgaard, R. B. (2010). Ecosystem services: From eye-opening metaphor to complexity blinder. *Ecological Economics*, 69(6):1219–1227.
- Pagiola, S. (2008). Payments for environmental services in Costa Rica. *Ecological Economics*, 65(4):712–724.
- Pagiola, S., Agostini, P., Gobbi, J., de Haan, C., Ibrahim, M., Murgueitio, E., Ramírez, E., Rosales, M., and Ruíz, J. P. (2004a). *Paying for biodiversity conservation services in agricultural landscapes*. World Bank, Environment Department.
- Pagiola, S., Arcenas, A., and Platais, G. (2005). Can payments for environmental services help reduce poverty? An exploration of the issues and the evidence to date from Latin America. *World Development*, 33(2):237–253.

- Pagiola, S., Von Ritter, K., and Bishop, J. (2004b). Assessing the economic value of ecosystem conservation.
- Pascual, U. (2005). Land use intensification potential in slash-and-burn farming through improvements in technical efficiency. *Ecological Economics*, 52(4):497–511.
- Pascual, U., Muradian, R., Rodríguez, L. C., and Duraiappah, A. (2010). Exploring the links between equity and efficiency in payments for environmental services: A conceptual approach. *Ecological Economics*, 69(6):1237–1244.
- Pascual, U., Phelps, J., Garmendia, E., Brown, K., Corbera, E., Martin, A., Gomez-Baggethun, E., and Muradian, R. (2014). Social equity matters in payments for ecosystem services. *BioScience*, page biu146.
- Pattanayak, S. K., Wunder, S., and Ferraro, P. J. (2010). Show me the money: Do payments supply environmental services in developing countries? *Review of Environmental Economics and Policy*, 4(2):254–274.
- Perrot-Maitre, D. (2006). The vittel payments for ecosystem services: a §perfectĩ pes case. *International Institute for Environment and Development, London, UK*, pages 1–24.
- Pfaff, A., Robalino, J., Sanchez-Azofeifa, G., Andam, K., and Ferraro, P. (2009). Park location affects forest protection: Land characteristics cause differences in park impacts across costa rica. *The BE Journal of Economic Analysis and Policy*, 9(2):5.
- Pfaff, A., Robalino, J. A., and Sanchez-Azofeifa, G. A. (2008). Payments for environmental services: empirical analysis for costa rica. *Terry Sanford Institute of Public Policy, Duke University, Durham, NC, USA*.
- Pirard, R. (2012). Market-based instruments for biodiversity and ecosystem services: A lexicon. *Environmental Science & Policy*, 19:59–68.
- Pirard, R., Billé, R., and Sembrés, T. (2010). Questioning the theory of payments for ecosystem services in light of emerging experience and plausible developments. Technical report, IDDRI Analyses 4/10.
- Porter-Bolland, L., Ellis, E. A., Guariguata, M. R., Ruiz-Mallén, I., Negrete-Yankelevich, S., and Reyes-García, V. (2012). Community managed forests and forest protected areas: An assessment of their conservation effectiveness across the tropics. *Forest Ecology and Management*, 268:6–17.
- Ravallion, M. (2007). Evaluating anti-poverty programs. *Handbook of development economics*, 4:3787–3846.
- Ring, I. and Schröter-Schlaack, C. (2011). Instrument mixes for biodiversity policies. *Helmholtz Centre for Environmental Research*.

- Robalino, J. and Pfaff, A. (2013). Ecopayments and deforestation in costa rica: A nationwide analysis of psa's initial years. *Land Economics*, 89(3):432–448.
- Robalino, J., Pfaff, A., Sanchez-Azofefia, G. A., Alpízar, F., León, C., and Rodríguez, C. M. (2008). Deforestation impacts of environmental services payments: Costa rica's psa program 2000–2005. Technical report.
- Robalino, J. and Villalobos-Fiatt, L. (2010). Conservation policies and labor markets: Unraveling the effects of national parks on local wages in costa rica. Technical report.
- Robalino, J. A. and Pfaff, A. (2012). Contagious development: Neighbor interactions in deforestation. *Journal of Development Economics*, 97(2):427–436.
- Robins, J. M., Rotnitzky, A., and Zhao, L. P. (1995). Analysis of semiparametric regression models for repeated outcomes in the presence of missing data. *Journal of the American Statistical Association*, 90(429):106–121.
- Rode, J., Gomez-Baggethun, E., and Krause, T. (2014). Motivation crowding by economic incentives in conservation policy: A review of the empirical evidence. *Ecological Economics*, (0):–.
- Rodríguez, L. C., Pascual, U., Muradian, R., Pazmino, N., and Whitten, S. (2011). Towards a unified scheme for environmental and social protection: Learning from pes and cct experiences in developing countries. *Ecological Economics*, 70(11):2163–2174.
- Rolon, E., Salas, I., and Islas, I. (2011). The mexican pes programme: targeting for higher efficiency in environmental protection and poverty alleviation. In B. Rapidel, F. D., LeCoq, J. F., and Beer, J., editors, *Ecosystem Services from Agriculture and Agroforestry: Measurement and Payment*. Routledge.
- Rosenbaum, P. R. (2002). *Observational studies*. Springer.
- Rosenbaum, P. R. and Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika*, 70(1):41–55.
- Rubin, D. B. (1974). Estimating causal effects of treatments in randomized and nonrandomized studies. *Journal of educational Psychology*, 66(5):688.
- Rubin, D. B. (1980). Randomization analysis of experimental data: The fisher randomization test comment. *Journal of the American Statistical Association*, 75(371):591–593.
- Rueda, X. (2010). Understanding deforestation in the southern yucatán: insights from a sub-regional, multi-temporal analysis. *Regional Environmental Change*, 10(3):175–189.

- Sadoulet, E., Janvry, A. d., and Davis, B. (2001). Cash transfer programs with income multipliers: Procampo in Mexico. *World Development*, 29(6):1043–1056.
- Salles, J.-M. (2011). Valuing biodiversity and ecosystem services: Why put economic values on nature? *Comptes Rendus Biologies*, 334(5):469 – 482. Biodiversity in face of human activities / La biodiversité face aux activités humaines.
- Sargan, J. D. (1988). Testing for misspecification after estimating using instrumental variables. *Contributions to Econometrics: John Denis Sargan*, 1:213–235.
- Scheer, S. J., White, A., and Kaimowitz, D. (2002). Making markets work for forests communities, forests trends. Technical report, Forests Trends.
- Schmook, B. (2010). Shifting maize cultivation and secondary vegetation in the southern Yucatán: Successional forest impacts of temporal intensification. *Regional Environmental Change*, 10(3):233–246.
- Schmook, B. and Radel, C. (2008). International labor migration from a tropical development frontier: globalizing households and an incipient forest transition. *Human Ecology*, 36(6):891–908.
- Schmook, B. and Vance, C. (2009). Agricultural policy, market barriers, and deforestation: the case of Mexico's southern Yucatán. *World Development*, 37(5):1015–1025.
- Schwarze, R., Niles, J. O., and Olander, J. (2002). Understanding and managing leakage in forest-based greenhouse-gas-mitigation projects. *Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences*, 360(1797):1685–1703.
- Shapiro-Garza, E. (2013). Contesting the market-based nature of Mexico's national payments for ecosystem services programs: Four sites of articulation and hybridization. *Geoforum*.
- Sianesi, B. (2004). An evaluation of the Swedish system of active labor market programs in the 1990s. *Review of Economics and Statistics*, 86(1):133–155.
- Sims, K. R. (2010). Conservation and development: Evidence from Thai protected areas. *Journal of Environmental Economics and Management*, 60(2):94–114.
- Sims, K. R. and Alix-Garcia, J. M. (2014). It's complicated: Direct vs. incentive-based land conservation in Mexico. Technical report, Working paper, Department of Economics, Amherst College, Amherst, MA.
- Sims, K. R., Alix-Garcia, J. M., Shapiro-Garza, E., Fine, L., Radloff, V. C., Aronson, G., Castillo, S., Ramirez-Reyes, C., and Yanez-Pagans, P. (2014). Improving environmental and social targeting through adaptive management in Mexico's payments for hydrological services program. *Conservation Biology*, 28(5):1151–1159.

- Smith, J. and Todd, P. (2005). Does matching overcome lalonde's critique of non-experimental estimators? *Journal of econometrics*, 125(1):305–353.
- Sohnngen, B. and Brown, S. (2004). Measuring leakage from carbon projects in open economies: a stop timber harvesting project in bolivia as a case study. *Canadian Journal of Forest Research*, 34(4):829–839.
- Sorrell, S. and Sijm, J. (2003). Carbon trading in the policy mix. *Oxford Review of Economic Policy*, 19(3):420–437.
- Staiger, D. O. and Stock, J. H. (1994). Instrumental variables regression with weak instruments.
- Swallow, B. M., Kallesoe, M. F., Iftikhar, U. A., van Noordwijk, M., Bracer, C., Scherr, S. J., Raju, K., Poats, S. V., Duraiappah, A. K., Ochieng, B. O., et al. (2009). Compensation and rewards for environmental services in the developing world: framing pan-tropical analysis and comparison. *Ecology & Society*, 14(2).
- Tinbergen, J. (1952). *On the theory of economic policy*.
- Torres-Rojo, J., Guevara-Sangines, A., and Bray, D. (2005). The managerial economics of sustainable community forestry in mexico: A case study of el balcon, tecpan, guerrero. *The Community Forests of Mexico: Managing for Sustainable Landscapes*, University of Texas Press, Austin, pages 273–301.
- Turner, I. (2010). Sustainability and forest transitions in the southern yucatán: The land architecture approach. *Land Use Policy*, 27(2):170–179.
- Vatn, A. (2010). An institutional analysis of payments for environmental services. *Ecological Economics*, 69(6):1245–1252.
- Vatn, A. (2015). Markets in environmental governance— from theory to practice. *Ecological Economics*, 105:97–105.
- Vincent, J. R. (2015). Impact evaluation of forest conservation programs: Benefit-cost analysis, without the economics. *Environmental and Resource Economics*, pages 1–14.
- Watson, R. T., Noble, I. R., Bolin, B., Ravindranath, N., Verardo, D. J., Dokken, D. J., et al. (2000). *Land use, land-use change and forestry: a special report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.
- Weber, J. (2013). Gestion des ressources renouvelables: fondements théoriques d'un programme de recherche. *Indisciplines*, pages 35–52.
- Wooldridge, J. M. (2002). *Econometric Analysis Cross Section Panel*. MIT press.
- Wu, J. (2000). Slippage effects of the conservation reserve program. *American Journal of Agricultural Economics*, 82(4):979–992.

- Wu, J., Zilberman, D., and Babcock, B. A. (2001). Environmental and distributional impacts of conservation targeting strategies. *Journal of Environmental Economics and Management*, 41(3):333–350.
- Wunder, S. (2005). *Payments for environmental services: some nuts and bolts*, volume 42. CIFOR Jakarta.
- Wunder, S. (2007). The efficiency of payments for environmental services in tropical conservation. *Conservation biology*, 21(1):48–58.
- Wunder, S. (2008). How do we deal with leakage. *Moving ahead with REDD: issues, options and implications*, pages 65–75.
- Wunder, S. (2015). Revisiting the concept of payments for environmental services. *Ecological Economics*.
- Wunder, S., Engel, S., and Pagiola, S. (2008). Taking stock: A comparative analysis of payments for environmental services programs in developed and developing countries. *Ecological Economics*, 65(4):834 – 852.
- Wünscher, T., Engel, S., and Wunder, S. (2008). Spatial targeting of payments for environmental services: a tool for boosting conservation benefits. *Ecological economics*, 65(4):822–833.
- Yanez-Pagans, P. (2013). Cash for cooperation? payments for ecosystem services and common property management in Mexico. In *2013 Annual Meeting, August 4-6, 2013, Washington, DC*, number 151295. Agricultural and Applied Economics Association.
- Zhao, Z. (2004). Using matching to estimate treatment effects: data requirements, matching metrics, and monte carlo evidence. *Review of Economics and Statistics*, 86(1):91–107.
- Zilberman, D., Lipper, L., and McCarthy, N. (2008). When could payments for environmental services benefit the poor? *Environment and Development Economics*, 13(03):255–278.
- Zilberman, D., Lipper, L., and McCarthy, N. (2009). Putting payments for environmental services in the context of economic development. In Lipper, L., Sakuyama, T., Stringer, R., and Zilberman, D., editors, *Payment for Environmental Services in Agricultural Landscapes*, volume 31 of *Natural Resource Management and Policy*, pages 9–33. Springer New York.

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THE EFFECTIVENESS OF PAYMENTS FOR ENVIRONMENTAL SERVICES IN MEXICAN COMMUNITY FORESTS

Résumé

La thèse contribue à la littérature concernant l'efficacité des paiements pour services environnementaux (PSE) en se concentrant plus spécifiquement sur l'impact d'un programme fédéral mexicain de PSE: le PSA-H. Après une introduction générale retraçant l'émergence des PSE et les débats académiques autour de l'instrument, le second chapitre présente les spécificités du système foncier mexicain, les politiques environnementales et plus spécifiquement le PSA-H ainsi que les données utilisées dans l'analyse empirique. La thèse s'intéresse ensuite dans un troisième chapitre aux méthodes d'analyse d'impact et à leur application dans le contexte des instruments de conservation de la forêt. Par la suite, nous proposons trois analyses empiriques s'appuyant sur des données primaires et secondaires. Le quatrième chapitre présente une nouvelle méthode permettant d'estimer l'additionnalité et les effets de fuite du PSA-H dans notre zone d'étude. Dans le cinquième chapitre, la thèse étudie comment l'usage de la terre peut influencer l'allocation des paiements au sein des communautés bénéficiaires. Le sixième chapitre étudie les interactions entre le PSA-H et la foresterie communautaire. Enfin, dans une conclusion générale, la thèse discute les implications des analyses empiriques pour la conception des PSE et les perspectives de recherche qui en découlent.

Mots clés: Analyse d'Impact; Conservation de la Forêt; Economie de l'Environnement; Mexique; Paiements pour Services Environnementaux

Abstract

This dissertation contributes to the literature regarding Payments for Environmental Services (PES) effectiveness with a specific focus on the impact of a federal Mexican PES scheme: the PSA-H. After a general introduction retracing the emergence of PES and the current academic debates, Chapter 2 introduces the particularity of the land tenure system in Mexico, the country's environmental policies and the PSA-H scheme and the data used in the empirical analysis. Chapter 3 looks at impact evaluation methodologies and how they have been used in the context of forest conservation instruments. Once discussed these challenges, we propose three empirical essays based on primary and secondary data. Chapter 4 presents a new methodology allowing us to estimate the additionality and leakages of the PSA-H in our study area. Chapter 5 studies how land use can influence the allocation of PES payments within the beneficiary community. Chapter 6 studies the interactions between the PSA-H and Community Forestry. Finally, in the conclusion, we discuss the implications of the empirical essays for the design of PES schemes and future research.

Keywords: Environmental Economics; Forest conservation; Impact evaluation; Mexico; Payments for Environmental Services