Title

This Land is Your Land: Property rights and land use in Mexico and Vietnam

Author

Kutzman, Daley Catherine

Publication Date

2016

This Land is Your Land: Property rights and land use in Mexico and Vietnam

By

Daley Catherine Kutzman

A dissertation submitted in partial satisfaction of the
requirements for the degree of
Doctor of Philosophy
in
Agricultural and Resource Economics

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor Elisabeth Sadoulet, Chair
Professor Alain de Janvry
Professor Pranab Bardhan

Spring 2016

This Land is Your Land: Property rights and land use in Mexico and Vietnam

Abstract

This Land is Your Land: Property rights and land use in Mexico and Vietnam

By

Daley Catherine Kutzman

Doctor of Philosophy in Agricultural and Resource Economics

University of California, Berkeley

Professor Elisabeth Sadoulet, Chair

When 70 percent of the world's poor are rural with agriculture as their main source of income, the intersection between land rights and land use becomes increasingly important to global poverty reduction. I explore the ways by which dimensions of land rights shape and distort land use away from its optimal allocation. Using a wide range of data, including satellite imagery, censuses, and household surveys, I present empirical evidence that demonstrates the effect of ill-defined and limited property rights on land use in poor, rural communities in two diverse countries.

Well-defined private property rights over land should incentivize efficient transactions between owners, efficient levels of investment as well as optimal allocation across different uses. Thus a strengthening of property rights would result in a land allocation closer to the counterfactual private property outcome due to a reallocation of land across uses (depending on their relative returns). In the first chapter, I examine the impacts of part of Mexico's second agrarian reform in 1993, Programa de Certificacion de Derechos Ejidales y Titulacion de Solares (Procede), which certified all land in Mexico's ejido communities. Using LANDSAT images of ejido and non-ejido land to characterize land use and suitability for different uses in Mexico over this period, we find that the average ejido does in fact alter its allocation of land across forest, agriculture and pasture in response to certification. While the average results indicate that Procede had a positive effect on forest (31 ha.), an offsetting negative effect on pasture (29 ha.), and no effect on agriculture, we explore further heterogeneity based on estimated land suitability. Using several spatial datasets of physical, climatic and economic characteristics, we estimate land suitability based on private property, non-ejido land in Mexico. The pattern suggests that strengthening property rights induced a convergence of ejido land allocation to the allocation implemented under private property. In total, the area deforested over 1990-2010 would have been approximately 14 percent higher, there would have been 40 thousand fewer hectares of cultivated land, and 715 thousand more hectares of pasture had Procede not been implemented and ejido land left uncertified.

The next chapter focuses instead on Vietnam, in which the state takes advantage of incomplete property rights to directly influence land allocation decisions. Across many economic contexts, there are policies whose efficacy is undermined by endogenous responses of agents due to a misalignment of incentives. In this chapter, I show that households' production responses to a food security policy in Vietnam that restricts household land to be used for rice considerably undermines the policy's purpose. I develop a model of farmer crop choice that demonstrates how divergence of interest between the farmer and commune authority, and subsistence rice production constraints for the household generate different testable predictions for the impact of restrictions at both the household and plot levels. I test these predictions using four rounds of the household and plot panels of the Vietnam Access to Resources Household Survey (VARHS) between 2006-2012. The evidence suggests that land use restrictions are largely ineffective at increasing household rice production and lower agricultural profits. This is due to the fact that households reduce rice production on their unrestricted land while complying with restrictions. Counterfactual household rice production without any such 'slippage' on unrestricted land is 12 percent higher, and I estimate that restrictions reduces household agricultural profits by 15 percent on average. Thus, the policy appears to be unsuccessful in increasing household rice production while at the same time imposing welfare costs to the household.

Graduate students, I suppose, were children once.

Contents

List of Tables

List of Figures

Acknowledgements

Both the existence and quality of this work is in great deal owed to my advisors, Elisabeth Sadoulet and Alain de Janvry. I met them when I was a 20-year-old in their undergraduate classes here at Cal, and even then they pushed me to meet and exceed their expectations. Betty, you were my first introduction to econometrics and empirical research 8 years ago, so it's only fitting that you hold the chair's seat on my committee now. Thank you for meeting me halfway any day, any time, for any reason. Your door was *always* open. While I may not always share your confidence in me, it has given me resilience in times of need.

Other faculty have been instrumental in the development of my research, including Ethan Ligon and Jeremy Magruder for their incredibly useful comments in the Friday Development Workshop, and Leo Simon for his patience and thoroughness. Sofia Villas-Boas and Max Auffhammer provided incredible assistance on the job market, responding to so many of my emails. I also have to single out my high school economics teacher, Mr. Jason Stowers, who often succumbed to hammering his forehead with his fist in (mock?) frustration as I insisted economics could make sense to me, if only he used calculus. Without that class, I may have never enrolled in economics as a college student to see what the fuss was about.

I'd like to thank Gabriel Demombynes at the World Bank for providing me the opportunity to work alongside him in Hanoi, Vietnam, and for giving me access to the data from which my second chapter miraculously sprung. The help and patience of Linh Hoang Vu, Ngoc Nguyen, Thomas Markussen and Finn Tarp will never be forgotten. Marco Gonzalez-Navarro was also instrumental in the formation of my first chapter—with every long Skype call, the paper improved immeasurably.

The program brought me a singular friend in Angeli Kirk, for whom I'll always be grateful. Her support, sarcasm, and sanity were essential to my survival for the past 6 years. I submit that having a friend like her should be a graduate admissions criterion, as I absolutely do not recommend attempting a Ph.D. program without a friend with whom you can share every happy, terrifying, humiliating, relieving, and hilarious moment. I'm also grateful for the companionship and camaraderie of Eduardo Montoya, Gavin McCormick, Elliot Collins, and Megan Stevenson. I'll never forget sitting in our tiny office on the second floor of Giannini Hall with Angeli, Eddie, and Elliot an hour before our development field exam, laughing ourselves to tears because we felt so unprepared.[1] A special thanks to Andrew Dustan is definitely in order, both for setting such a great example for me and for behaving like a human being, full of understanding and wisdom.

The administrative staff in the coziest corner of Giannini also have a well-deserved place here. Gail Vawter, Diana Lazo, and Carmen Karahalios never failed to get me out of every

---

[1] Spoiler: We weren't, as it turns out.

tight spot I got myself into, providing a wealth of support and community over these many years. The graduate students of Giannini are so lucky to have them.

I never would have believed I could do such a thing as write a dissertation without my family, whom no adjective can sufficiently describe. To my mom, I owe my wealth of intrinsic motivation and curiosity that was put to infinite use in a program that often requires more than just effort. To my dad, I owe the tenacity, the resolve, the stubbornness in my bones that I draw on every time it would be easier to quit. To my brother Blair and my sister Morgan, whose accomplishments leave me—the Ph.D.—as the least accomplished sibling, I owe the grounding perspective that there is life outside of success or failure and the belief that goals are attainable to those willing to reach for them.

Finally, I have to thank you, Kurt, probably the only person who will read this. You've practically earned a degree just dealing with me and all of the "sweat, blood, and tears" (as you often say) that I've shed in the making of this. I will gladly claim that no one has ever taken better care of a graduate student. How can I sufficiently thank you for staying up with me while I worked just to keep me company, for all the days you used your lunch break to visit and give me a hug, for the rides to/from campus when I was exhausted, for every time you surprised me with a knock on my office door because you could tell I was feeling discouraged? I could go on and on, this list is countably infinite.

Kurt, you are an oasis of reassurance and solace and fun that I probably don't deserve, and absolutely none of this was possible without you. You can pick our next adventure.

DALEY KUTZMAN
3764 Shafter Ave, # 106 ⋄ Oakland, CA 94609 ⋄ United States
1-530-305-4443 ⋄ dkutzman@berkeley.edu

EDUCATION

University of California, Berkeley *August 2010 - May 2016*
PhD. in Agricultural and Resource Economics
M.S. in Agricultural and Resource Economics
Overall GPA: 3.89

University of California, Berkeley *August 2006 - May 2010*
B.S. in Environmental Economics and Policy
Overall GPA: 3.91

WORKING PAPERS AND PRESENTATIONS

"Of rice and men: Land use restrictions in Vietnam"
Job Market Paper 2015

"The effects of communal land certification on land use: Evidence from Mexico"
Coauthors: Alain de Janvry, Elisabeth Sadoulet, and Marco Gonzalez-Novarro *2014*
Presented at PacDev 2014, World Bank's Land and Poverty conference 2014, NEUDC 2015

"Adolescent girls and agricultural technology adoption"
Coauthors: Alain de Janvry and Elisabeth Sadoulet, Angeli Kirk *2011*
Funded by the Nike Foundation, CEGA.

TEACHING

Graduate Student Instructor, UC Berkeley:
EEP 118, Introductory Applied Econometrics, Prof. Elizabeth Sadoulet *Fall 2012, Fall 2013*
ECON 204, Mathematical Tools for Economists (departmental tutor) *Summer 2012*
EEP 1, Introduction to Environmental Economics and Policy, Prof. Gordon Rausser *Spring 2013*
ARE 299, Consumer Theory and General Equilibrium, Prof. Leo Simon *Fall 2014*
Acting Instructor-Graduate Student, UC Berkeley:
ARE 298, Game Theory and Contract Theory *Spring 2015*

OTHER WORK EXPERIENCE

World Bank: Vietnam PREM office, *Short term consultant* *June-August 2014*
Task Team Lead: Gabriel Demombynes

UC Berkeley Agricultural and Resource Economics, *Graduate student researcher* *2010-2014*
Advisors: Professors Alain de Janvry and Elisabeth Sadoulet.

UC Berkeley Agricultural and Resource Economics, *Admissions committee member* *2014-2015*

Center for Effective Global Action (CEGA), Visiting Fellows Program *2012,2015*
Mentored visiting graduate students in their graduate coursework and research.

Nike Foundation and CEGA, *Research Consultant* *Nov 2010 - June 2011*
Analyzed LSMS-ISA and other data from the Bill & Melinda Gates Foundation.

HONORS AND DISTINCTIONS

- Certificate in Teaching and Learning in Higher Education, (expected Spring 2016)
- Outstanding Special Service to the Department for Graduate Teaching, 2015
- Outstanding Graduate Student Instructor Award, 2014
- Phi Beta Kappa Society member, 2010
- Mellis Medal winner for Outstanding Honors Presentation, College of Natural Resources, 2010
- Graduated UC Berkeley with High Distinction

MISCELLANEOUS

Languages	English (native), Spanish (basic read and write), Hungarian (minimal)
Programs	Stata, Matlab, GIS, basic Python, basic R

Chapter 2

The effects of communal land certification on land use: Evidence from Mexico

Alain de Janvry[1], Marco Gonzalez-Navarro[2], Daley Kutzman[1], Elisabeth Sadoulet[1]
[1]University of California, Berkeley, [2]University of Toronto

May 2016

2.1 Introduction

The establishment or strengthening of property rights is arguably one of the most effective pro-poor policies, encouraging land investments that can increase agricultural yields, improving credit access, and increasing the general efficiency of both land markets and natural resource management (Acemoglu et al., 2001; Besley, 1995; De Soto, 1989; De Soto et al., 2000; Deininger et al., 2004; Demsetz, 1967). These potential benefits of well-defined property rights and low tenure insecurity helped motivate the second agrarian reform in Mexico, which certified over 45 million hectares of land in ejido communities and granted secure rights to over 3.5 million people (Deininger et al., 2001). Prior to the reform, property rights in ejidos were insecure and ill-defined. Such uncertainty of tenure can distort productive decisions away from an efficient optimum by preventing land transactions that would allocate land to the most productive owner, by discouraging investment, limiting credit access, or by keeping land from its most productive application (Feder and Feeny, 1991; Mendelsohn, 1994). Additionally, optimal land use depends on the timing of profit, expected returns to investments, any tenure-investment features of specific uses, legality of land transactions and other aspects that would be shaped by tenure insecurity. For example, while a common economic argument is that securing property rights will slow deforestation by reducing the discount rate on forest's future returns, Liscow (2013) demonstrates that increased land investment due to higher tenure security increases agricultural productivity enough to actually increase deforestation. Furthermore, usufruct property rights, such as those present in ejidos prior to the reform, have been shown to distort land use in other contexts. Goldstein and Udry (2008) found that more insecure property rights prevented land from being left fallow for the optimal period, and Rozelle and Li (1998) found that risk of expropriation in Chinese villages depended on off-farm employment and use.

This paper explores how a national land certification program for ejidos in 1993, Programa de Certificacion de Derechos Ejidales y Titulacion de Solares (Procede), influenced land use change within those communities. In particular, we ask whether ejido land use converged to a private property allocation when property rights were reformed to be more private. The answer to this question is particularly policy relevant, as developing countries progress towards stronger property rights while possessing large stocks of natural resources, including forest. As Mexican ejido communities contained over 78 million acres of forest and jungle at the start of the reform, rapidly altering the nature of property rights over this land could have far-reaching environmental impacts due to the global positive externality of forest cover. Observing how this reform affected deforestation could inform global efforts to curb it, especially considering that almost 11 percent of the world's forest was communally owned in 2002 (Bray et al., 2008).

Ejidos are (mostly rural) communities in Mexico that consist of land expropriated from haciendas and foreign interests as a part of the first agrarian reform, which followed the 1917 revolution. Tenure insecurity persisted in ejido communities prior to certification through Procede for a few reasons. Ejido land was divided between individual agricultural plots, housing plots, and common use land, to which all residents with ejidatario status had rights to use. In addition to the potential collective action problems that coincide with common property, the individual plots were initially held under a usufruct rights system which exposed landholders to additional insecurity and created a tenure-investment aspect of land cultivation. Finally the state's heavy, paternalistic hand in ejido production and commons management may not have encouraged optimal natural resource extraction or land use.

While we find that the aggregate effect of Procede appears to induce pasture to be converted to forest, such an aggregate result ultimately only masks the heterogeneity. Land use change should only occur when the benefits of conversion exceed the economic costs, both of which will depend on physical and economic characteristics determining the suitability of a piece of land for each use. It's trivial to see, for example, that where land is particularly profitable for agriculture but currently covered with forest, there should be a higher incentive to deforest. When Procede reformed property rights for ejido residents, it did not alter the underlying productivity of ejido land for pasture, forest or agriculture, which should continue to influence land use change. Several aspects of the initial ejido property rights system, such as usufruct rights on individual plots, that were reformed under Procede distorted land use from the optimal use under private property rights. With knowledge of what a plot's current use is and private optimal use might be, we could test that the easing of these distortions incentivized land conversion in ejidos towards optimal land use under a private property system. To test this prediction empirically, we use administrative data from Procede, satellite image land cover data of Mexico from 1980 to 2007, a set of maps of geographic and climatic characteristics, and ejido characteristics from the ejido censuses. Mexico is an ideal setting for investigating this prediction, as both a private property system and communal property system exist literally side by side. Suitability of land for forest, pasture and agriculture are constructed using land cover and land characteristics data from private, non-ejido land, which is then applied to ejidos. We find considerable heterogeneity in the effect of Procede, depending on characteristics of the ejido's land and the initial allocation of land across uses. It appears that ejidos with land employed in a use that didn't correspond to its estimated private suitability under responded to Procede by converting that land. For example, we see ejidos with forest standing on land suitable for agriculture deforesting with certification and ejidos that have cultivated land suitable for grazing expanding pasture with certification.

Though there has been considerable study of land allocation and common property management in ejidos (Alix-Garcia, 2007; Bray et al., 2006, 2008; de Janvry et al., 2001; Deininger and Minten, 1999; Duran-Medina et al., 2005; McCarthy et al., 1998), to our knowledge there hasn't been a paper that explores how land allocation and deforestation responded to Procede. Many papers that analyze the relationship between property rights and land use or investment (Deininger and Jin, 2006; Goldstein and Udry, 2008; Liscow, 2013) use instruments or subjective measures as proxies for changes in tenure security or property rights, whereas this analysis uses an (arguably) exogenous change to measure the effect. To our knowledge, this is the only instance in which a land cover panel has been used to study the effect of tenure security on land use.

Another innovation in this paper is our use of physical attributes of both ejido and non-ejido land to construct indices of suitability for a given use. Land evaluation commonly ignores economic considerations when determining land suitability, focusing only on physical attributes (Rossiter, 1995), even though there's evidence that economic decisions by cultivators, such as fallowing or fertilizer application, are more important for predicting crop yields than soil type (Young and Goldsmith, 1977). While we also attempt to predict land suitability based on physical characteristics, we exploit observed market land use decisions in this estimation instead of controlled, agronomic experiments. In this way, we implicitly account for the problem faced by the economic decision maker and instead map exogenous land features directly to land use outcomes. The concerns described by Young and Goldsmith (1977) about the arbitrariness inherent in the necessary assumptions for economic land evaluation are somewhat assuaged here, as we avoid assuming input costs, discount rates, etc. when determining the economic suitability of a plot. Ultimately we find that our measures of land suitability influence an ejido's response to certification in predictable and intuitive ways.

The paper is organized as follows: Section 2 provides background on the ejido system and Procede. Section 3 describes the data. Section 4 explains our main hypotheses concerning the impact of Procede on ejido land use, concluding that it will depend on the underlying land suitability. Section 5 details the estimation and construction of ejido-level land suitability measures. Section 6 discusses the rollout of Procede and tests for exogeneity and Section 7 analyzes the results.

2.2 The Ejido system and Procede

Mexico's peasant-led revolution of 1917 expropriated large amounts of land from *haciendas* and foreign interests, granting it to communities to create ejidos, and is considered to be one of the largest land reforms in the world (Yates, 1981), redistributing about 103 million hectares of Mexican land. While the restructuring of rural production was meant to favor the residents of the newly created ejidos, in many respects they were largely controlled by the government.[1] Most importantly, the state had a major role in the management of the commons, it maintained legal ownership of ejido land, and any ejido land left uncultivated for 2 years could be taken away from an individual and reallocated. Mexico's second agrarian reform came as a consequence of its first: by the early 1990s, the ejidos and Mexico's agricultural sector as a whole were characterized by low investment, low productivity and stagnation (de Janvry et al., 1997; Deininger et al., 2001). Procede provided ejido members with certificates to their individual plots and certificates to their share of output from the commons. Additionally, it eliminated transfer restrictions and turned over ownership and control of ejido land to the local ejido government, or assembly.

The process of certification proceeded as follows. First, officials from Procuraduria Agraria approached an ejido assembly to present the program, after which the assembly voted whether or not to participate.[2] If the ejido agreed to the program, it was surveyed for free by officials from the Instituto Nacional de Estadistica y Geografica (INEGI), who determined what land belonged to whom. Any disagreements over plot or ejido boundaries had to be resolved at this point in the process. Once all land was surveyed and all disputes sorted out, INEGI produced a map of the ejido which delineated the plots assigned to individuals. After this final map was approved by the ejido assembly with a vote, it was sent to Registro Agrario Nacional (RAN) and certificates were distributed to all residents of the ejido whose claims to land were approved by the process (de Janvry et al., 2013b).

Residents of an ejido have different rights depending on their status as ejidatarios, avecindados, or posesionarios, and an important aspect of Procede is that it allowed ejidos to incorporate more ejidatarios from the non-ejidatario population. Incorporation entailed assigning any new ejidatario an individual plot, which could be provided by dividing up all or part of the common property land and giving or selling it to individuals it wished to incorporate. We will return to this characteristic of the reform when testing the robustness of the results, as it's conceivable that clearing of pasture and forest for newly incorporated members drives the effects we find.

A critical aspect of Procede was in Article 59 of the reform: it was not permitted to certify forest or jungle land (Ley Agraria). Any forested land on individual plots before the program could not be individually certified to the landholder, creating an incentive to clear any such forest in order to gain a certificate to that land. Given the usufruct, use-it-or-lose-it, system in place before Procede, we are skeptical that there was a significant amount of at-risk forested land on individual plots. However, land in the commons is typically forest or pasture with occasional cultivation. Thus, if the ejido or individuals in the ejido wished

---

[1] Access to markets, credit, insurance, as well as allocation of public goods and management of common property were mediated by local ejido leadership, which was heavily influenced by the state. Land transferability was also legally restricted: ejido residents were not permitted to hire wage labor for individual plots or sell land (de Janvry et al., 2001).

[2] Over 95 percent of the ejidos in my sample chose to participate.

to claim forested land individually, the land would have to be cleared prior to Procede completion. This is a potential channel by which certification could have encouraged deforestation when coupled with high returns to deforestation.

2.3 Data

2.3.1 Data sources and construction

This paper uses several data sources, which can be divided into two groups: spatial maps of physical characteristics of land, and ejido-level data. The former set includes four series of land cover maps of Mexico, maps of soil and subsoil, maps of municipality boundaries and locality centers, and a digital elevation map (DEM), all of which were obtained from the Instituto Nacional de Estadistica y Geografica (INEGI). The land cover maps are LANDSAT images with 30m resolution that underwent several field verifications performed by INEGI. This set also consists of average precipitation and temperature maps representative of 1950-2000 from WorldClim.org[3] and a map of land slope that was constructed from the DEM. In the second group, we have Procede administrative data and the 1991 and 2007 Censos Ejidal, also from INEGI. The administrative data contains the dates of the first assembly and the program completion date, as well as maps of the boundaries of all ejidos. The ejido censuses contain ejido membership measures and indicate whether or not the ejido reported significant tenure insecurity.

An ejido level dataset and a polygon level dataset were constructed using these sources.[4] Polygons were first defined by the intersection of the INEGI land cover maps from 1980 (Series 1), 1993 (Series 2), 2002 (Series 3) and 2007 (Series 4) with the map of soil types and the municipality or ejido boundaries. These sets of polygons are thus defined to cover exactly one land use and exactly one soil-type. As the elevation, slope, precipitation and temperature data are in pixelated form, called "rasters," we first overlaid each of these rasters with each series' set of polygons, and took the area-weighted average elevation, slope, precipitation and temperature of the pixels contained in each polygon. [5] The last step in the creation of the polygon-level dataset was to calculate the distance from the center of each polygon to the closest locality center. The final product is a dataset that describes each polygon's land use, soil type, precipitation, temperature, elevation, slope, and distance to closest city center, which we use to estimate parameters for predicting land use, or estimating a polygon's suitability for a particular use.

For the ejido-level dataset, we intersected the spatial boundaries of the ejidos obtained with the Procede administration data with each land use series, generating a measure of the area applied to each land use in ejidos over time. This data was then merged with the census data based on spatial matching, ejido name, and locality name (de Janvry et al., 2013a).

2.3.2 Summary statistics

Figure 2.1 describes the rollout of Procede, which was initially quite rapid. Half of ejidos completed Procede within 3 years of its start in 1993 and all ejidos in our sample had been certified within another 10 years. Relative to our land use series, about 4 percent of ejidos were certified by Series 2, 85 percent by Series 3, and 11 percent by Series 4. Figure 2.2 shows how the percent of ejido area devoted to each use changed between Series 1 and Series 4. Each of these distributions has a large peak at zero, which indicates—for example—that the ratio of forest in an ejido in Series 1 was identical to the ratio of forest in Series 4. However, each distribution has long tails, especially forest and pasture. This reflects a high degree of heterogeneity in the land use trends across ejidos during Procede's implementation, and hints at the heterogeneous results we will find.

---

[3] From website: "WorldClim version 1 was developed by Robert J. Hijmans, Susan Cameron, and Juan Parra, at the Museum of Vertebrate Zoology, University of California, Berkeley, in collaboration with Peter Jones and Andrew Jarvis (CIAT), and with Karen Richardson (Rainforest CRC)."

[4] The term polygon refers to an irregularly shaped piece of land, a common unit in spatial datasets.

[5] For precipitation and temperature, we also calculated the standard deviation of these pixels contained by the polygon.

In Table 2.1, we report the percent converted to each use for both ejido land and non-ejido land between Series 4 and Series 2 (the length of Procede). To compute these percentages, first we converted the polygons that made up the land use maps from Series 2 and 4 to rasters, which are grids of pixels in which each pixel is assigned a land use.[6] Lining up the grid of Series 2 with that of Series 4 tell us what use each pixel was applied to in either series. This way we can see, for example, what percentage of the pasture pixels from Series 2 became agriculture pixels by Series 4. The amount of cleared forest is an alarming 10 percent for both ejidos and non-ejidos, but note that this is not net deforestation and so does not take into account land that is reforested. In fact, surprisingly large percentages of each land type are converted to forest, for both ejidos and non-ejidos—in particular, the majority of land converted out of agriculture is turned into forest. While the rates of conversion on agriculture and forest are similar across ejidos and non-ejidos, ejidos appear to convert more land out of pasture and non-ejidos convert more land out of the "Other" category.[7] Of land that was deforested, there is relatively more land moved to pasture in ejidos than in non-ejidos; of land taken out of pasture, there is relatively more land moved to forest in ejidos than in non-ejidos. This pattern may reflect the fact that both forest and pasture are common property in ejidos, and the boundary between them within the commons likely shifts. Ejidos and non-ejidos alike, however, convert the majority of cleared forest to pasture and the majority of cleared pasture to agriculture.

Table 2.2 presents summary statistics for ejidos in the 1990 census, divided by those that reported problems of tenure insecurity (Insecurity=1) and those that didn't (Insecurity=0).[8] While ejidos that reported initial insecurity are 40 percent larger on average, the breakdown of land into our three main land uses are very similar: 37-39 percent in agriculture, 27-31 percent in forest, and 17-20 percent in pasture. Ejidos with initial insecurity tend to be larger, with more members, but also with more land per member.

The more interesting differences between them are found in the suitability measures generated from geographic and climatic characteristics (construction is detailed in Section 3). For both types of ejidos, land that is actually cultivated is more suitable for agriculture than land that is not cultivated. Though the same is true of forest, we don't see this selection of grazing-suited land into pasture, most likely because the physical characteristics that map to pasture suitability are less clear, partway between agriculture and forest. Generally, we see a higher degree of "mismatched" or "misallocated" land for ejidos that report initial insecurity. Correlations between our measures of "misallocation" and self-reported insecurity are only suggestive and cannot support many conclusions, though they do indicate some relationship between land allocation, land suitability and tenure insecurity that our main analysis investigates further.

Figure 2.3 depicts deforestation between Series 1 and Series 4 for all of Mexico, as an illustration of the spatial detail in our data. Focusing on the area enclosed in the rectangle, Figures 2.4 and 2.5 make a visual argument for how land suitability impacted land allocation, specifically deforestation. Forested polygons in Figure 2.4 are colored by a polygon's suitability for agriculture or pasture (whichever is larger) based on its physical characteristics, where warmer colors indicate a higher suitability. In the next figure, only polygons that were deforested by Series 4 remain. Comparing the two, we see that the largest swaths of deforestation occurred where there was higher suitability for a non-forest use, demonstrating that our suitability measures do contain some information about land quality that influenced allocation decisions.

Table 2.3 presents evidence verifying that Procede certification does appear to have impacted tenure insecurity in ejidos. The dependent variable is an indicator for whether or not the ejido reported boundary issues in the 2007 census, and we control for whether or not the ejido reported these issues in the 1991 census and how many years have passed since the ejido competed Procede. A little under 20 percent of census ejidos reported boundary problems in 2007, and in the estimated linear probability model, an ejido that experienced insecurity in 1991 was 6.5 percent more likely to experience insecurity in 2007. The negative coefficients for the years since certification indicate that the longer an ejido had been certified, the less likely it was to experience insecurity in 2007. Since the average number of years since certification in 2007 is 10, the probability of experiencing insecurity in 2007 fell by about 20 percentage points for the average certified ejido. Fan regressions of 2007 insecurity on the years since certification are shown in Figure 2.6 separately by 1991 insecurity. We see that each group of ejidos—those that reported boundary problems in 1991 and

---

[6] We cannot use the land use maps in polygon form, as polygons are not constant over time.

[7] "Other" includes any land classification that is not forest, agriculture, or pasture, for example: thicket, and settlements.

[8] The sample is limited to census ejidos as this is the source of the data on tenure insecurity.

those that did not—saw the probability of insecurity in 2007 fall with time spent certified. Thus a basic assumption of this paper seems to hold: Procede is associated with reduced tenure insecurity in ejidos.

2.4 Hypotheses and empirical specifications

Procede brought about four main changes for ejido property rights that likely affected land use: it ended the usufruct property rights over individual agricultural plots, it formalized rights over commons output, it prohibited the titling of forest, and it permitted ejidos to incorporate new members. These changes may have eliminated preexisting distortions in land use caused by the initial property rights system, and their elimination promoted a land allocation more closely resembling that under private property rights. The conversion spurred by Procede should therefore be guided by the private suitability of land for different uses.[9] Here we examine specific avenues by which Procede altered ejido property rights and land use decisions to demonstrate land suitability's role in the response to the reform.

2.4.1 *Agricultural plots and forest titling*

Prior to Procede, individual plots outside the commons could be kept as long as they were not left uncultivated for more than 2 years. In this way, the initial property rights system added to agriculture an investment in tenure security—cultivation was a means to reduce the chance of one's individual plot being lost. Ending the usufruct system reduced tenure insecurity for land held in agriculture in addition to reducing tenure insecurity for pasture or forest on individual plots. If the tenure insecurity on individual plots distorted land use away from the optimal private use then its elimination with the certification will incentivize conversion. Thus the estimated private suitability of agricultural land for alternate uses will be relevant in our estimation of Procede's impact, and to what extent conversion patterns responded to land suitability.

Another relevant aspect of Procede was that forested land was prohibited from being titled to individuals. While this does not represent a preexisting distortion relaxed by the reform inducing convergence to private land use patterns, it did create an environment in which deforestation—clandestine or sanctioned by the ejido—could confer property rights. If forested land in the ejido covered land that had a high private suitability for agriculture or pasture, the reform both provided a one-time opportunity to claim common forest or pasture for an individual plot and increased the expected return from the land with a reduction in tenure insecurity (Angelsen, 1999). As such, the suitability of forest for agriculture or pasture is also relevant to our estimation.

2.4.2 *Commons output*

While Procede maintained the common property in ejidos, it did strengthen and formalize rights by providing memebers with titles to percentages of commons output. With a secure (and limited) stake in the commons production, any incentive for individuals to insulate themselves from risk of losing their assigned share of commons output (such as encroaching or distorting management practices) would have been reduced. In addition, a well-defined split between members encourages monitoring of the amount allocated to each person, which could similarly reduce encroachment by increasing the probability of being caught. By removing such distortions, Procede increased the efficiency of commons management, again moving the optimal use under the ejido system closer to that under private property rights. Therefore the private suitability of forest for pasture and pasture for forest would more heavily influence the direction of any conversion initiated by improved management after the reform. For example, in an ejido which previously converted more forest to pasture than privately optimal because of encroachment on forest and inefficient management, we would see land suited for forest converted from pasture to forest with Procede's formalization of output shares. So, another explanation of heterogeneity in Procede's impact may be found through the suitability of forest for pasture and vice versa as common property moves closer to private property.

---

[9] This is not to say that the private property optimal use is the inherent optimal use for any piece of land, but that it is the optimal use given all other constraints, institutional and others, acting upon Mexico's private sector.

2.4.3 *Member incorporation*

Finally, Procede offered ejidos a one-time opportunity to incorporate new members. As previously mentioned, ejido residents have different rights depending on their status, and the status of *ejidatario* confers the right to one's own agricultural plot. Prior to Procede, the transfer of individual plots was highly restricted. Plots could not be sold, divided and bequeathed to more than one family member, or cultivated with hired labor, for example. While Procede also eliminated these sale, inheritance and labor restrictions (de Janvry et al., 2013a; Valsecchi, 2014), it provided the extended family members of *ejidatarios* who remained in the ejido an opportunity to officially obtain their own agricultural plots—land which could have been taken from the commons, formally or informally.[10] Commons pasture and forest suited for agriculture would be most valuable to the new *ejidatarios*, and if ejidos simply maximize the total profit of it's members, allocating agriculturally-suited land to new members from the commons is optimal. Therefore if ejidos incorporated more members with Procede and took land out of the commons to supply the new individual plots, land converted from pasture or forest to agriculture should've been relatively suited for agriculture—another reason why agricultural suitability of pasture and forest is relevant to understanding the conversion induced through certification.

Based on these hypotheses, we propose the following empirical specifications:

$$\begin{aligned}
\text{Forest}_{it} &= \beta_0 + \Big[\beta_1 + \beta_2 \text{P-Index}^{f}_{i1} + \beta_3 \text{Ag-Index}^{f}_{i1} + \beta_4 \text{F-Index}^{a,p}_{i1}\Big]\text{Procede}_{it} + \alpha_i + \delta_t + \varepsilon_{it} && (2.1)\\
\text{Agric}_{it} &= \beta_0 + \Big[\beta_1 + \beta_2 \text{P-Index}^{a}_{i1} + \beta_3 \text{F-Index}^{a}_{i1} + \beta_4 \text{Ag-Index}^{f,p}_{i1}\Big]\text{Procede}_{it} + \alpha_i + \delta_t + \varepsilon_{it} && (2.2)\\
\text{Pasture}_{it} &= \beta_0 + \Big[\beta_1 + \beta_2 \text{F-Index}^{p}_{i1} + \beta_3 \text{Ag-Index}^{p}_{i1} + \beta_4 \text{P-Index}^{a,f}_{i1}\Big]\text{Procede}_{it} + \alpha_i + \delta_t + \varepsilon_{it} && (2.3)
\end{aligned}$$

where $J\text{-Index}^{h}_{i1}$ is the suitability of land in use h for use J in ejido i in Series 1. For example, P-Index^{f}_{i1} is the pasture-suitability of forest in ejido i in Series 1.[11] The arguments above suggest that $\beta_2, \beta_3 < 0$ and $\beta_4 > 0$ for each equation. If the suitability measures are standardized, then β_1 will be equal to the average effect of Procede, which will depend on which of the channels dominate and any conflict between an ejido's initial allocation of land and the underlying suitability.

2.5 Construction of land suitability index

Models 2.1-2.3 all require that we calculate some measure of ejido lands' "suitability" for a particular use. This exercise is similar to the process of "land evaluation," a method of predicting the use potential of land. While the FAO's "Framework for Land Evaluation" in 1976 acknowledged and promoted the idea that both a physical evaluation and economic evaluation of land is critical in the assessment of land's potential use, subsequent work incorporating the economic side of land use decisions is scarce (Rossiter, 1995). Since land allocation is ultimately a set of decisions by economic actors and hence depends on the potential returns from difference uses, applying exclusively agronomic measures is suboptimal for our purposes. However, to specify the problem faced by land users, expected returns from all alternative uses would have to be determined, a process involving pricing inputs, outputs, and transportation costs in addition to mapping physical characteristics to yield for each potential use.

As a solution, we exploit observations of *market outcomes* of land use choice to create a mapping from physical, climatic and economic attributes of land to the outcome of an economic decision without measuring actual returns. Clearly, land use choices from ejidos during Procede's rollout cannot be used to construct

---

[10] Based on a 2002 random sample of 312 ejidos that had finished Procede or were still completing the program, over 80% of incorporated members were from ejido families, each incorporated member received 7 hectares on average, about 20% of which was taken from the commons.

[11] Only levels of these suitability measures are employed due to the endogeneity with land use choices. The *amount* of deforestation from one series to the next and *what* land to clear are made jointly, for example, and affect both the amount of forest (regress and) and the suitability of an ejido's forest for pasture or agriculture (regressors). To avoid this issue, we only use suitability measures from Series 1, before the start of the program.

the suitability measures, so only land use choices from non-ejido land are used. This strategy has two advantages. First, it flexibly incorporates the economic as well as physical influences of land use decisions, which makes our measures more like market-driven estimates than agronomic suggestions. Second, because it's estimated using non-ejido land, i.e. land under private property rights, we don't use land use decisions that were distorted by tenure insecurity and ill-defined rights, which is especially appropriate since Procede reformed ejido tenure to be closer to private property.

Generally, our strategy is to estimate the probability that a non-ejido polygon is applied to each use, controlling for average precipitation and temperature, the standard deviations of precipitation and temperature, average elevation and slope, and the population-weighted inverse of the distance from the polygon's center to the nearest locality center. This is done for each state at a time, so that we capture regional heterogeneity without relying on fixed effects. We apply the estimated coefficients to ejido polygons to find the suitability of ejido land for each series. Figure 2.10 confirms that the ejido and non-ejido polygons are similar across all the characteristics used in estimation. Finally, we aggregate the polygon measure to the ejido level by computing area-weighted average suitabilities across groups of polygons that are employed in the same use, matching the measures in models 2.1-2.3.

2.5.1 Suitability estimation

The construction of these suitability measures begins at the polygon level. In a given state, consider the use of all non-ejido polygons p from series t:

$$Use_{pt} = j \text{ where } j \in \{\text{Forest, Agric, Pasture, Other}\}$$

Let the characteristics of a polygon be represented in a vector X_{pt}. We can use these characteristics to predict the probability of a polygon being in any of the three uses using a multinomial logit model[12]:

$$Pr(Use_{pt} = j | X_{pt}) = \frac{e^{\beta_{jt} X_{pt}}}{1 + \sum_{k \neq j} e^{\beta_{kt} X_{pt}}}$$

We can take the estimated coefficients and apply them to *ejido* polygons to determine their "suitability," or probability of being in use j in series s. Note that the series of suitability doesn't need to match the series of origin for the polygon, since we can apply coefficients estimated using polygons in Series 4 to the characteristics of a polygon from Series 1 (i.e. $s \neq t$). The suitability of a polygon p *from* series t for land use j in series s can be defined as,

$$S_{pt}(j, s) = \hat{Pr}(Use_{pt} = j | X_{pt}, \hat{\beta}_s) = \frac{e^{\hat{\beta}_{js} X_{pt}}}{1 + \sum_{k \neq j} e^{\hat{\beta}_{ks} X_{pt}}}$$

We'd like to have a land suitability index that reflects suitability across the whole period during which Procede took place. Since we have a polygon's suitability for any of the three uses in any of the four periods, we can simply average these suitabilities over time for a given use. This can be thought of as a polygon's "period average" suitability for use j,

$$\bar{S}_{pt}(j) = \frac{1}{4} \sum_{s=1}^{4} S_{pt}(j, s)$$

With appropriate suitability indices at the polygon level, now we must aggregate these measures up to the ejido level, as this is the unit of observation in our main dataset. This can be done in several ways, but our goal is to distinguish ejido land that is more likely to be converted to another use from land that is less likely to be converted. Our chosen method gives us the area-weighted average suitability of land for a use besides the one it is currently employed in. For example, we calculate the area-weighted average agricultural suitability of an ejido's forested land and the area-weighted average pasture suitability of an

---

[12] A separate model is estimated for each land use and for each series, which means we have four sets of coefficients for each land use—one from each series.

ejido's agricultural land. To define this formally, first let $P_{it}(h)$ be the set of polygons in ejido i in use h in series t; $T_{it}(h)$ be the total area in use h where $h \in \{\text{Forest, Agric, Pasture}\}$; and a_{pt} give the area of polygon p in series t. Then call the area-weighted average of j suitability over land in use(s) h in ejido i at time t,

$$S_{it}(h,j) = \sum_{P_{it}(h)} \frac{a_{pt}}{T_{it}(h)} \bar{S}_{pt}(j)$$

For example, the area-weighted average *pasture* suitability of ejido i's *forested* land at time t would be,

$$S_{it}(Forest, Pasture) = \sum_{P_{it}(Forest)} \frac{a_{pt}}{T_{it}(Forest)} \bar{S}_{pt}(Pasture)$$

Figure 2.11 plots the distribution of a given ejido suitability measure on each type of land. In the first plot, the distributions of F-Index$_{i1}^{f}$, F-Index$_{i1}^{a}$ and F-Index$_{i1}^{p}$ are compared, and we can see that F-Index$_{i1}^{f}$ has the most mass at higher values of forest suitability. While the same pattern holds for pasture and agriculture suitability, there is a great deal of overlap between these distributions, implying that there may be significant amounts of land suitable for an alternative use—possibly more suitable than the land already employed in that use.

2.6 Exogeneity of the rollout

The theoretical benchmark to estimate the effect of certification on ejido land use is to randomly select ejidos for certification and compare land use between these ejidos and those with land that remained uncertified. However, Procede was not randomly assigned in its rollout, so we must argue for its exogeneity with respect to land use in order to interpret the results that follow causally. We informally talked with officials involved in Procede that have remained in public service to gain more insight into the rollout. First, before the start of the program, the state believed it could complete Procede in 2 years when ultimately the roll out took close to 7 times that long. This tells us that officials likely did not have a planned ordering for approaching ejidos over a longer term, as they thought it would be very rapid. Secondly, Procede's implementation was decentralized, as each state in Mexico had its own office from which the program was run. These urban located offices naturally approached ejidos that were closer to the cities first and left larger ejidos (a larger ejido meant more time spent surveying) for later.

de Janvry et al. (2013b) analyze the rollout of Procede and also reason that it was largely a top-down rollout of a program at a national scale. Ejidos that had high demand for certification (with much of their land already in individual plots rather than common property) and those for which certification would be easier (which would be less-populated, smaller ejidos with fewer landless inhabitants) were reached first. While this resulted in a rollout bias against poorer ejidos, what is most important is that the completion of the program isn't correlated with *changes* in land use. For instance, if ejidos that were deforesting more quickly between 1980-1993 finished Procede earlier, this would bias the estimate of Procede's effect downwards for forest area. To use the rollout to establish causality we must confirm that land use trends prior to certification are not correlated with the timing of program completion. We use the following empirical specification estimated as SUR across uses:

$$\Delta Use_{em} = Use_{em2} - Use_{em1} = \alpha_0 + \alpha_1 ProcedeYear_e + \alpha_2 X_e + \delta_m + \varepsilon_{em} \tag{2.4}$$

Where $Use_{em2} - Use_{em1}$ is the change in the number of hectares in that use between Series 1 and 2 for ejido e in municipality m, X_e contains ejido characteristics that are correlated with Procede's timing and controlled for in the main analysis,[13] δ_m is a municipality fixed effect and ε_{em} is an error term. We should be more comfortable interpreting our main results as causal if α_1 is small in magnitude and statistically insignificant.[14]

---

[13] See de Janvry et al. (2013b).

[14] Note that the 961 ejidos (out of 25,032 total) that completed Procede in 1993 (Series 2) must be excluded from these estimations, as we only have one "untreated" observation for this group. In addition, the ejido characteristics in X_e limit the sample to ejidos present in the 1991 Censo Ejidal, reducing the sample to 17,685 ejidos.

The exogeneity test determines whether these trends are correlated with $ProcedeYear_e$, the numerical year the ejido completed the certification program. Additional controls for ejido characteristics are appropriate, as it is impossible to include fixed effects at any lower level than municipality in this specification, and our main analysis includes ejido fixed effects, controlling for all time-invariant ejido characteristics.

As briefly discussed in the introduction, our results support a story of heterogeneity, an example of which is explained visually in Figure 2.12. Panel A presents a simplified visual of the average effect of Procede for forest area: The Treated ejido sees an increase after treatment relative to the uncertified, or Control ejidos. Panel B presents the heterogeneous story that we find: within the certified ejidos, some experience a positive effect of certification and some experience a negative effect. However, if we permit heterogeneity for the treated ejidos when examining trends post-treatment, we should also be concerned about pre-treatment trends along the same characteristics. Panel C presents an example in which differential pre-treatment trends between Groups A and B might drive the results of Panel B. Group A, which would have an estimated negative effect of certification, was actually deforesting at a faster rate before certification, and Group B, which would have an estimated positive effect of certification, was actually reforesting before certification. To resolve this potential source of bias, we also use the following empirical specification:

$$\Delta Use_{em} = \alpha_0 + (\alpha_1 + X_e\beta_1)\, ProcedeYear_e + \alpha_3 EjidoSize_e + X_e\beta_2 + \delta_m + \varepsilon_{em} \tag{2.5}$$

In this specification, we would be more comfortable interpreting our main results as causal if α_1 and β_1 are small and insignificant. The results of these estimations for forest, agricultural and pasture area are presented in Tables 2.4. The first three columns of Table 2.4 tests equation (2.4), and we see that though α_1 is not significantly related to land use changes for agriculture and forest, it is statistically significant for pasture (but still less than 1.5 percent of the average magnitude).

The remaining three columns test equation (2.5). The estimates of α_1 are no longer statistically significant, and the only elements of β_1 that are significant at the 10 percent level is the coefficient for the interaction of A-Index$_1^{pf}$. This result indicates that ejidos with pasture and forest highly suited for agriculture that were certified later were also increasing agriculture faster between series 1 and 2. This would ultimately induce an upward bias in a positive estimate in our main results. However, the point estimate is fairly small relative to the magnitude of the dependent variable: just 1 percent of the mean, and 0.7 percent of a standard deviation. Also notice that this exogeneity test requires 12 parameters to be statistically insignificant at the 10 percent level, thus we would expect about one estimate to be significant at the 10 percent level by chance.

This test is relatively weak because we have only two "pre-treatment" observations for ejidos; ideally, we would be able to show that for several years before the rollout, ejidos that completed certification earlier or later behaved no differently in terms of deforestation rates, and further reduce the size of the remaining significant coefficient. Thus, we proceed with the analysis somewhat satisfied that Procede's rollout was unrelated with initial land use change, though the weaknesses of the exogeneity test should not be ignored.

2.7 Results

We propose that heterogeneity in a plot's suitability will determine how the allocation of land adjusts when tenure insecurity is reduced, and attempt to capture this heterogeneity by controlling for an ejido's initial distribution of estimated suitability and land cover. We only employ the initial (i.e. from Series 1) levels of these measures to avoid endogeneity with the dependent variable: how agriculturally-suitable an ejido's forest is at any given time depends on deforesting and reforesting decisions from a previous period. The fixed measures from Series 1 allow us to simple separate ejidos into groups—for example, distinguishing ejidos with a lot of pasture "at risk" of being converted to agriculture because of its high agricultural suitably and ejidos with pasture sitting on land that is unsuitable for anything else.

The aggregate effect of certification with Procede on an ejido's hectares of forest, agriculture and pasture is shown in Table 2.5. There is no significant aggregate effect on agricultural land, but there are sizable effects for both forest and pasture that almost exactly offset each other. With certification, we estimate that an ejido's forest increases by 29.8 hectares—though this is less than 3 percent of the average amount of forest in an ejido, it is about 90 percent of the median amount for ejidos. Certification reduces the predicted hectares of pasture in an ejido by 28.3, which suggests that Procede spurred a conversion between pasture land and forest (or more likely, a reduction in the rate of conversion from forest to pasture).

The next two tables explore heterogeneity in these aggregate effects for each land use type. The first three columns in Table 2.6 represent specifications 2.1-2.3, and show our main heterogeneity results. The average effect of Procede[15] on forest has remained around 30 hectares, but the degree of heterogeneity across ejidos with different land suitability and initial allocations is of similar magnitude. The directions of heterogeneity are intuitive. A one unit increase in the regressor, P-Index$_1^f$, represents a 1 SD change in the area-weighted average pasture suitability of an ejido's forested land in Series 1 (the other measures are analogously defined). We expect this measure would have a negative effect on forest area as it implies that the ejido has forest sitting on land that has high suitability for pasture relative to the average ejido. Consider an ejido with forested land that is 1 SD more suitable for both pasture and agriculture, relative to the mean for all ejidos: the estimated effect of Procede is then -65.5 hectares. This falls to -107.1 hectares if the ejido's pasture and agriculture is on land that's 1 SD less suitable for forest than the average ejido, which is about 10 percent of the mean amount of forest. The results indicate that an ejido had a more negative response to titling on forested hectares if it:

1. Initially had allocated land to forest that was suitable for another use, or
2. Initially had low forest suitability on land that was not allocated to forest

The same reasoning is reflected in columns 2 and 3 of Table 2.6. While the average ejido sees little change in agricultural area, if the ejido cultivated land 1 SD less suitable for pasture or forest in Series 1 and had pasture and forest sitting on land that was 1 SD more suitable for agriculture relative to the average ejido, we estimate that certification increases agricultural area by 107.6 ha. With 1 SD higher agricultural suitability on pasture land in an ejido, the average effect of certification on pasture is more than doubled, but with 1 SD higher pasture suitability on land employed in another use, the average effect of certification is reduced by 85 percent. Columns 4-6 in Table 2.6 test the robustness of these estimates by including state-series fixed effects in addition to ejido and series fixed effects. Additional controls for any state-aggregate trends over time do not change the results from the first columns.[16] By Series 4, Table 2.8 shows that ejidos that had been certified for more years have lower measures of "misallocation" based on estimated land suitability.

Using the estimates from columns 1-3 in Table 2.6, we've calculated the predicted effect of certification on forest, pasture and agricultural land, and plotted their distributions in Figure 2.13.[17] The supports of these distributions are bounded by ±200 hectares which emphasizes the large spread of heterogeneity in land use responses to Procede, since 200 ha is about a fifth of the average ejido's land. Both pasture and agriculture have peaks near zero, while forest has a sharp mass below 100. With such variation in each of the estimated effects, it's important to see how they relate to each other. In Figure 2.14 there are scatter plots and linear fit lines between each estimated effect. References at zero are included in each plot so it's obvious that there are ejidos in each quadrant. Though the fit lines show that these effects are negatively correlated, they are far from having a slope of -1, which would indicate that the two effects in the plot offset each other.[18] With slopes between $-.23$ and $-.47$, we see that there is not a singular conversion (e.g. from forest to agriculture) stimulated by certification but a more plural response to Procede that involved all land uses.

---

[15] In every specification, all continuous variables are standardized.

[16] Restricting the sample to that used in the exogeneity tests does not alter the observed pattern in responses; the economic significance and the statistical significance remain. These results are reported in Table 2.7.

[17] The effects are summed in Figure 2.15. If most of the effects sum to a value close to zero, we can conclude that the changes in land use as a response to Procede were generally limited to the three uses considered here. The distribution reveals that over 60 percent of ejidos increased the amount of forest, agriculture and pasture with certification. The average increase in forest, agriculture and pasture land was around 45.5 ha and the average decrease was around 66.2 ha. Any land gained or lost with certification was taken or converted to the "Other" land use category, which includes both human developments and unproductive thicket.

[18] All the p-values from hypothesis tests against the null that the true slope is -1 are zero.

Columns 1-3 in Table 2.9 add measures of ejido membership change between the 1991 census and the time of certification. If the conversion of land with Procede was mainly driven by member incorporation and the allocation of plots to these new members instead of mismatched land suitability and land use, then its presence should severely weaken our results. Yet, the only estimation in which it's statistically significant is that of pasture, and our suitability results are unchanged for all estimations.

Columns 4-6 in Table 2.9 includes an additional set of interaction terms—the set of land suitability measures interacted with a dummy variable from the 1991 Censo Ejidal, indicating the ejido reported problems with internal and external boundaries. Higher tenure insecurity prior to Procede would mean that certification represented a *larger* change to the ejido, which could generate larger estimated effects of the program. Additionally, the intuition for our main predictions suggests that some conversions would be less costly with less secure property rights before Procede—for example, clearing forest in the commons in order to claim it as part of ones individual plot would be less costly in ejidos with highly insecure tenure. There is limited support for this intuition in Table 2.9, and we only see that agricultural suitability of forested land drives conversion out of forest more for insecure ejidos, as expected.

2.8 Conclusion

The main results of this paper go beyond the aggregate result that the strengthening of property rights in Mexico, on average, lead to slower deforestation and more conversion out of pasture. We find the effects were quite heterogeneous, and what we've presented supports our hypothesis that the heterogeneity varied across ejidos in a systematic way: conflict between an ejido's initial allocation of land and its estimated *private* suitability for one use or another guided its response to certification. Procede ended the usufruct system on agricultural land, formalized rights over commons output, prohibited forested land from being titled, and permitted ejidos to incorporate new members. The predicted effect of these channels is to further convergence of optimal ejido land use and private property land use, and the pattern of conversion we find in response to certification matches our intuition. For a given use, an ejido expands the land allocated to this use if there is more land that's suited for it, and contracts the land allocated to this use if it's on land suited for something else. The general pattern suggests that strengthening property rights induced a shift in land allocation towards one that better fits the physical, climatic and economic characteristics of the land. We have no data to support the idea that this re-allocation improves productivity or efficiency, but as the suitability measures were constructed from private property land cover and characteristics, we can conclude that there is evidence that certification pushed ejidos more toward the private distribution of land and reduced our measures of estimated "misallocation" over time. These results are robust to arbitrary regional time trends, and are not driven entirely by the division of common property to incorporate new members.

Table 2.10 presents the average estimated effects of certification on hectares of forest, agriculture and pasture. Though the average effect of certification on forest was 31 hectares, 38 percent of ejidos saw a negative effect with an average of -74. Almost 49 percent of ejidos have an estimated negative effect of certification on agriculture with an average of 42 hectares. Finally, the estimated effect for pasture was negative for 60 percent of ejidos, with an average of -61 hectares. We can total up the estimated effects for each land use, again grouping by sign. In the 62 percent of ejidos for which we estimated a positive effect on forest, Procede prevented 1.44 million hectares of deforestation, but caused 0.66 million hectares of deforestation in the remaining 38 percent. According to the FAO's State of the World's Forests 2011 report, Mexico cleared 3.540 million hectares of forest in 1990-2000, and another 1.940 million in 2000-2010. Without Procede over these two decades, the total amount of deforestation would have been 14 percent higher. If the deforestation Procede caused could have been avoided the total amount of land deforested would have fallen 12 percent.

As mentioned in the introduction, 11 percent of the world's forest was communally owned in 2002 (Bray et al., 2008) and there is a general trend towards improving property rights in the developing world, where there are large stocks of natural resources. The effects of Mexico's 1993 land reform and Procede on deforestation thus inform both the implications of the current trend towards secure property rights and how this trend could impact a significant portion of the world's remaining natural resources. Though this paper reveals no evidence of how welfare was affected by the reallocation of land precipitated by certification, there is a pattern to the heterogeneity based on land suitability that's both intuitive and suggestive that property rights reduced the distance between private property land allocation and ejido land allocation.

2.9 Tables and figures

Figure 2.1: The rollout of Procede from 1993-2007.

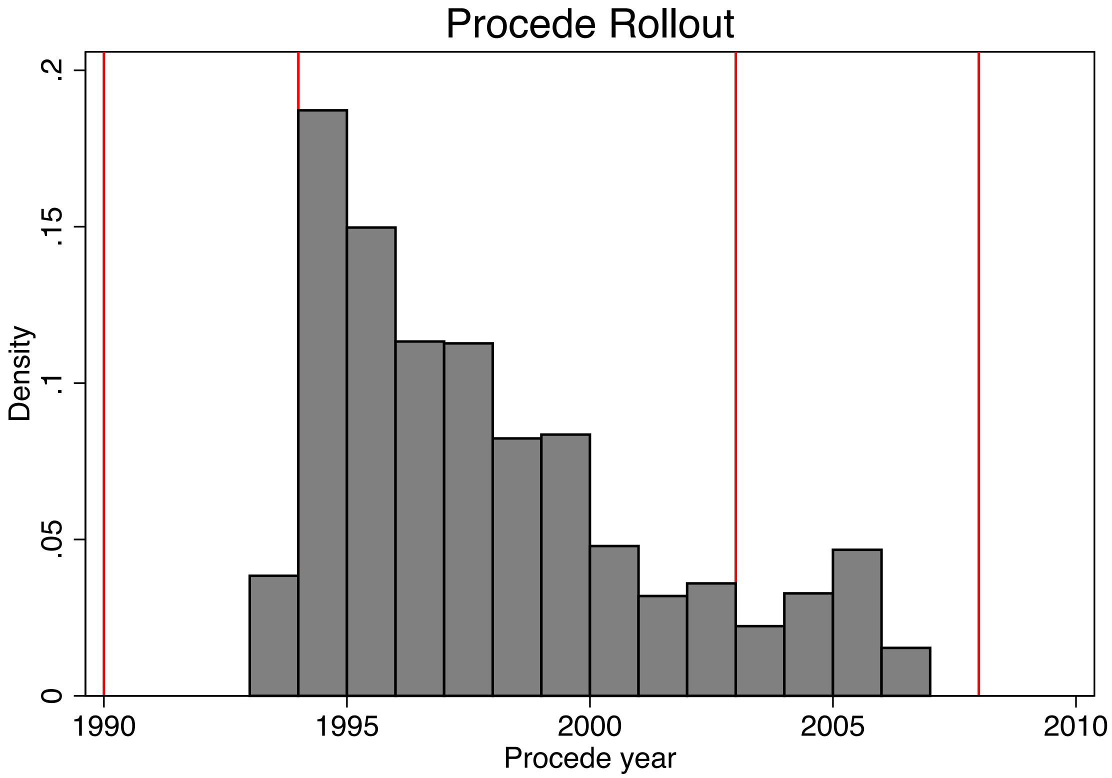
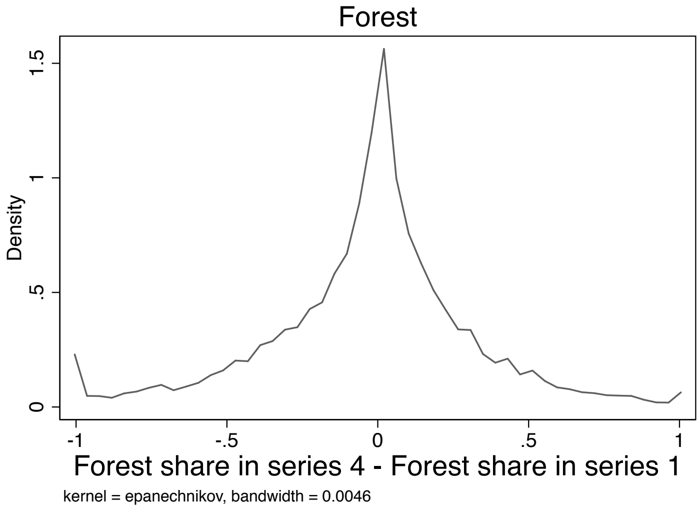
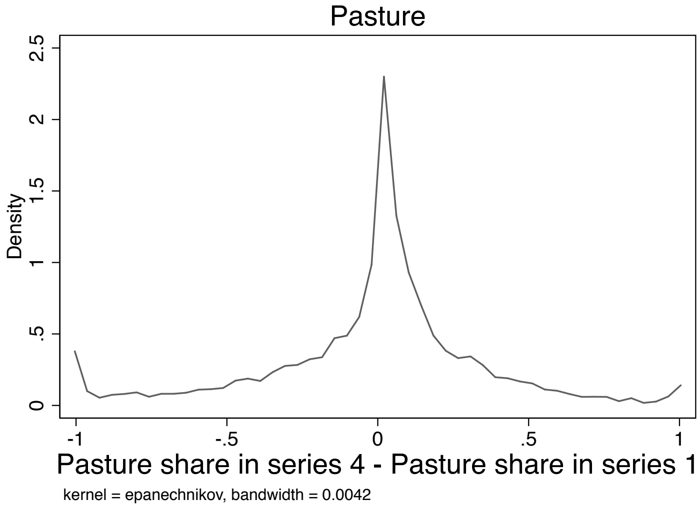


Figure 2.2: Changes in use between Series 1 and 4.





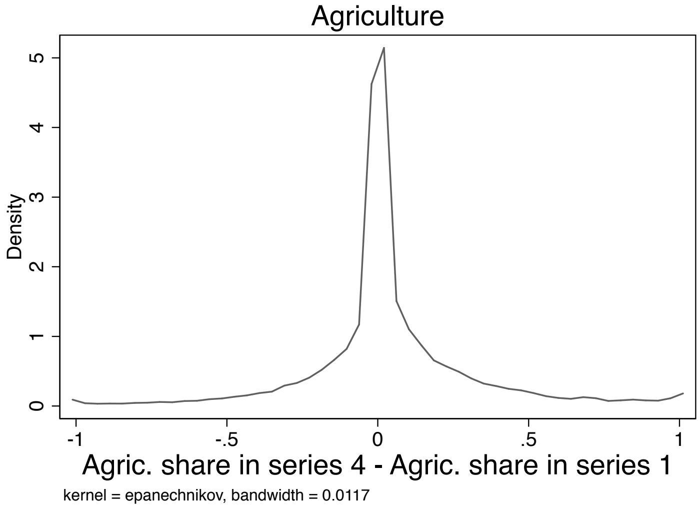


Table 2.1: Transition matrix between Series 2 and Series 4.

Ejidos

Use	S2 Area (mill ha.)	Total % conv.	Conv. to Forest (%)	Conv. to Agric.(%)	Conv. to Pasture(%)	Conv. to Other(%)	S4 Area (mill ha.)
Forest	32.35	10.11	-	37.29	48.57	14.14	31.02
Agric.	13.67	9.78	43.05	-	35.28	21.68	15.15
Past.	10.38	19.10	43.09	49.53	-	7.38	11.13
Other	30.14	5.87	29.64	34.07	36.29	-	29.23

Non-Ejidos

Use	S2 Area (mill ha.)	Total % conv.	Conv. to Forest (%)	Conv. to Agric.(%)	Conv. to Pasture(%)	Conv. to Other(%)	S4 Area (mill ha.)
Forest	36.51	10.46	-	29.22	43.52	27.26	35.15
Agric.	15.85	10.97	40.29	-	39.02	20.69	17.52
Past.	20.28	14.73	38.36	48.61	-	13.03	21.00
Other	36.68	9.09	34.43	22.66	42.90	-	35.65

Table 2.2: Summary statistics by initial insecurity.

	Insecurity=0	Insecurity=1	P-Value
Ejido area (ha.)	2627.440	3703.519	0.000
F& J (percent)	0.266	0.308	0.000
Agric (percent)	0.387	0.365	0.000
Pasture (percent)	0.202	0.167	0.000
Population '91	82.424	102.795	0.000
Hectares per cap. (1991)	40.368	48.568	0.000
Member incorp.	15.065	14.864	0.885
A-index on forest	0.124	0.143	0.000
A-index on pasture	0.101	0.103	0.639
A-index on agric.	0.272	0.279	0.089
P-index on forest	0.119	0.138	0.000
P-index on agric.	0.119	0.124	0.020
P-index on pasture	0.127	0.119	0.004
F-index on agric.	0.078	0.095	0.000
F-index on pasture	0.068	0.076	0.001
F-index on forest	0.218	0.279	0.000
Observations	11783	6806	

Figure 2.3: Deforestation between Series 4 and Series 1.

Figure 2.4: Forested polygons by suitability for pasture or agriculture.

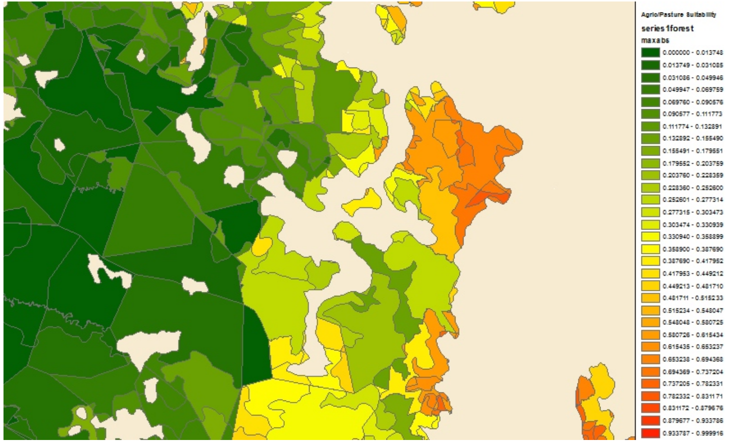


Figure 2.5: Deforested area by suitability for pasture or agriculture.

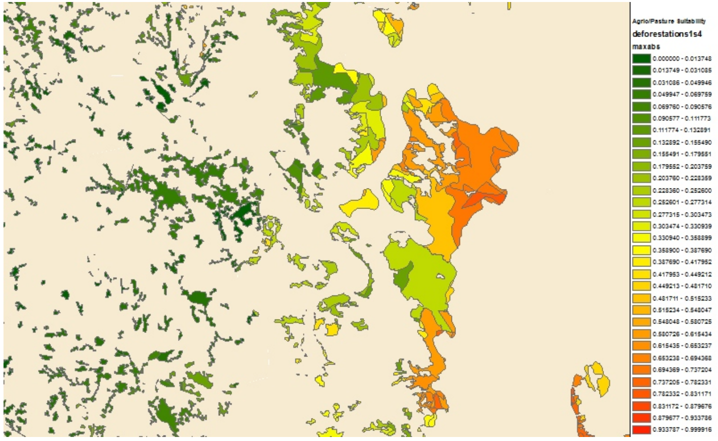


Figure 2.6: Fan regression of 2007 insecurity on number of years certified.

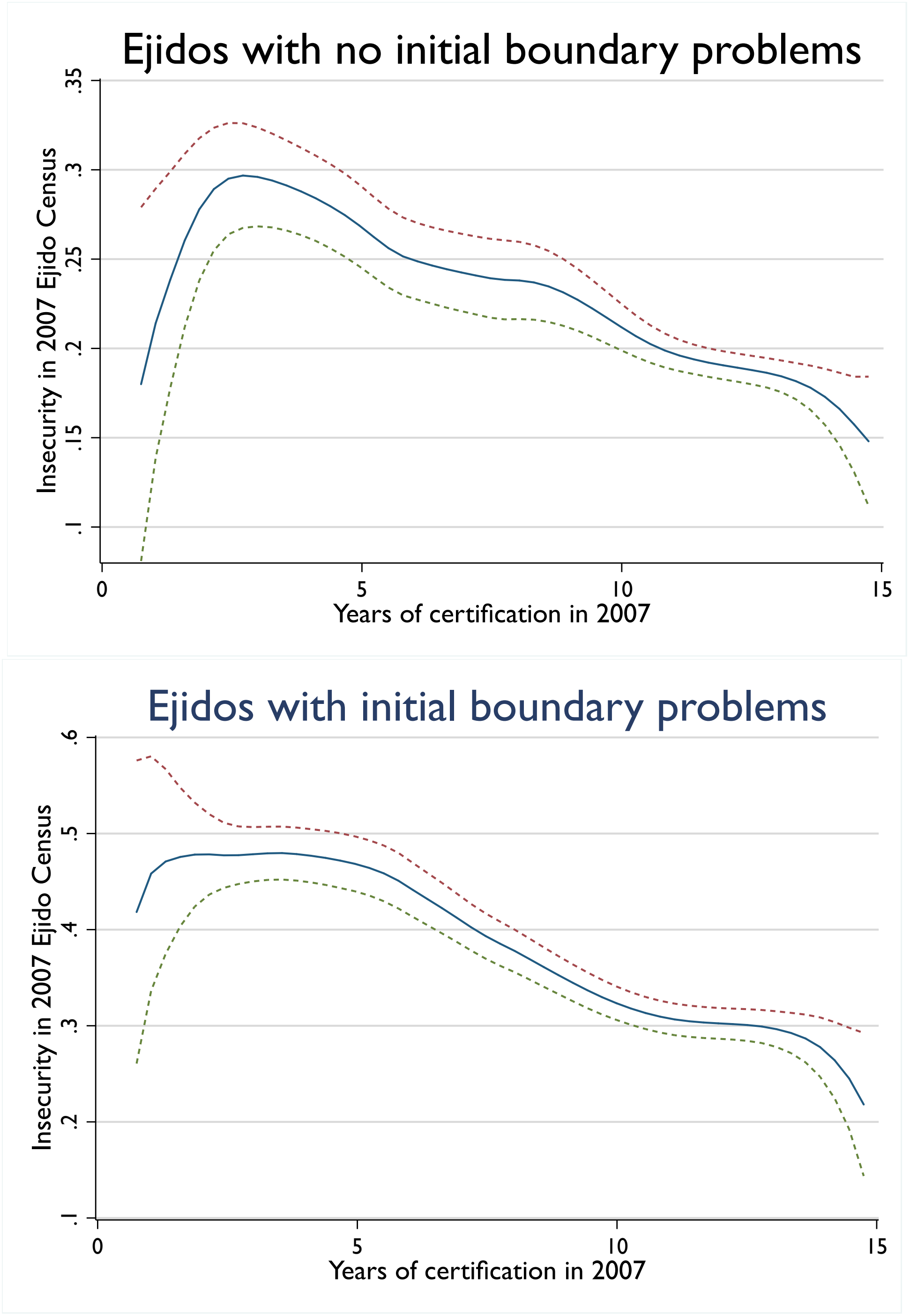


Table 2.3: Correlation between security problems and years since certification.

	Insecurity '07	Insecurity '07	Insecurity '07
Insecurity '91	0.0653***	0.0647***	0.0648***
	(0.00708)	(0.00709)	(0.00709)
Years Cert.	-0.0198***	-0.0137***	-0.00738
	(0.00120)	(0.00527)	(0.0184)
(Years Cert.)^2		-0.000363	-0.00123
		(0.000299)	(0.00246)
(Years Cert.)^3			0.0000350
			(0.0000977)
Observations	18589	18589	18589
Mean DV	0.195		
Municipality fixed effects	No	Yes	Yes

Standard errors in parentheses

Standard errors clustered at the municipality level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure 2.7: Forest suitability of non-ejido polygons by land use.

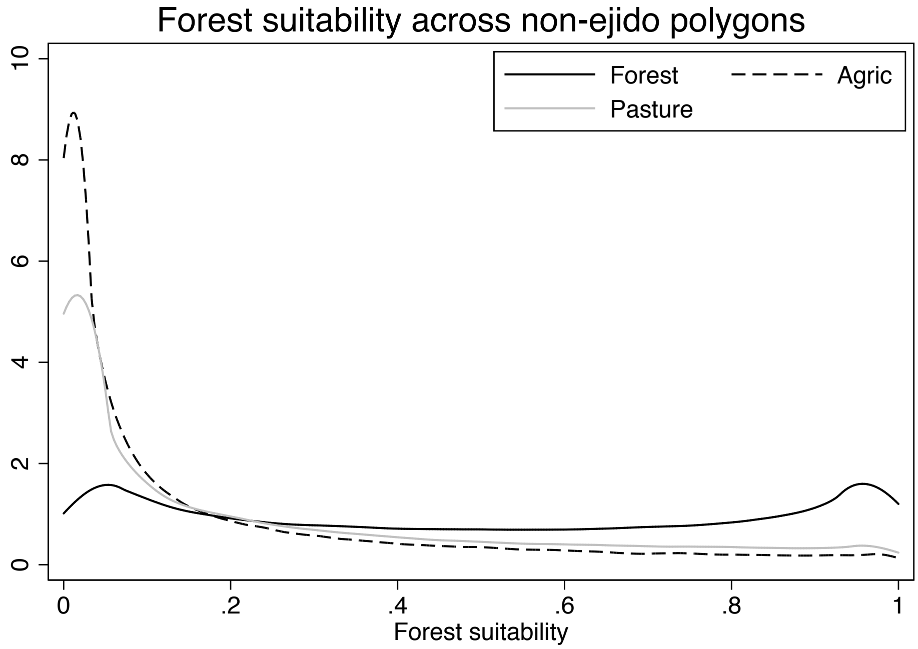


Figure 2.8: Agricultural suitability of non-ejido polygons by land use.

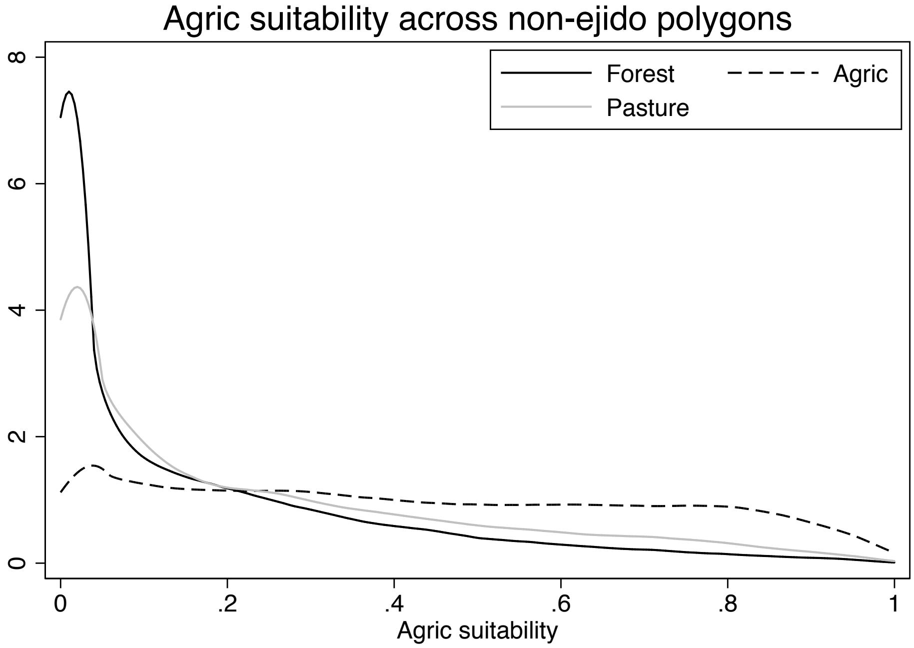


Figure 2.9: Pasture suitability of non-ejido polygons by land use.

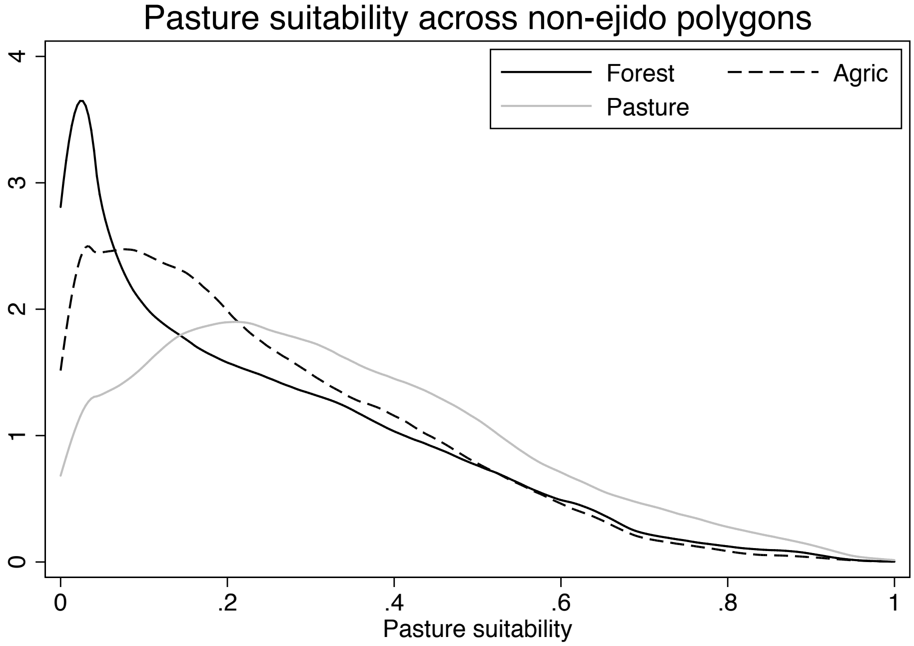


Figure 2.10: Polygon characteristics.

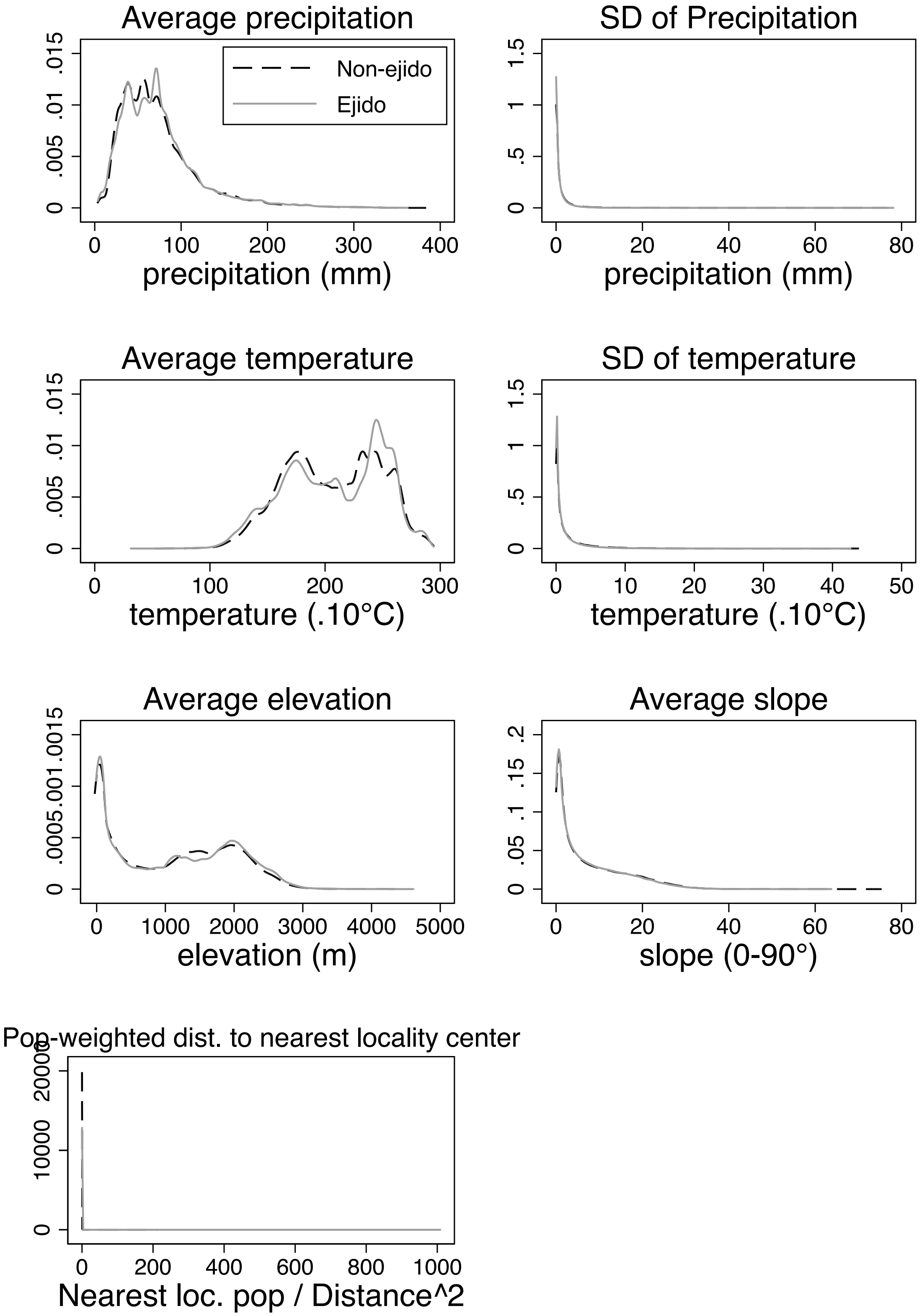


Figure 2.11: Comparing suitabilities across initial land allocation.

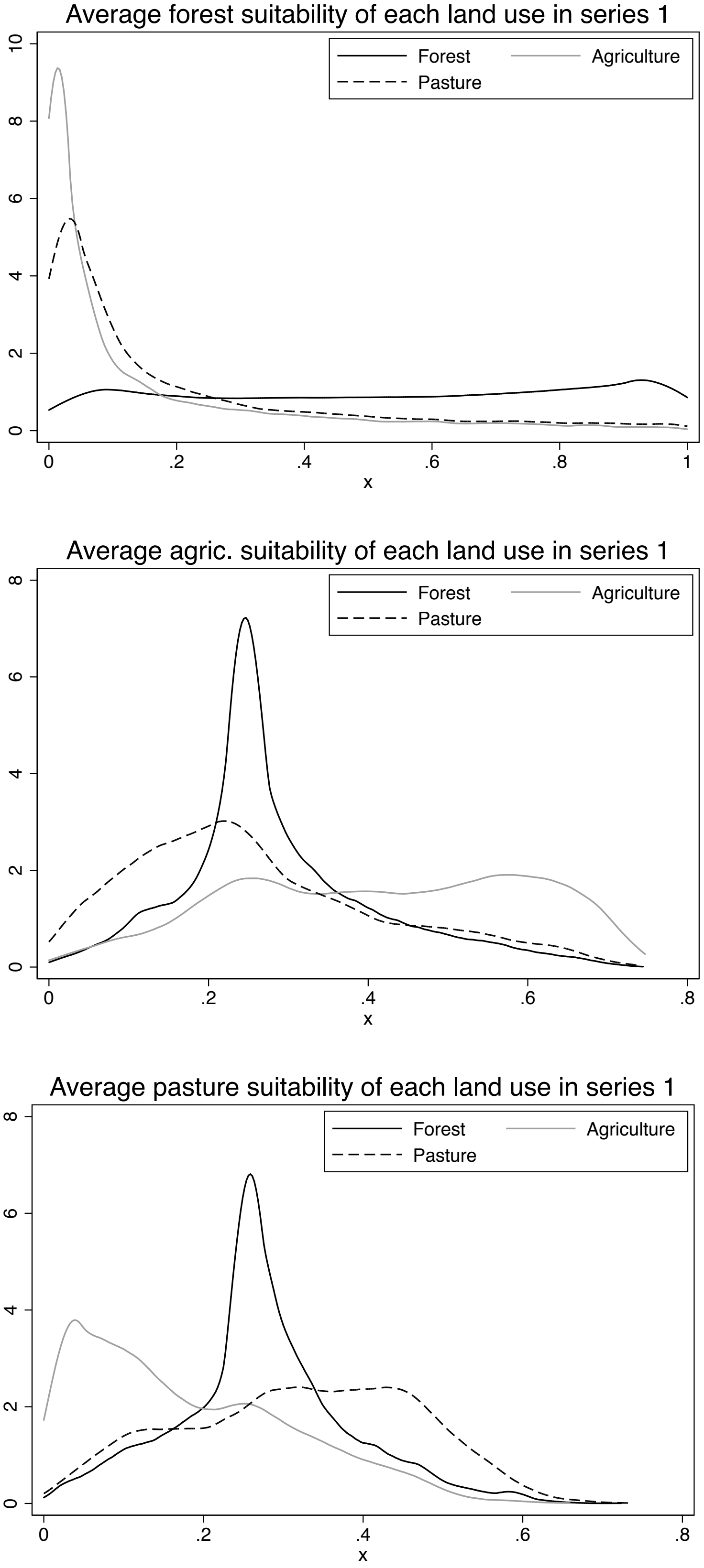


Figure 2.12: Rollout exogeneity.

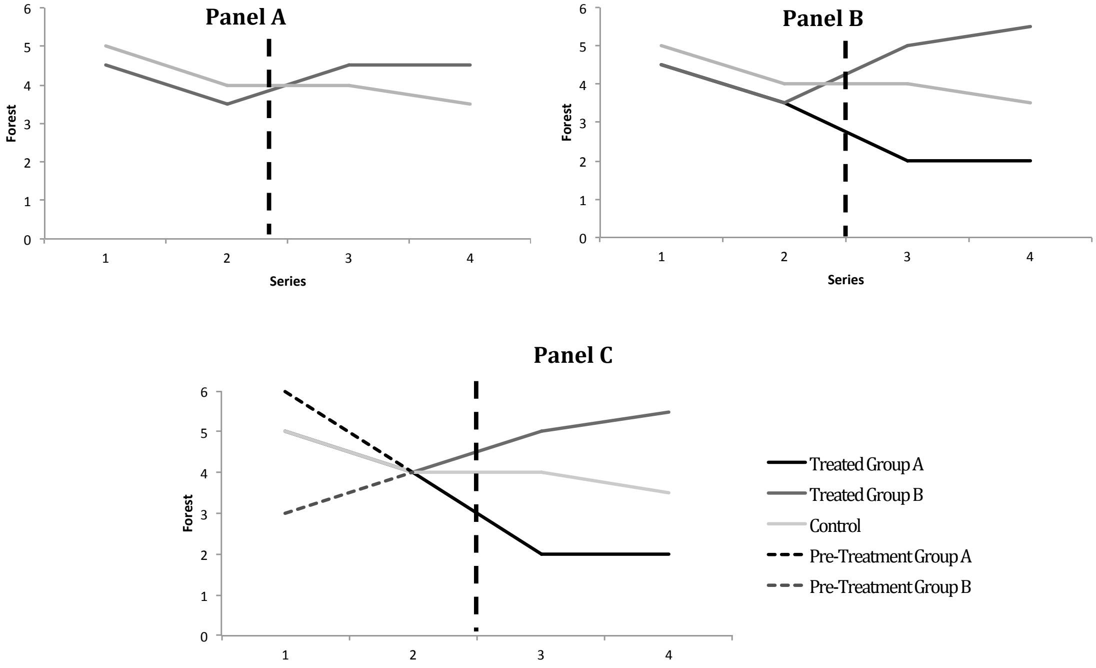


Table 2.4: Exogeneity of Procede rollout on full sample.

	Δ Forest	Δ Agric.	Δ Pasture	Δ Forest	Δ Agric.	Δ Pasture
Procede Yr	-3.050	0.0406	3.211*	-2.896	0.892	2.468
	(2.229)	(1.485)	(1.934)	(1.951)	(1.417)	(2.167)
P-Index$_1^f \times$ Procede Yr				-0.298		
				(3.189)		
A-Index$_1^f \times$ Procede Yr				-6.097		
				(3.922)		
F-Index$_1^{pa} \times$ Procede Yr				3.872		
				(3.046)		
P-Index$_1^a \times$ Procede Yr					2.877	
					(1.887)	
F-Index$_1^a \times$ Procede Yr					-5.660	
					(3.449)	
A-Index$_1^{pf} \times$ Procede Yr					2.324*	
					(1.362)	
A-Index$_1^p \times$ Procede Yr						-1.836
						(2.386)
F-Index$_1^p \times$ Procede Yr						-2.076
						(2.527)
P-Index$_1^{af} \times$ Procede Yr						2.340
						(1.698)
Observations	17685	17685	17685	17685	17685	17685
Mean DV	3.953	1.788	-0.321	3.953	1.788	-0.321
Med DV	0	-1.638	-0.669	0	-1.638	-0.669
SD DV	722.0	484.4	615.3	722.0	484.4	615.3
Mean abs(DV)	252.7	226.7	236.4	252.7	226.7	236.4
Med abs(DV)	40.75	81.08	36.45	40.75	81.08	36.45
SD abs(DV)	676.3	502.8	657.9	676.3	502.8	657.9

Standard errors in parentheses. Bootstrapped standard errors are clustered at the municipality level. Un-interacted controls for suitability measures not shown.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2.5: Aggregate effect of certification.

	F&J	Agric.	Pasture
Procede	29.78***	1.116	-28.27***
	(7.451)	(5.329)	(6.354)
Series 2	4.187	-10.65***	23.78***
	(4.570)	(3.397)	(4.712)
Series 3	-46.19***	18.64***	67.11***
	(9.069)	(6.404)	(8.826)
Series 4	-71.76***	43.46***	77.34***
	(10.15)	(7.181)	(9.759)
Observations	100128	100128	100128
Mean DV	1043.5	529.8	387.6
Median DV	33.01	247.5	7.29
Mean Size	3113.1		
Median Size	1044.0		
Ejido, Series fixed effects	Yes	Yes	Yes

Standard errors in parentheses. Bootstrapped standard errors clustered at the ejido level. Dependent variables are measured in hectares

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2.6: Heterogeneous effects of certification by Series 1 suitability measures.

	F&J	Agric.	Pasture	F&J	Agric.	Pasture
Procede	31.20***	1.624	-28.60***	23.05***	7.029	-28.87***
	(7.578)	(5.405)	(6.390)	(7.667)	(5.515)	(6.674)
P-Index$_1^f$× Procede	-68.29***			-60.61***		
	(4.960)			(4.949)		
A-Index$_1^f$× Procede	-28.39***			-21.36***		
	(4.103)			(4.679)		
F-Index$_1^{pa}$× Procede	41.61***			47.65***		
	(3.978)			(4.241)		
P-Index$_1^a$× Procede		-12.44***			-17.86***	
		(2.369)			(2.496)	
F-Index$_1^a$× Procede		-44.54***			-42.44***	
		(3.999)			(4.057)	
A-Index$_1^{pf}$× Procede		37.26***			40.31***	
		(1.565)			(1.471)	
A-Index$_1^p$× Procede			-50.98***			-44.47***
			(2.903)			(3.033)
F-Index$_1^p$× Procede			-13.01***			-16.30***
			(4.266)			(4.133)
P-Index$_1^{af}$× Procede			29.80***			24.76***
			(2.824)			(3.430)
Observations	100128	100128	100128	100128	100128	100128
Mean DV	1043.5	529.8	387.6	1043.5	529.8	387.6
Median DV	33.01	247.5	7.29	33.01	247.5	7.29
Mean Size	3113.1					
Median Size	1044.0					
Ejido, Series FE	Yes	Yes	Yes	Yes	Yes	Yes
State-Series FE	No	No	No	Yes	Yes	Yes

Standard errors in parentheses. Bootstrapped standard errors clustered at the ejido level. Dependent variables are measured in hectares, and all suitability indices are standardized.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

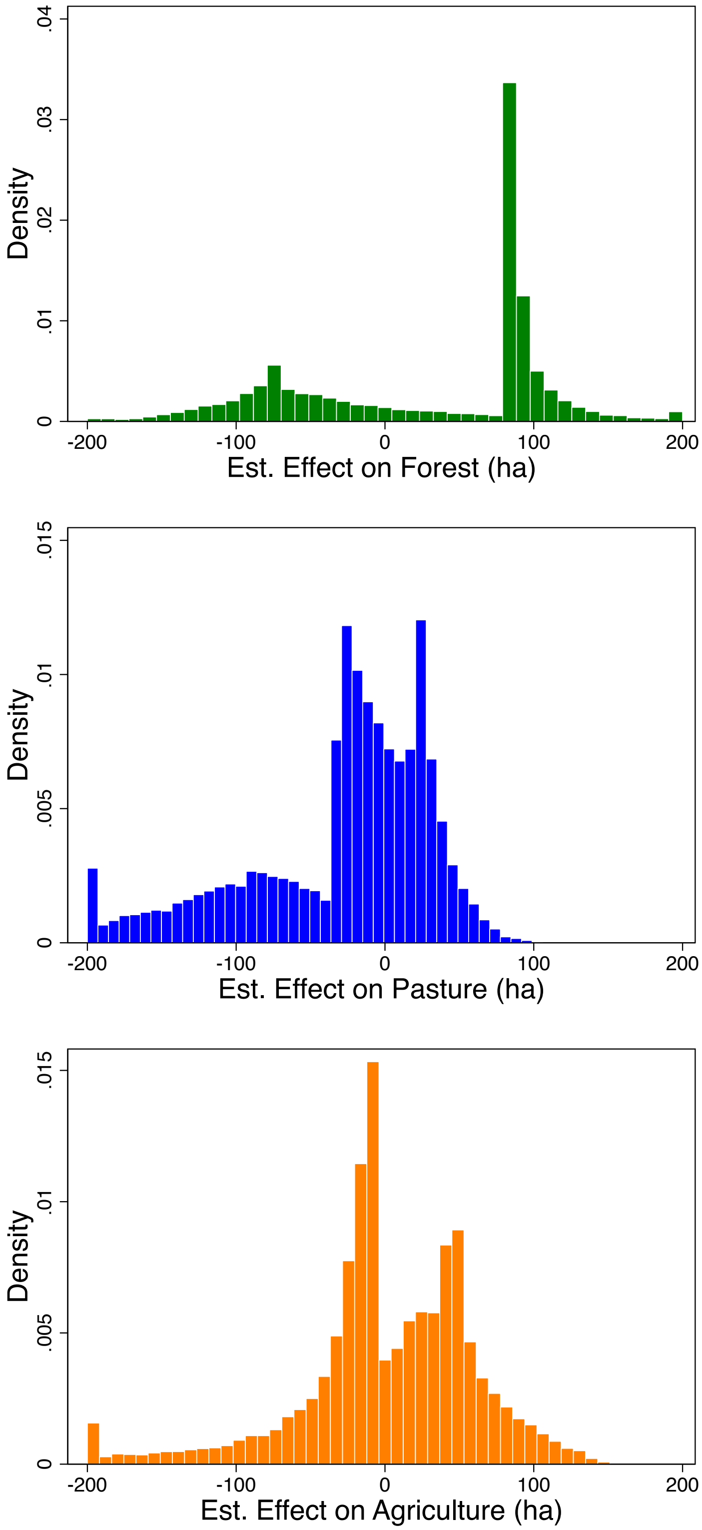
Table 2.7: Heterogeneous effects of certification by Series 1 suitability measures, census sample.

	F&J	Agric.	Pasture
Procede	42.47***	2.390	-39.04***
	(11.11)	(6.722)	(8.578)
P-Index$_1^f$× Procede	-70.16***		
	(5.358)		
A-Index$_1^f$× Procede	-29.85***		
	(4.407)		
F-Index$_1^{pa}$× Procede	45.37***		
	(4.954)		
P-Index$_1^a$× Procede		-15.22***	
		(2.817)	
F-Index$_1^a$× Procede		-45.57***	
		(4.980)	
A-Index$_1^{pf}$× Procede		38.03***	
		(2.126)	
A-Index$_1^p$× Procede			-52.46***
			(2.792)
F-Index$_1^p$× Procede			-14.55***
			(4.100)
P-Index$_1^{af}$× Procede			31.38***
			(3.235)
Observations	74356	74356	74356
Mean DV	1056.0	544.86	396.29
Median DV	48.57	278.92	11.298
Mean Size	3021.4		
Median Size	1099.3		
Ejido, Series fixed effects	Yes	Yes	Yes
State-Series fixed effects	No	No	No

Standard errors in parentheses. Bootstrapped standard errors clustered at the ejido level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

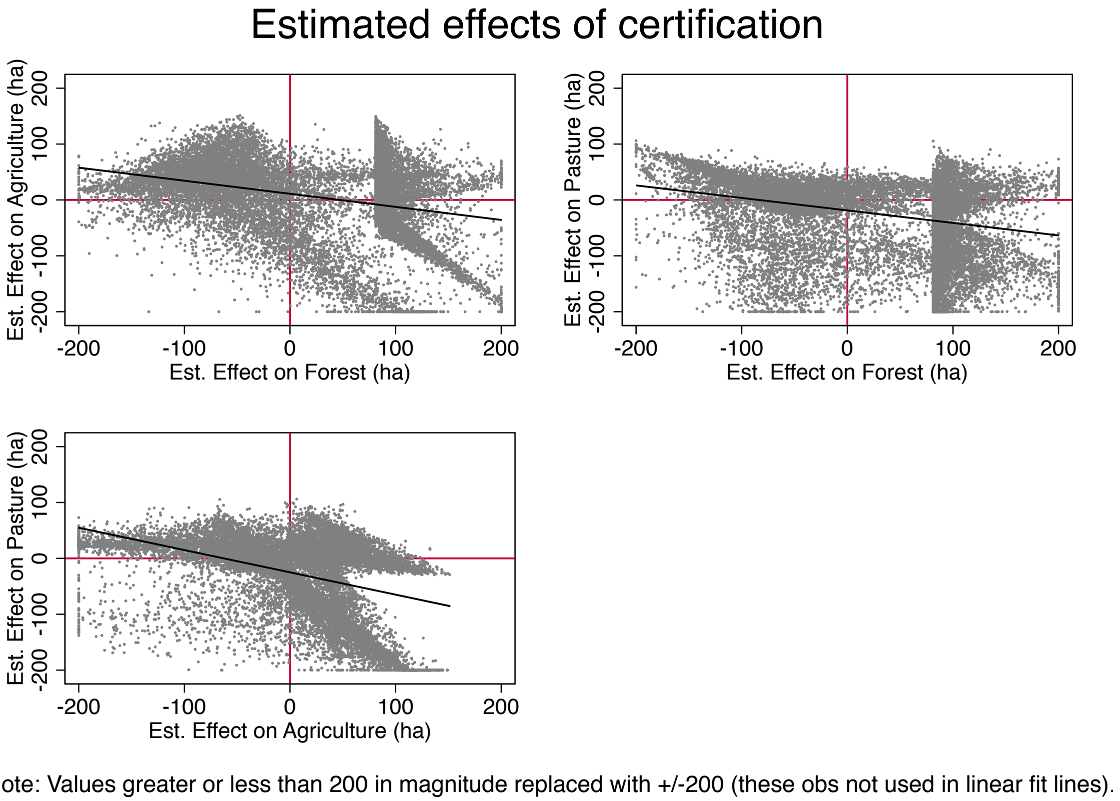
Figure 2.13: Distributions of est. effects of certification on forest, pasture and agriculture.



Estimated effects of certification

Note: Values greater or less than 200 in magnitude replaced with +/-200.

Figure 2.14: Correlations between estimated effects



Estimated effects of certification

Note: Values greater or less than 200 in magnitude replaced with +/-200 (these obs not used in linear fit lines).

Table 2.8: Correlations between suitability measures and years since certification (by series 4)

Dependent variable	Years w. cert.	Std. Error	P-Value	N
Ag-Index$_4^f$	-0.0195322	0.0019951	.000	25032
P-Index$_4^f$	-0.0210133	0.0023174	.000	25032
F-Index$_4^{pa}$	-0.019328	0.002291	.000	25032
F-Index$_4^a$	-0.0136842	0.0024963	.000	25032
P-Index$_4^a$	0.0032811	0.0039437	.406	25032
Ag-Index$_4^{pf}$	-0.0121971	0.0019605	.000	25032
F-Index$_4^p$	-0.0213995	0.0022881	.000	25032
Ag-Index$_4^p$	-0.013345	0.0020704	.000	25032
P-Index$_4^{af}$	-0.0054455	0.0038518	.000	25032

Table 2.9: Heterogeneous effects by member incorporation and insecurity.

	F&J	Agric.	Pasture	F&J	Agric.	Pasture
Procede	42.46***	2.409	-39.09***	41.62***	-1.163	-42.30***
	(11.17)	(6.791)	(8.589)	(11.40)	(7.907)	(9.391)
Member incorp. × Procede	-15.48	-11.33	31.04**			
	(21.47)	(10.29)	(14.99)			
Insecurity × Procede				2.939	8.438*	9.785
				(6.616)	(4.883)	(6.266)
P-Index$_1^f$ × Procede	-69.79***			-74.14***		
	(5.310)			(6.896)		
A-Index$_1^f$ × Procede	-29.26***			-22.00***		
	(4.582)			(4.713)		
F-Index$_1^{pa}$ × Procede	45.55***			43.49***		
	(4.918)			(5.942)		
P-Index$_1^a$ × Procede		-15.61***			-14.41***	
		(2.750)			(3.490)	
F-Index$_1^a$ × Procede		-45.13***			-50.97***	
		(4.786)			(7.269)	
A-Index$_1^{pf}$ × Procede		38.30***			37.69***	
		(2.105)			(2.659)	
A-Index$_1^p$ × Procede			-51.74***			-54.52***
			(2.856)			(3.879)
F-Index$_1^p$ × Procede			-15.16***			-9.228
			(4.016)			(5.845)
P-Index$_1^{af}$ × Procede			30.89***			34.75***
			(3.223)			(3.997)
P-Index$_1^f$ × Insecurity × Proc.				10.07		
				(11.66)		
A-Index$_1^f$ × Insecurity × Proc.				-20.80*		
				(10.74)		
F-Index$_1^{pa}$ × Insecurity × Proc.				4.528		
				(9.583)		
P-Index$_1^a$ × Insecurity × Proc.					-1.729	
					(5.948)	
F-Index$_1^a$ × Insecurity × Proc.					12.19	
					(10.93)	
A-Index$_1^{pf}$ × Insecurity × Proc.					0.843	
					(4.397)	
A-Index$_1^p$ × Insecurity × Proc.						5.472
						(6.715)
F-Index$_1^p$ × Insecurity × Proc.						-13.12
						(9.207)
P-Index$_1^{af}$ × Insecurity × Proc.						-10.48
						(7.964)
Observations	74356	74356	74356	74356	74356	74356
Mean DV	1056.0	544.86	396.29	1056.0	544.86	396.29
Median DV	48.57	278.92	11.30	48.57	278.92	11.30
Ejido, Series fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
State-Series fixed effects	No	No	No	No	No	No

Standard errors in parentheses. Bootstrapped standard errors clustered at the ejido level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure 2.15: Density of sum of estimated effects.

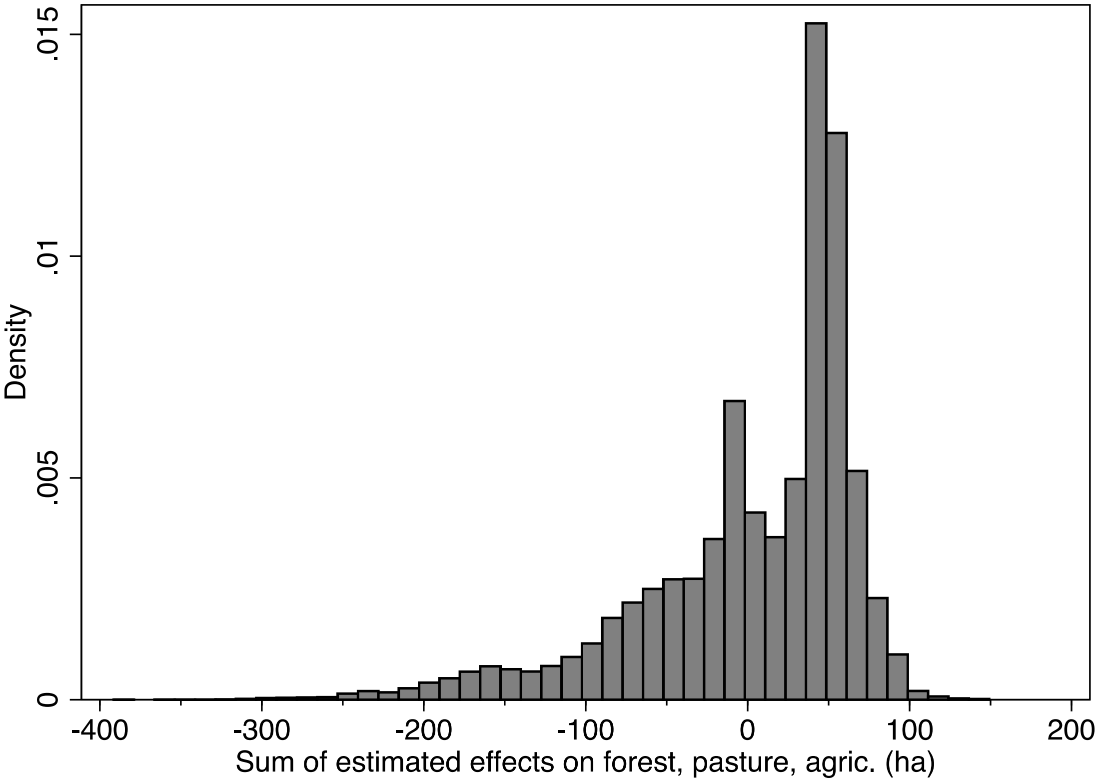


Table 2.10: Average and totaled effects for forest, pasture and agriculture, by sign.

	Average effects (ha)		Aggregate effects (ha)		
	Negative	Positive	Negative	Positive	Net
Forest	-74	89	-660,686	1,441,626	780,940
Agric.	-42	46	-531,298	571,956	40,658
Pasture	-61	26	-955,390	239,413	-715,977

Chapter 3

Of rice and men: Land-use restrictions in Vietnam

Job Market Paper
Daley Kutzman
University of California, Berkeley

January 2016

3.1 Introduction

A long history of food insecurity and famine preceded Vietnam's practice of centralized planning. The memories have not faded of the 1945 famine that killed nearly 2 million people and the food shortages from 1950-1987, when population growth often exceeded growth in rice production (Gunn, 2011; Pingali and Xuan, 1992). A persistent struggle with food insecurity and stagnant rice production was ultimately a major catalyst for Vietnam's transition to a 'socialist-oriented market economy' in 1986 under the *doi moi* economic reforms. Decollectivization delivered expansive growth, and the annual 5.5 percent growth rate of crop production between 1990-2004 is largely attributed to the improvement in incentives (Do and Iyer, 2008; Pingali and Xuan, 1992).

Rice is the most important agricultural crop in Vietnam, contributing over 60 percent of the average caloric intake, grown by 77 percent of the poorest quintile, and generating about 3 billion USD in export revenue (Ha et al., 2015; Minot and Goletti, 2000; Nielsen, 2003). Due to its cultural and economic significance, Vietnam continues to intervene in the agricultural sector and rice market after *doi moi*, through price controls and export quotas, among other policies. In addition, the government restricts land-use on 35.3 percent of its agricultural land in order to limit the conversion of paddy to other uses in the name of food security, despite the consequences for efficiency. Policies controlling land use with the objective of internalizing externalities (e.g. from environmental damage) are not limited to developing countries, and are common in transitional and rice-producing countries as a relic of past command-and-control practices (Giesecke et al., 2013; Markussen et al., 2011; Nielsen, 2003; Pingali and Siamwalla, 1993). However, study of such programs reveals there is risk of 'slippage' of the unwanted land-use from policy-targeted land to untargeted land due to endogenous optimization of landowners and price effects (Alix-Garcia et al., 2012; Lichtenberg and Smith-Ramirez, 2011; Wu, 2000). Examples of endogenous responses of households, firms, etc., working against a policy's purpose span several contexts, e.g. when energy efficient technology increases energy consumption due to the 'rebound' effect (Borenstein, 2013). Unanticipated and counterproductive responses are more prevalent where the policy level does not coincide with the policy instrument; such as the use of land restrictions to manage rice production in the case of Vietnam. Given the magnitude of rice's importance in Vietnam and all Asian countries, and the abiding concern for food security and rural development, understanding the impacts of the policy is highly relevant.

Land-use plans generated at the national, provincial, district and communal levels culminate in area targets for rice land within communes. Commune officials must then determine how to meet the target by restricting individual parcels within its boundaries. In this paper, I use rich household and plot level panel data from Vietnam over 2006-2012 to determine whether the restriction of household land for rice cultivation increases household aggregate rice output and how household behavior may thwart the policy's efforts. Communes do not generally restrict all of a single household's land, giving households the ability to endogenously adjust productive decisions on unrestricted land to reduce the utility cost of the policy. My empirical results at the household and plot levels indicate that endogenous farmer responses ultimately undermine the efficacy of the policy, and that household rice production is unaffected by land-use restrictions due to changes in production on unrestricted land. Furthermore, I show that the distortion to households' land allocation is costly, reducing agricultural profit by 450,000 2010VND for every 1SD increase in the share of restricted land.

The dual panels at the household and plot levels allow me the unique opportunity to identify both the aggregate effects of the policy on household production as well as the endogenous 'slippage' on households' unrestricted plots. While restrictions appear ineffective at the household level, increasing household rice production by just 3 percent for a 1SD increase in the share of restricted land, estimations at the plot level show that a restricted plot is 14 percentage points (hereafter referred to as 'pp') more likely to grow rice and produces 0.17 tons more rice. Yet unrestricted plots of households facing restrictions on other land are 20 pp less likely to grow rice and produce 0.14 tons less rice. This explains how restrictions may bind at the plot level and be ineffective at the household level.

A simple model of a farmer's crop choices under a subsistence constraint for rice production demonstrates how restrictions may generate this empirical pattern. The household and plot level results depend on the divergence or convergence of interest between the farmer and commune, as well as whether the farmer faces a binding subsistence constraint. The former determines whether the farmer would rather plant restricted land with a non-rice crop, and the latter determines whether productive decisions are dependent across the farmer's land. The pattern of the empirical results suggest that restrictions do 'bind' at the plot level, so that restricted plots are more likely to be planted with rice and planted more intensively with rice, but also that restrictions reduce rice production on unrestricted land. I can use the model to infer from these results that there is a divergence of interest between the commune and farmer, in addition to binding rice subsistence constraints.

The data provide the rare opportunity to utilize variation in land use restrictions while controlling for time-invariable plot characteristics. To my knowledge, only Goldstein and Udry (2008) have used a plot level panel to study issues of land rights and production. The plot panel also permits a secondary analysis to predict restriction status using dynamic panel data methods and reveals the characteristics that induce cross-sectional and temporal variation in restrictions. Econometrically, the analysis is challenging due to unobserved plot-specific heterogeneity as well as possible state dependence. I address these issues by employing two different estimation strategies: first, I use Arellano and Bond's (1991) difference GMM estimator in a linear probability model, and second, I use Wooldridge's (2000) dynamic probit panel estimator that utilizes a Chamberlain-Mundlak device. Both methods yield surprisingly similar results across most covariates, including the lagged dependent variable. With these results, I show that the main drivers of restriction are time-invariant plot characteristics and observable characteristics that make land suitable for rice production, such as access to commune-managed irrigation. Since no viable instrument is available to isolate exogenous variation in plot restrictions, understanding the source of variation in restrictions is critical. My identifying assumption is that restriction status is exogenously given once I control for plot and year fixed effects, rice suitability, plot-, household- and commune-level shocks, household political connections, etc. To support this assumption, I add more flexible time trends to investigate whether the effects are the result of omitted variables driving both production and restriction decisions.

The micro- and macroeconomic impacts of Vietnam's land use policy have not been studied extensively, and just three economic papers address plot restrictions explicitly. Nielsen (2003) employs the Global Trade Analysis Project (GTAP) to simulate the aggregate impact of allowing 5 percent of arable land in Vietnam to move out of rice cultivation and estimates that this relaxation actually reduces welfare.[1] In contrast, Giesecke et al. (2013) use a computable general equilibrium model to find that reduced restrictions would have positive impacts along many dimensions—annual consumption, poverty reduction, food security and nutrition diversity. Thus, the macroeconomic insights into this policy are sensitive to assumptions and ultimately equivocal. Markussen et al. (2011) turn to microeconomic evidence and empirics to investigate the effects of land-use restrictions. The authors utilize the first two rounds of this panel to show that while restrictions increased the probability a plot was used for rice production and agricultural labor supply of the household, it did not affect household crop income. The authors hypothesize that this lack of a negative impact could be due to access to superior inputs (fertilizer, irrigation) through the commune authorities. However, they do not pursue how restrictions ultimately affect household rice production, or how household land allocation—including unrestricted land—is altered by the policy. The latter is particularly relevant to understanding household responses as well as the efficiency costs of the policy.

Other examples of agents' endogenous behavior in response to a policy or innovation undermining the intended goal span many contexts. In the study of land conservation programs, there is 'slippage,' in which price and substitution effects increase the undesirable activity on unenrolled land. In the U.S., Wu (2000) estimates that for every 100 acres enrolled in the Conservation Reserve Program, 20 acres of unenrolled land was converted to cropland. In a developing country context, Alix-Garcia et al. (2012) shows that a program that pays landowners for hydrological services shifts deforestation to unenrolled land in Mexico, and that this 'slippage' is stronger in poorer *ejido* communities where landowners are credit constrained. In the study of governmental and household spending, transfers may or may not increase expenditures in a targeted category, as recipients allow the transfer to displace initial spending and respond no differently than when facing an aggregate budget increase.[2] Knight (2002) demonstrates that intergovernmental transfers as part of the Federal Highway Aid Program in the U.S. ultimately crowd out state spending. Finally, the 'rebound' effect in the energy economics literature describes the phenomenon in which an increase in energy efficiency of a technology may increase total energy consumption due to the lower marginal cost of use. Borenstein (2013) develops a theoretical framework for this effect, distinguishing between the income and substitution channels by which a lower cost of energy affects use, and Beltramo and Levine (2013) provide empirical evidence of rebound in the use of improved (fuel-efficient) cookstoves in Senegal. In each of these cases, the efficacy of the policy or innovation is weakened when its goal is not incentive compatible at the individual level.

In the next section, I describe Vietnam's long history of land reform and the policy of land use restrictions. Section 3 provides summary statistics for the household and plot level panels, and explores both compliance and the characteristics of households and plots selected for restriction. The simple model of household crop decisions is given in Section 4, empirical results are presented in Section 5, and Section 6 concludes.

3.2 Background

3.2.1 Land reform in Vietnam

Land reform has been an integral issue to the political and economic evolution of Vietnam, from French colonialism, to conflict with U.S., to post-reunification Communist rule. The incredible improvement in the agricultural sector, highlighted by Vietnam's emergence as a net rice exporter in 1989 and as the second largest exporter in 1997 after two decades of being a net importer, has long been attributed to changes made to its land policy (Marsh and MacAulay, 2002; Nielsen, 2003).

The first major departure from collectivization was in 1981, when communes began contracting individual farmers to produce a certain level of output to be delivered to the commune. All inputs necessary to meet the expected output level were provided by the commune and any excess output could be kept by the household or sold on a separate market. Short term gains were large: according to Pingali and Xuan (1992), rice yields in 1984 had increased by 32 percent and 24 percent relative to 1980 in the north and south, respectively.

---

[1] Giesecke et al. (2013) point out that this is likely due to the fact that she neglects the effects such a shift would have on rental rates.

[2] If spending in the targeted category is observed to increase, this is called a 'flypaper' effect.

In 1986, a set of economic reforms called *Doi moi* (the renovation) began Vietnam's transformation to a "socialist-oriented market economy." The waning benefits of the contract system and a massive famine in 1988 spurred further reform in agricultural and land markets. Resolution 10 passed by the Politoburo in April 1988 (Marsh and MacAulay, 2002) officially recognized the household as the main productive unit, and allocated farmers land in the commune with use rights for 10-15 year terms. In the North, the principal goal was equity amongst households in a commune, which in many cases lead to significant fragmentation as holdings were determined by both size and land quality. The South attempted to return to households land they had cultivated prior to collectivization and reunification.

The third major reform came in 1993 with the issuance of household land use rights (LUC or redbooks), covering 71 percent of households by 1998 and over 90 percent by 2000 (Do and Iyer, 2008). With LUCs, farmers were permitted to exchange, transfer, lease, inherit and mortgage land, though total holdings were still limited based on crop type (annual or perennial) and land is still officially "owned" collectively by all Vietnamese. The aim of the 1993 Land Law was to promote land investment and an efficient land allocation by reducing tenure insecurity and creating a market for land use rights.

Adjustments to the land law were made in 1998, 2001 and 2003, awarding households the right to re-lease land, to use land as joint venture capital for investment, to gift land to others, and formalizing procedures to register land related changes. The 1998 Land Law granted private ownership of input factors (machines, tools, draft animals) and released households from selling a contracted amount of output back to the commune (Nielsen, 2003). The 2001 and 2003 reforms further encouraged the exchange of LUC to form a land market, and increased the possible number of names to be listed on a LUC from one to two, in hopes that female spouses would be included as well.

3.2.2 Land use restrictions

Part of the motivation for such reforms to land policy and agricultural markets stemmed from Vietnam's struggle with food insecurity. Pingali and Xuan (1992) estimate that from 1950-1987, annual population growth often exceeded growth in total rice production. The decade preceeding *doi moi* saw shortages in food production ranging from 15-20 percent (Pike, 1981) and rice imports of over 1 million tons a year, with widespread malnutrition (Pike, 1981; World Bank, 1998). By 1988, 12 million people were short of food with 3 million starving (Gill et al., 2003). Thankfully, *doi moi* reforms were extremely effective in increasing rice production and efficiency: in 1994-1999, total agricultural output grew 6.7 percent annually, and remained at 4.6 percent for 2000-2003 (**?**).

Despite these large gains in food production, agricultural policies have continued to be directed towards achieving food security rather than promoting rural income growth (World Bank, 1998). With rice accounting for 50-75 percent of the average household's calorie intake (Bui, 2010), and about 40 percent of the value of agricultural exports (Nielsen, 2003), the state's particular policy interest in controlling rice markets in pursuit of food security is understandable. Important agricultural inputs including credit, extension services, and fertilizers (which are supplied by the state) are provided preferentially to rice producers (World Bank, 1998). In addition, massive irrigation efforts beginning in the 1980s doubled the size of Vietnam's irrigated area in 20 years, but focused on paddy areas: 70-90 percent of rice-growing land in the deltas was irrigated by 1998, while less than 50 percent of all annual crop land was irrigated in other areas. While this focus on rice irrigation extended the season in some areas enough to grow another crop of rice every year (Ives, 2013), it has come at the expense of neglected irrigation needs of dryland, subsidiary and cash crops, and requires significant improvements to support multi-cropping and crop diversity (Tu, 2002; World Bank, 1998). Finally, as domestic rice production increased, pushing Vietnam from a net importer to net exporter, export quotas were erected to stabilize prices and ensure sufficient domestic supply (Alavi, 2012; Nguyen and Grote, 2004; World Bank, 1998).[3].

The right to determine land use and crop choice has consistently been withheld by the state (Hung and Murata, 2001; Markussen et al., 2011; Marsh and MacAulay, 2002; World Bank, 1998) by nominally

---

[3] This quota is set annually by the Ministry of Agriculture and Rural Development, but is often adjusted in response to domestic supply situations. For example, during a drought in 1998, the government refused to authorize export contract prices to effectively reduce the export quota of 4 million tons that was set initially (CIE, 1998)

requiring any change to be consistent with existing “physical planning” (Markussen et al., 2011; Vasavakul et al., 2006) even while the 1988, 1993 and 2003 land law reforms steadily added to the list of rights farmers had over their land. Restrictions on land use existed before the major expansion of rights in 1993; Pingali and Xuan (1992) reports that the persistent top-down approaches by the State Planning Commission to determine land use and crop choice at the farmer level contributed to the erosion of benefits from the 1981 contract system. In addition to land being restricted to general agricultural use, individual plots may be required to grow rice in all seasons or a subset of seasons by commune authorities: Tien et al. (2006) state that “[rice] production targets are set at the local level in response to government directives and individual households may have to grow crops as directed.”

These restrictions are implemented through long term (10 year) and short term (1 and 5 year) Land Use Plans (Giesecke et al., 2013; Markussen et al., 2011; Vasavakul et al., 2006) at the national, provincial, and district levels of the Ministry of Natural Resources and Environment (MONRE). National rice area and production targets are guided by considerations of projected domestic consumption, export goals and planned land conversion (from socioeconomic “Master Plans”). According to the Government’s Resolution on National Food Security, 3.8 million hectares (encompassing around 90 percent of current paddy and 35 percent of cultivated land) must be reserved for rice cultivation by 2020—a reduction from the 2010 target of 4.2 million hectares (Giesecke et al., 2013). The national targets are then divided among provinces, which are then divided among districts, eventually filtering down to the commune level. Rice is a special category of land-use, and is specifically defined in all land-use plans. Unlike other higher levels, communes must produce “detailed land-use plans” that specify land-use parcel by parcel within its boundaries from one year to the next. This spatial plan is posted at the land management office of the commune, or announced parcel-by-parcel over the commune’s loudspeaker.

From the administrative side, the plans are generally rigid, as any adjustment at the commune level would require adjustment at higher levels to keep all land-use plans consistent. Communes are also required to submit land-use reports to the district multiple times a year, and district land officials unpredictably inspect commune land-use in person. The Land Administration Officer (LOA) of the commune bears the responsibility of the plan’s implementation, facing political punishments for unofficial deviations from the plan. From the households’ side, their land-use rights are officially conditional on their land-use being consistent with government planning. Marsh and MacAulay (2002) report that “illegally used” land can be confiscated from households who do not obey restrictions. The commune LOA monitors restricted land, and government officials anecdotally mention flooding or otherwise destruction of crops or coersion of households who do not obey restrictions. Also, households would have significant incentive to comply with commune direction, as most inputs, credit and extension services are supplied through the state and depend on a commune’s evaluation of the household.

Vietnam is not the only country to control land use in this way, particularly for maintaining or increasing rice cultivation. Myanmar similarly restricts land to be used as rice paddy, preventing conversion to non-rice or non-agricultural uses, and other rice-producing nations employ policies that either directly regulate paddy land or use financial incentives (Giesecke et al., 2013; Nielsen, 2003; Pingali and Siamwalla, 1993). Vietnam’s official stated purpose of land use restrictions is food security, particularly rice self-sufficiency and price stabilization (Government of Vietnam, Hanoi 2009). However, 20 percent of domestic rice is ultimately sold in foreign markets, and a large share of agricultural exports is exported rice, suggesting that unofficial trade targets could be another justification for restricting land (Markussen et al., 2011; Nielsen, 2003).

On a more local level, there are two additional explanations for the persistence of the policy over time. First, there may be local negative externalities of land conversion that the commune uses restrictions to limit. For example, converting a plot from rice to a perennial crop such as fruit trees may result in surrounding plots being shaded by the new trees. Given the community irrigation systems in place, the irrigation of one plot may rely on particular plots being used for paddy rice. Vasavakul et al. (2006) reports that Vietnamese policy makers claim “environmental damages” as justification for placing restrictions on plot use. Note that it is not uncommon for crop choice to be restricted based on surrounding cultivation in developed contexts—to control cross-pollination, for example. Unfortunately, without knowing the locations of the plots, I am unable to determine which plots are in sensitive positions, with the potential of producing negative externalities without restrictions. Thus, this angle of plot restrictions must be left for another dataset. Second, there are reports (The Economist, 2013) of local officials strategically restricting land to seek rents from future development or infrastructure projects. An official may enforce a restriction to keep land agricultural in order to suppress property values (which are partly determined by the state). Then once land is rezoned, they are able to extract bribes from developers to release the land from the restrictions and seize it from farmers for the purpose of "economic development" (The Economist, 2013). Because the land was previously kept in agriculture or paddy, the compensation given to the farmer is comparatively low. However, these officials are more often exploiting restrictions concerning conversion of agricultural land to non-agricultural use, rather than conversion between crops. In addition, plots targeted in this way would not see their restriction status change over time unless they were claimed by the state for development, in which case they would fall out of the plot-level panel.

3.3 Data

The data used here are the Vietnam Access to Resources Household panel survey (VARHS) from 2006, 2008, 2010, and 2012, covering 12 provinces across Vietnam (see Figure 3.1). Initially, households were chosen from the 2002 and 2004 Vietnam Household Living Standards Survey (VHLSS), but with the purpose of supporting evaluation of Danida programs in Vietnam. Poorer regions that were targeted by these programs, such as the north west and central highlands, are consequently oversampled. I limit the sample to a panel of 2,054 households across 466 communes that own and operate at least one agricultural plot. From these households, I have a panel of 4,707 plots that were followed over time using plot maps collected each year.

In Tables 3.1 and 3.2, summary statistics at the plot and household level are shown for each year of the study period. Most plots are irrigated and irrigation expands over time, increasing from 73 to 81 percent of panel plots. The proportion of plots restricted in some way is fairly constant across years, with the exception of 2010 and those plots restricted to grow rice in all seasons. Policy changes in 2010 that reduced the national target of rice paddy coupled with a drought in regions covered by the survey likely contributed to this decline. In addition to crop choice, the rights to build permanent structures or convert land out of agriculture are heavily restricted, demonstrating another dimension of land use that is controlled by the state.

Up to three seasons of rice can be cultivated in a year in Vietnam, depending on the region and irrigation structure. The average plot in this panel grows 1.3 seasons a year, making it by far the most common crop cultivated in the sample. The second most common is maize, which is grown for less than 1 season on average. Both rice and maize yields marginally increase between 2006 and 2012, averaging at 8.3 and 4 tons/ha, respectively.

Household level summary statistics by year are also included in Table 3.1. While the plot level panel includes only plots that the household used all years and that could be matched by the enumerators, household variables encompass all plots reported by the household each year. The land rental and sale markets are puzzlingly thin, despite the issuance of LUC and the series of reforms that came afterward to promote exchange: the average number of plots rented in or out by households over the period is never more than 0.45. Land holdings are on average very fragmented, with the average plot size below one fifth of a hectare and total holdings below one hectare. The average household cultivates rice on over 40 percent of its used land, amounting to about 5 seasons per household per year. Though the average household grows less than one season of maize per year, 32-55 percent cultivate another annual crop and 28-33 percent cultivate perennial crops.

On average, 4.5 households were sampled in each commune, with a range from 1 to 23. When a commune did restrict household land, a total of 1.3-1.8 hectares is restricted across 14.6 plots and 74 percent of sampled households. Figure 3.5 shows these average amounts of land by year at the commune and household levels, and the decline in restrictions in 2008 and 2010 is clearly visible. While I observe plot restrictions in every province and district sampled, not all communes restrict land use and these policies are not constant over time—at the commune, plot or household levels. I consider a unit to be never-restricted (or unrestricted) if it's recorded as unrestricted in all four years, and restricted if it's recorded as restricted at least once. For 132 communes (30 percent), I observe restricted plots in every period, and for 85 (19 percent), I don't observe any restricted plots. However, as not all households in a commune were sampled, we cannot conclude that these communes didn't impose restrictions on unsampled households and plots. There is comparable variation in the burden of plot restrictions at the household and plot levels: about 20-30 percent of households and plots are never-restricted, 15-17 percent always-restricted, with the remaining units both restricted and unrestricted in the study period. This variation in restriction does appear to have a stabilizing effect on rice production. Figure 3.2 fits communes' coefficients of variation of total household rice production over the four surveys to the communes' average proportion of household area restricted. There is a clear negative correlation between these two measures, indicating that the variability of rice production is lower when more land is restricted by the commune.

3.3.1 Explaining restrictions

It is important to understand how plot restrictions are determined, as communes select plots to be restricted based on household and plot characteristics. Thus it's useful not only to compare plots or households that are contemporaneously restricted or unrestricted, but plots or households that are *ever* restricted to those that do not face restrictions. Summary statistics are disaggregated in Tables 3.4 and 3.3 based on whether I ever observe a plot or household to be restricted or unrestricted.

Predictably, plots selected for restriction are those more suited for rice cultivation, flat with canal irrigation—both essential qualities for rice cultivation. Interestingly, they are less likely to have a male manager, though this is not predetermined with respect to restriction—it could be that women are assigned to manage plots that are restricted. The stark difference in the proportion of plots growing rice is a hint at the degree of compliance with the policy. While almost 90 percent of restricted plots grow at least one season of rice, just 30 percent of unrestricted plots do so. Unrestricted plots are twice as likely to grow maize and are about 13 times more likely to grow a perennial crop.

If negative externalities of plot conversion are more relevant or larger with higher fragmentation (and therefore more plots sharing borders), we'd expect that plots under restriction will be smaller in size. Consistent with this logic, I see that plots that are restricted are 70 percent smaller than plots that are never restricted. There is also evidence that plots are selected for their rice productivity. Restricted plots yield an additional 3.2 tons of rice per hectare than unrestricted plots on average. The fact that maize yields are also higher on restricted plots suggests that these plots aren't only particularly productive for rice. This can also be seen in Figure 3.3, where the yields of plots under restrictions are shifted above those of unrestricted plots. This could be due to either selection of plots into different restrictions and restriction patterns, or if the state of being restricted influences yield (through more rice seasons grown, or preferential treatment by the commune, for example).

The commune's decision to restrict a plot may also depend on household characteristics. Though household size doesn't vary significantly, unrestricted households have slightly more educated and more often female household heads. The amount of used land per household member is about 30 percent lower for restricted households, suggesting they are more land-constrained. Consistent with land fragmentation-related restrictions, households who face restrictions have about twice as many plots despite the fact their land holdings are 30 percent smaller. Whether due to the selection of productive land and farmers into restriction or selection of farmers with productive land, rice yields for household that face restrictions are 25 percent higher. Unlike the plot-level results, household level maize yields aren't significantly higher for restricted households—suggesting that restrictions target productive plot characteristics more than household ability.

3.3.2 Predicting restriction status

I also use the plot panel to predict restriction status using dynamic panel data methods. The estimation is econometrically sensitive due to the possibility of 'true' state dependence as well as 'fake' or 'spurious' state dependence. The latter is simply the time-invariant unobserved plot heterogeneity in the disturbance term—in other words, the plot fixed effect. The former describes the circumstance when the outcome variable is truly dependent over time and lagged outcomes should be included as regressors, even after controlling for other covariates and fixed effects. The distinction between fake and true state dependence is often very relevant for policy: distinguishing between a "scarring" effect of unemployment where the current unemployed are more likely to be unemployed next period (all else constant), and the existence of people with constant characteristics that make them more likely to be unemployed in any period, has important implications for public programs to reduce short run unemployment. In this context, the extent of true state dependence in restriction status can provide insight into the commune's objective. For example, negative state dependence could suggest that communes ‘rotate’ the burden of restriction among households who are made to share the burden of restricted rice production.

Allowing for true state dependence introduces the “initial conditions problem,” however. This occurs when the researcher does not observe the entire dynamic process, collecting data only after the process has started. Without the full history, it’s unclear how the first *observation* of the dependent variable is influenced by either the unobserved previous value or unobserved heterogeneity. With a continuous dependent variable or a linear probability model, this issue is resolved by transforming the data to eliminate the fixed effect and instrumenting for the lagged dependent variable to eliminate dynamic panel bias as in Arellano and Bond (1991), who suggest using lagged values of the dependent variable as instruments. In a discrete model, no transformation can eliminate the fixed effects, so the solution is more difficult. Wooldridge (2005) suggests a conditional maximum likelihood estimator that models the distribution of the unobserved heterogeneity given the covariates as well as the initial observation of the outcome. The mean of this distribution is allowed to depend on all values of the covariates, their initial values, and time-invariant covariates, thus allowing the fixed effect to be correlated with plot characteristics. The advantage of this method over others (for example Honoré and Kyriazidou (2000)) is that it can be easily implemented in standard software and it’s possible to compute average partial effects, which is critical to interpretation. I include the results of both estimations mainly because they are remarkably similar despite very different underlying models, which imparts more confidence in their individual results.

Table 3.5 shows the results from application of Wooldridge (2005)’s model. Coefficient estimates, coefficient standard errors, and average partial effects are shown for each variable. The characteristics that determine the correlation between the fixed effect and covariates are each listed variable at each period (including 2006), as well as flexible controls for plot area, slope, distance from home, household size, way of acquiring the plot, household gender, household age, and household education. In each model, the coefficient for lagged restrictions is significant, though the largest average partial effect is just 5pp. In the last column, the degree of state dependence has fallen to 3pp. Compared to irrigation, which increases the probability of restriction by 13pp on average, state dependence seems less critical to restriction patterns. Irrigation, possession of a redbook, and political connections are the only other statistically significant, sizable effects. Notably, household size and household land holdings do not significantly affect the probability of restriction, which suggests that communes do not restrict land in order to minimize their burden. The average partial effect of the district rice price is large and positive though insignificant at 13pp. This indicates that communes restrict more land to rice when prices rice, which could indicate restrictions are used as a response to food insecurity. Finally, these results provide no evidence that previous shocks to either plot or household rice yields affect restriction status.[4]

Results of the same estimations using Arellano and Bond’s (1991) method are shown in Table 3.6. Most surprising is the similarity between the two sets of results with full controls in the last column. State dependence is around 3pp, irrigation increases the probability of restriction by 14pp, redbook possession increases it by 13pp, and household political connections increase it by 7pp. As with the Wooldridge (1991) method results, there is a large positive estimated effect of the price of rice: if the price increased by 20 percent, the probability of restriction of any plot increases by about 3pp. The effect of growing a non-rice crop in the previous year is larger and more significant with this method, suggesting that new restrictions target plots that aren’t already being used for rice. As before, there’s still no evidence that restriction depends on past yield shocks or household land or labor supply. Additionally, it is only plot-level natural shocks that affect restriction status rather than household level shocks, which makes more sense if communes care more about production than household utility.

The two main concerns with Arellano and Bond’s (1991) method are weak instruments or invalid instruments. In this case, our instruments would be weak if restriction status followed a random walk and thus had a true coefficient of 1. However, the downward biased fixed effect estimate and upward biased OLS estimate that should bound Arellano and Bond’s (1991) estimate are both well below 1, so this is of little concern. Our instruments would be invalid when there is serial correlation in the errors, violating the exclusion restriction for the lagged levels. This is solved by using further lags as instruments and identified by the Sargan or

---

[4] If households were playing some form of game with commune authorities and manipulating their rice production to affect their probability of restriction, we might see evidence of it here. However, the effects of lagged household and plot yields are both small and insignificant,

Hansen-J Wald statistics. In Table 3.6, we see that the null hypothesis of exogenous instruments is rejected in the Sargan test. Allowing more characteristics to be endogenous, collapsing the instrument matrix, and clustering at the commune level produces valid instruments, as seen in the last column of Table 3.7, without affecting the main conclusions from the predictive analysis.

To summarize, these predictive results suggest that restrictions are mostly determined by time-invariant plot characteristics, changes in irrigation and redbook possession, as well as household political connections.

3.3.3 Compliance

For plot restrictions to impact farmer behavior, households must comply with restrictions, and restrictions must actually constrain plot choice (i.e. the constraint must be binding). To determine how often plots are in compliance with restrictions in a given period, I compare a plot's restriction status to it's rice cultivation status. A plot can either grow no rice, grow rice in some of the seasons for which I have data, or grow rice in all seasons for which I have data. As restrictions can require a plot grow rice in all seasons or require it to grow rice in some seasons, I consider the following to be "in compliance:"

Rice cultivation	Restricted in all seasons	Restricted in some seasons	Unrestricted
No rice	Noncompliant	Noncompliant	Compliant
Rice in some seasons	Noncompliant	Compliant	Compliant
Rice in all seasons	Compliant	Compliant	Compliant

Figure 3.6 compares these at the plot level. We can see that when a plot is restricted to grow rice in all seasons, 86 percent of the time the plot is compliant and grows rice in every (non-missing) season. When a plot is restricted to grow rice in some seasons, 94 percent of the time the plot is compliant and grows rice in at least some seasons (exceeding the restriction 55 percent of the time and growing rice in all seasons). Plots that don't face restrictions are much less likely to cultivate it: while over 40 percent of plots don't grow any rice when unrestricted, less than 8 percent of restricted plots cultivate no rice. In fact, 30 percent of the time, rice is replaced with another crop as the main crop cultivated on a plot when it happens to be unrestricted. Secondary and tertiary rice crops are similarly replaced when unrestricted. However, given the degree of selection into restrictions based on plot and household characteristics, it's unwise to draw any conclusions about whether or not the policy binds from Figure 3.6 and such correlations.

3.4 Model

The following model formalizes a single household's crop choice across a continuum of land, and demonstrates how restrictions may affect decisions on both restricted and unrestricted land. It attempts to separate two conditions which influence the impact of restrictions on household production: whether restrictions require households to grow rice where they would prefer to grow a different crop, and whether production decisions are dependent across land within a household. The former is determined by the objectives of the commune and farmer, particularly whether they coincide or diverge. As previously argued, the commune likely selects land for restriction that's more suitable for rice production and has higher rice yields, whereas the farmer will incorporate the opportunity cost of rice cultivation and select land for rice based on relative profitability. If land characteristics are such that plots with the highest rice yields would be more profitably used for another crop, then the interests of the farmer and commune diverge, and land restrictions will change the use of restricted land. The latter condition is determined by the tightness of the household's subsistence production constraint. If binding, this constraint would bring land into rice production that would be more profitably allocated to another crop. Restrictions may also release such unrestricted land from subsistence rice production if restrictions cause conversion of land from non-rice to rice.

I simplify these decisions by only allowing the farmer to choose between two crops, rice and non-rice, which can be produced with standard technologies. Let $Z = [\Theta, C_\Theta, \Gamma, C_\Gamma]'$ be jointly normal across household land according to the cumulative density function F_Z, where Θ and Γ are rice and non-rice yields per unit of area, respectively, and C_Θ and C_Γ are rice and non-rice input costs per unit of area, respectively.[5] Thus $F_Z(\theta, c_\theta, \gamma, c_\gamma)$ specifies the proportion of the household's land with $\Theta \leq \theta$, $C_\Theta < c_\Theta$, $\Gamma \leq \gamma$ and $C_\Gamma \leq c_\Gamma$. Also normalize the price of rice to 1, so that non-rice profits on a unit of land with $\Gamma = \gamma$ and $C_\Gamma = c$ are given by $\pi_N = p\gamma - c$, and rice profits on a unit of land with $\Theta = \theta$ and $C_\Theta = c$ are given by $\pi_R = \theta - c$. Without any other constraint, the farmer will clearly plant with rice all land such that $\Pi = \pi_R - \pi_N \geq 0$, which will also be normally distributed as it is a linear combination of jointly normal variables. Let $F_{\Pi,\Theta}$ give the joint density of (Π, Θ) across the farmer's land with $\mu = AZ$, and $\Sigma = A\Sigma_Z A^T$, where A is the linear transformation, $(\Pi, \Theta)^T = AZ$. Thus the farmer's total area in rice, A_0, and total rice production, R_0, when unconstrained will be given by,

$$\begin{aligned} A_0 &= 1 - F_\Pi(0) \\ R_0 &= \int_{-\infty}^{\infty} \int_{0}^{\infty} \theta f_{\Pi,\Theta}(\pi, \theta) d\pi d\theta \end{aligned}$$

Now suppose that the farmer faces two constraints. The first is a land use restriction implemented by the commune authority. The commune must restrict a proportion of its land to be used for rice production, $\Omega \in [0, 1]$, as determined by higher levels of government, and I assume that the commune selects land for restriction based on rice suitability, represented by rice yield, Θ. Let G_Θ be the density of rice yield across all of a commune's land, so that $G_\Theta(\theta)$ gives the proportion of commune land with rice yield below θ. This restriction results in the commune's choice of $\bar{\theta}$, such that all land with $\Theta \geq \bar{\theta}$ is restricted to grow rice:

$$1 - G_\Theta(\bar{\theta}) = \int_{\bar{\theta}}^{\infty} g_\Theta(\theta) d\theta \geq \Omega$$

which implicitly defines a cutoff, $\bar{\theta}(\Omega)$, if the constraint holds with equality. Then each household will face restrictions on all of their land with $\Theta \geq \bar{\theta}(\Omega)$. Define a household's restricted area as,

$$\Omega_i = \int_{\bar{\theta}(\Omega)}^{\infty} f_\Theta(\theta) d\theta$$

---

[5] I assume that the mean, μ_Z, and covariance matrix, Σ_Z, are such that a value of 0 is more than two standard deviations from their means, making negative values for any of these variables very unlikely.

In this set up, households will face different degrees of restriction on their land depending on where their land holdings fall in the distribution G_Θ.

The second is a subsistence constraint for total rice production, requiring that household rice production is above $\omega \in R_+$. Taking into account the rice production on restricted and unrestricted land, the farmer's subsistence constraint will take the form,

$$\int_{-\infty}^{\bar{\theta}(\Omega)} \int_{\bar{\pi}}^{\infty} \theta f_{\Pi,\Theta}(\pi,\theta) d\pi d\theta + \int_{\bar{\theta}(\Omega)}^{\infty} \theta f_\Theta(\theta) d\theta \geq \omega$$

which implicitly defines a second cutoff, $\bar{\pi}(\omega,\Omega)$, if the constraint holds with equality. Thus, when constrained, the farmer's total area in rice, A_1, and total rice production R_1, will be given by,

$$\begin{aligned} A_1 &= \int_{-\infty}^{\bar{\theta}(\Omega)} \int_{\min\{0,\bar{\pi}(\omega,\Omega)\}}^{\infty} f_{\Pi,\Theta}(\pi,\theta) d\pi d\theta + 1 - F_\Theta\left(\bar{\theta}(\Omega)\right) \\ R_1 &= \int_{-\infty}^{\bar{\theta}(\Omega)} \int_{\min\{0,\bar{\pi}(\omega,\Omega)\}}^{\infty} \theta f_{\Pi,\Theta}(\pi,\theta) d\pi d\theta + \int_{\bar{\theta}(\Omega)}^{\infty} \theta f_\Theta(\theta) d\theta \end{aligned}$$

Rice will be grown on unrestricted land where there are positive returns ($\Pi \geq 0$), but if $\bar{\pi}(\omega,\Omega) < 0$, the farmer will cultivate rice until $\Pi = \bar{\pi}(\omega,\Omega)$ in order to meet the subsistence constraint. Therefore, the lower bound for rice cultivation in the Π dimension on unrestricted land is instead $\min\{0,\bar{\pi}(\omega,\Omega)\}$. For what follows, I initially assume that the subsistence constraint is binding for the farmer, $\bar{\pi}(\omega,\Omega) < 0$. The key comparative statics are $\frac{\partial A_1}{\partial \Omega}$ and $\frac{\partial R_1}{\partial \Omega}$, which give the effect of an increase in the amount of restricted land on total rice area and rice production, respectively. First, however, note that $\bar{\theta}(\Omega)$ will fall and $\bar{\pi}(\omega,\Omega)$ will rise with an increase in restricted land, Ω.[6]

$$\begin{aligned} \frac{\partial \bar{\theta}(\Omega)}{\partial \Omega} &= \frac{-1}{g_\Theta(\bar{\theta}(\Omega))} < 0 \\ \frac{\partial \bar{\pi}(\omega,\Omega)}{\partial \Omega} &= \frac{\frac{\partial \bar{\theta}}{\partial \Omega}\bar{\theta}(\Omega)\left(f_\Theta\left(\bar{\theta}(\Omega)\right) - \int_{\bar{\pi}}^{\infty} f_{\Pi,\Theta}\left(\pi,\bar{\theta}(\Omega)\right) d\pi\right)}{-\int_{-\infty}^{\bar{\theta}(\Omega)} \theta f_{\Pi,\Theta}\left(\bar{\pi},\theta\right) d\theta} > 0 \end{aligned}$$

The cutoff rice yield for land restrictions, $\bar{\theta}(\Omega)$, will fall because the commune will select land with lower yields in order to restrict more land, and the relative profit cutoff $\bar{\pi}(\omega,\Omega)$ will rise because the increase in restricted area reduces the residual subsistence constraint on unrestricted land. These cutoffs give the boundaries of rice production on the household's land, and consequently drive the impacts of restrictions on rice area and production.

When the subsistence constraint binds, the effect of restrictions on household rice area can be decomposed into two opposing effects,

$$\frac{\partial A_1}{\partial \Omega} = -\frac{d\bar{\pi}}{d\Omega}\left[\int_{-\infty}^{\bar{\theta}(\Omega)} f_{\Pi,\Theta}\left(\bar{\pi}(\omega,\Omega),\theta\right) d\theta\right] - \frac{\partial \bar{\theta}}{\partial \Omega}\left[f_\Theta\left(\bar{\theta}(\Omega)\right) - \int_{\bar{\pi}(\omega,\Omega)}^{\infty} f_{\Pi,\Theta}\left(\pi,\bar{\theta}(\Omega)\right) d\pi\right]$$

---

[6] This follows from the derivation of marginal densities from joint densities.

The first term in the above derivative gives the reduction in rice area as unrestricted land once planted with rice in order to meet the subsistence constraint is converted to non-rice; this production is effectively replaced by the increase in rice production on restricted land. The size of this effect is determined by the adjustment of the $\bar{\pi}(\omega, \Omega)$ cutoff, as well as the density of unrestricted plots along this cutoff. If the subsistence constraint was not binding, then this negative term would be dropped from the derivative, and an increase in Ω would unambiguously increase A_1 due to the remaining two terms. The sum of these two terms gives the increase in rice area simply due to the lower $\bar{\theta}(\Omega)$ cutoff, and is similarly determined by the adjustment of $\bar{\theta}(\Omega)$ and the density of plots along this cutoff. Note that land distributed around the $\bar{\theta}(\Omega)$ cutoff with $\Pi \geq \bar{\pi}(\omega, \Omega)$ is already planted with rice by the household and so does not contribute to the derivative. Also, the density of land distributed there depends on the covariance between Π and Θ. When the covariance is negative, more land is likely to be distributed around the $\bar{\theta}(\Omega)$ cutoff with $\Pi \leq \bar{\pi}(\omega, \Omega)$, and when the covariance is positive, less land is likely to be distributed there.

The derivative for total rice production appropriately mirrors that of rice area.

$$\frac{\partial R_1}{\partial \Omega} = -\frac{d\bar{\pi}}{d\Omega}\left[\int_{-\infty}^{\bar{\theta}(\Omega)} \theta f_{\Pi,\Theta}\left(\bar{\pi}(\omega, \Omega), \theta\right) d\theta\right] - \frac{\partial \bar{\theta}}{\partial \Omega}\bar{\theta}(\Omega)\left[f_{\Theta}\left(\bar{\theta}(\Omega)\right) - \int_{\bar{\pi}(\omega,\Omega)}^{\infty} f_{\Pi,\Theta}\left(\pi, \bar{\theta}(\Omega)\right) d\pi\right]$$

The negative effect on production of conversion of land from rice to non-rice is captured by the first term; the loss in rice area represented by the first term of $\frac{\partial A_1}{\partial \Omega}$ generates this decrease in production. Likewise, the sum of the remaining terms encompasses the net impact of restricted area on rice production on restricted land: the added output from newly restricted land, ignoring the output from land that was already allocated to rice.

As previously discussed, the signs of these derivatives and thus the affect of changes in restrictions on household rice area and production are decided by the sign of $\text{Cov}(\Pi, \Theta)$, and the tightness of the subsistence constraint. The more negative the covariance between Π and Θ, the more the interests of the commune and farmer diverge, as the commune will restrict land with the highest relative non-rice profits. This positive effect may be diminished if the subsistence constraint is binding, and rice production falls on unrestricted land.

3.4.1 Empirical Specification

To evaluate the hypothesis of the model, I estimate fixed effect regressions at both the household and plot level. The household regressions correspond to the farmer level from the model, for which it's ambiguous how restrictions will affect aggregate rice outcomes. The household level models take the form,

$$\begin{aligned} Y_{hct} &= \beta_0 + \beta_1 Res_{hct} + \boldsymbol{\beta}\mathbf{X}_{hct} + \alpha_h + \delta_t + \varepsilon_{hct} \\ Y_{hct} &= \beta_0 + \beta_1 Res_{hct} + \boldsymbol{\beta}\mathbf{X}_{hct} + \alpha_h + \delta_{ct} + \varepsilon_{hct} \end{aligned}$$

where Y_{hct} is the outcome of interest for household h in commune c in period t, including an indicator for whether the household grows any rice, the number of seasons of rice grown across all household plots, rice output in tons, and the total area devoted to rice production. Res_{hct} is either an indicator that the household faces restrictions or a measure of the share of household land that's restricted. Instead of using the share, for which a 1 unit change is extreme, or a standardized share, for which a 1 unit change is too low[7], I simply divide the share of restricted land by the standard deviation of the shares of *restricted* households, excluding those that are unrestricted. This way, a value of 0 still indicates that the household is unrestricted, and a 1 unit increase in the variable is a reasonable change in the amount of restricted land. X_{hct} is a vector of household controls, α_h is a household fixed effect, and δ_t and δ_{ct} are year and commune-specific year fixed effects. To further examine how households respond to restrictions, I also estimate parallel models with maize outcomes, using an indicator for maize cultivation, number of maize seasons, etc.

As previously discussed, the sign and size of β_1 will depend on how farmers' and communes' choices diverge or converge about which plots to plant with rice, as well as the tightness of the households' rice production constraint. If β_1 is large and positive, it would suggest that commune and farmer interests diverge and it's likely that households do not face binding subsistence constraints. If β_1 is small in magnitude, then household level estimation will not be able to distinguish between two cases: (1) commune and farmer interests converge, and restrictions are placed where households choose to grow rice, or (2) commune and farmer interests diverge, but a binding subsistence constraint leads to 'slippage' on unrestricted land. However, these cases are distinguishable at the plot level. The former will yield no effect of restriction on plot level outcomes, and the latter will yield positive effects for restricted plots in addition to negative effects for unrestricted plots. At the plot level, I estimate models of the form,

$$\begin{aligned}
Y_{ihct} &= \beta_0 + \beta_1 Res_{ihct} + \beta_2 OtherRes_{ihct} + \boldsymbol{\beta}\mathbf{X}_{ihct} + \alpha_i + \delta_t + \varepsilon_{ict} \\
Y_{ihct} &= \beta_0 + \beta_1 Res_{ihct} + \beta_2 OtherRes_{ihct} + \boldsymbol{\beta}\mathbf{X}_{ihct} + \alpha_i + \delta_{ct} + \varepsilon_{ict} \\
Y_{ihct} &= \beta_0 + \beta_1 Res_{ihct} + \beta_2 OtherRes_{ihct} + \boldsymbol{\beta}\mathbf{X}_{ihct} + \alpha_i + \delta_{h1} t + \delta_{h2} t^2 + \varepsilon_{ict}
\end{aligned}$$

where Y_{ihct} is the outcome of interest for plot i in household h in commune c in period t, including an indicator that rice is grown on the plot, the number of rice seasons grown, rice output in tons, and rice yield in tons per hectare. While Res_{ihct} is an indicator that the plot is restricted to grow rice, $OtherRes_{ihct}$ is an indicator that *another* plot controlled by household h is restricted to grow rice. Together, these variables separate restricted from unrestricted land. X_{ihct} is a vector of plot and household controls, α_i is a plot fixed effect, δ_t and δ_{ct} are year and commune-specific year fixed effects, and t is a period count. Again, to further test the results, I run analogous estimations using maize outcomes. The coefficients of interest are β_1 and β_2. If commune and farmer interests converge, then $\beta_1, \beta_2 \approx 0$, but if commune and farmer interests diverge, then $\beta_1 > 0$. Finally, there is evidence of 'slippage' and therefore a binding subsistence constraint if $\beta_1 < 0$.

3.5 Results

The first set of tests are at the household level, in order to evaluate the net effect land restrictions on households after they have had the opportunity optimize production. Tables

---

[7] With a standardized version, the standard deviation is calculated including observations from unrestricted households with a share of 0. This makes the standard deviation an inaccurate measure of a reasonable increase in the restricted share of land when the household is restricted.

3.9 and 3.10 explore how restrictions shift the extensive and intensive margins of rice and maize production. Dependent variables are an indicator that the household grows at least one season of rice across its plots, the cumulative number of rice seasons grown by the household, and the measure of land (in hectares) of land that is planted with rice for at least one season. Regressions include controls for household size, gender of household head, whether the household reported facing a negative natural shock, total land used by the household (owned land and rented in land), district median price of rice, and the shares of household land with a redbook and with irrigation, converted to standard units. The first four columns include plot and year fixed effects, and the last four include commune-specific year dummies. Thus the results in the last four columns are robust to any commune level shocks that would affect both household rice production decisions and commune restriction decisions. Having restricted land increases a household's probability of growing rice by 5.4-8.3 pp according to results in columns 1 and 5, and increases the number of rice seasons grown by 0.2-0.25 according to columns 2 and 6. The estimated effects are statistically- but not economically significant: a 5.4 pp increase in the probability of growing rice is just 7.3 percent of the average, and an increase of 0.2 rice seasons is just 3.8 percent of the average. Statistically significant results for hectares of rice are only found in level form, where they are between 5.2-11.6 percent of the mean value. Table 3.10 completes a parallel analysis restriction's effect on maize production decisions. In this case, there are no statistically significant effects of restriction, and all point estimates are small relative to the averages. Overall, there is little evidence that restrictions alter household rice production at the extensive or intensive margins.

Restrictions seem to have comparably small and insignificant effects on household rice output, as shown in Tables 3.11 and 3.12. In Table 3.11, the dependent variables are either household rice production in tons and household rice yield in tons per hectare. In columns 1 and 4, I see that restrictions do not significantly affect rice production. In accordance with the earlier negative relationship between restriction and rice area, I see a positive effect of restriction on rice yields in the rest of the columns. Though the effects are small—none are larger than 8 percent of the mean rice yield—they are robust to the inclusion of commune-year fixed effects as well as the number of cumulative rice seasons grown by the household. As land-use restrictions specify land used for rice as well as rice seasons, if controlling for these non-predetermined household outcomes absorbs the estimated effect of restrictions, then it's less likely my results are driven by unobservables.[8] In columns 3 and 6, the addition of household rice seasons only shrinks the magnitude of the coefficient for restriction but does not totally absorb the effect. From the model, however, a persistent positive effect of restrictions on rice yields is expected if there is a divergence of interest. In this case, the commune restricts land that's highly suitable for rice that the household would rather plant with non-rice, which leaves the household with higher rice yields under restrictions.

The dependent variable of Table 3.12 is the log of rice output from all household rice production measured in tons. In addition to the restriction indicator, I also introduce a measure of the share of households' land under restriction, measured in standard deviations

---

[8] If my results are driven by unobservable shocks that affect both restriction decisions and household production, then I might see residual effects of restrictions on household and plot outcomes even after controlling for the amount of land/seasons planted with rice.

of restricted households. The discrete change from unrestricted to restricted is not significantly correlated with logged rice production. However, a 1 SD increase in the share of restricted land increases rice production by 3 percent—which is, again, statistically but not economically significant. The inclusion of rice seasons and rice area—which are not predetermined with respect to restriction status—absorbs the magnitude and significance of this effect in column 3, suggesting that way restrictions affect household rice production is entirely through changes in the amount of rice planted, as expected. With commune-specific year dummies in columns 3-6, the estimated effect of a 1 SD increase in the share of restricted land almost doubles and the effect of the restriction indicator remains insignificant. In contrast to column 3, a small positive effect of restricted share stays significant even with the addition of household production variables. Such a positive relationship could either indicate that households that experience higher than usual rice productivity in a given year are more likely to be restricted, or that households receive some beneficial treatment from the commune when restricted that is not captured by the household production variables. Yet the effect is still ultimately negligible at 1.8 percent, and in either case, we might expect for this positive shock or beneficial treatment to spill over to a household's other crops. Table 3.13, which performs a similar analysis for maize production, shows that this does not hold.

The remaining tables utilize the plot-level panel. With this finer unit of analysis, I can control for time-invariant, unobservable plot characteristics in addition to those of households. This analysis can also test the predictions of the model, which distinguishes between the effect of restrictions on restricted plots and the effect it may have on unrestricted plots. Tables 3.14 and 3.15 investigate the effect of restriction on the probability that rice is cultivated on a plot as well as number of seasons of rice. The first two columns of both tables include plot and year fixed effects, columns 3 and 4 include commune-specific year effects, and the last two columns control for household-specific quadratic time trends. These further controls assuage concerns about commune—and now household—level shocks as previously discussed. In contrast to the household results, at the plot level, a restriction indicator does significantly increase the probability of growing rice by 13-21 pp and increases cultivation by 0.25-0.38 seasons as seen in columns 1, 3 and 5 of Tables 3.14 and 3.15. These are relatively large effects at 17-28 percent and 18-28 percent of the average, respectively.

These effects seem incongruous with the lack of impact observed at the household level, until a control is added for whether any of the household's *other* plots face restriction, in columns 2, 4, and 6 of Tables 3.14 and 3.15.[9] This variable controls for plots that were not chosen for restriction by the commune, which, as we saw in the model of household behavior, can still affect production on such plots. While plots still grow rice more often and more seasons of it when restricted, these gains are lower when the household has other plots that are restricted, and if the plot is unrestricted while other household plots are restricted, the effect is negative. For example, a household's only restricted plot will be 28 pp more likely to grow rice and grow 0.5 more seasons if there are no other plots restricted,[10] and an

---

[9] Though only a subset of a household's plots are included in the panel due to matching difficulties and gaining/losing plots over time, this variable is constructed at the household level: if a household has other restricted plots in a given year, this variable will equal 1 even if those plots are not a part of the panel of plots.

[10] If other plots are restricted, this increase is reduced to 8 pp more likely to grow rice, and 0.18 more seasons of rice.

unrestricted plot of a household who faces restriction will be 20 pp less likely to grow rice and grow 0.37 fewer seasons. If this pattern is driven by the fact that households are targeted for restrictions precisely when they reduce rice production on their land, then the variety of controls for temporal shocks across the columns should alter the results. Instead, they are both statistically significant and stable across these controls. These results are consistent with a divergence of interest between the farmer and commune concerning where rice should be planted and with binding subsistence constraints for households, as demonstrated by the model.

Additional support is given by Tables 3.16 and 3.17, which reveals a complementary pattern for maize production decisions. Plots that face restriction are less likely to grow maize and grow fewer seasons, but are more likely to grow maize and grow more seasons if they are unrestricted plots of a household facing restrictions on other plots. These effects are admittedly small in magnitude—a restriction decreases the probability of growing maize by 11 percent and maize seasons by about 0.18 seasons—but are very large relative to the mean. As the case with rice, they are also robust to various controls for temporal shocks and trends at the commune and household levels. Taken together, Tables 3.14-3.17 suggest that households shift production across plots in order to comply with restrictions in a way that results in little change in rice cultivation at the level of the household.

Tables 3.19 and 3.18 show the corresponding effects on rice output measured in tons and yields measured in tons per hectare. As in earlier tables, the first two columns utilize plot and year fixed effects, and the remaining columns add more detailed temporal controls. Again, the effects of restriction and the restriction of other household plots is remarkably stable across columns 1, 3 and 5: a restricted plot produces 0.17 tons more rice and an unrestricted plot in a restricted household produces 0.14-0.17 fewer tons. If these effects are due to compliance with restrictions and a shift in cultivation across households as described before, adding controls for growing rice and number of rice seasons should eliminate the effect of restrictions. Columns 2, 4, and 6 show that this is the case.

Table 3.19 instead examines rice yields. When the restriction status of other household plots is not included, restriction of a plot increases its yield by about 0.8 tons per ha, an effect that's erased when growing rice and rice seasons are controlled for. As shown by column 3, this effect rises to 2.3 tons per ha (35 percent of the average yield) when other household plots are not restricted, and rice yields on unrestricted plots of restricted households fall by 1.9 tons per ha. However, that negative effect is not absorbed by controls for rice growing and rice seasons. This could either indicate that households otherwise reduce production on unrestricted plots or that commune authorities anticipate plot-level negative shocks to productivity when making restriction decisions so that plots left unrestricted have significantly worse rice yields. However, if this were the case, then we could expect to find a similarly persistent negative effect for other crops, such as maize. Plot-level maize production was not recorded in 2006, but Table 3.20 repeats this analysis for maize production for 2008-2012. There is no persistent negative effect of other restricted plots in the household after controlling for maize growing and maize seasons, as seen in column 4.

The empirical results discussed thus far suggest that there is a divergence of interest between the commune and farmers, such that a significant subset of restricted land would be more profitably planted with non-rice crops. Moreover, the reduction in rice production on unrestricted land suggests that households face binding subsistence constraints and the rice produced on restricted land releases a significant subset of unrestricted land from subsistence rice production. Because restrictions are effectively a distortion of households' land allocation across crops, they should also reduce household agricultural profits. In Table 3.21, I show that household agricultural profits fall by 450,000 2010-VND for every 1SD increase in the share of land restricted. This is a large effect, at 14 percent of the average level of agricultural profit. Table 3.22 decomposes this into rice profits and non-rice agricultural profit, to find the loss is due to a reduction in non-rice profit.

3.6 Conclusion

In Vietnam, a history of food insecurity and famines associated with both national and local rice shortages have lead to a preoccupation with rice production in agricultural policy. While all agricultural land use was once centrally planned and households were required to deliver quantities of rice to the commune for collective consumption, the latter policy was abandoned as a part of Vietnam's move toward a "socialist-oriented market economy." Land use planning, on the other hand, has persisted along with the importance of rice to the Vietnamese diet and economy.

I develop a model of crop choice that explains the patterns I observe at both the household and plot levels, depending on whether household and commune interests diverge and if the household faces a binding subsistence constraint. If household and commune interests converge, land that's restricted would've been planted with rice without any restrictions. If they diverge, the commune restricts land the household would more profitably plant with another crop. In the model, the correlation between rice yields and the relative profits of rice over a non-rice crop govern the degree of convergence. Clearly, if restrictions don't change crop choice on any household land, we shouldn't see any impacts of restriction on restricted or unrestricted land. The tightness of the household subsistence constraint determines whether changes in production on restricted land prompts adjustments in production on unrestricted land. If the constraint is binding, then the household grows rice where it would more profitably grow a non-rice crop in order to meet its subsistence constraint. Restrictions may effectively relax the subsistence constraint if they increase rice production on restricted land, which releases this land to the more profitable non-rice crop. When interests diverge and the subsistence constraint binds, then households may increase rice on restricted land, decrease rice on unrestricted land, and see only small effects of restriction at the household level due to the offsetting effect.

The question of how restriction affects household production is clearly an empirical question. Using household survey data from Vietnam between 2006-2012, I exploit variation in household- and plot-level restrictions to estimate how restrictions affect crop choice, cropping intensity, rice production, and agricultural profits. At the household level, restrictions marginally increase the probability that the household grows rice and the number of seasons grown. I find that restrictions have no effect on household rice production levels and a 1SD increase in restricted land share increases rice production by just 6 percent among intensive rice households. However, restrictions do increase households' rice yields. In the model, this could be expected if the subsistence constraint binds even after restrictions, which require the household to meet this production on the household's 'best' land for rice. However, the effect is still small: a 1SD increase in the restricted land share increases household rice yield by 0.45 tons per hectare, which is just 7 percent of the average yield. At the plot level, I see evidence of rice production being shifted across household land as a result of restrictions. Households grow 0.6 more seasons of rice on restricted plots, but grow 0.4 fewer seasons on unrestricted plots with a parallel pattern found for maize production.

Consequently, the aggregate effect of restrictions is to shift rice production across plots, but not significantly alter the amount of rice produced due to households' endogenous responses. With the plot level estimates, I can construct counterfactual rice production in the absence of the 'slippage' on unrestricted land and find that this behavioral response reduces household rice by about 0.4 tons on average, which is about 12 percent of the average household's output. Since the household-level effect was estimated to be zero, this suggests that in the absence of 'slippage,' restrictions would have increased rice production by 12 percent for the average household. As is expected, I estimate that this distortion from household's optimal land allocation reduces agricultural profits by about 15 percent—a cost which does not seem to be justified by increased food security. Note that this likely underestimates the full cost of the restrictions, as it does not include the cost of actions taken by households in anticipation of restrictions. Just as households must re-optimize once land restrictions have been imposed on their land, they must re-optimize as well to the risk of facing restriction.

3.7 Tables and Figures

Figure 3.1: Provinces included in VARHS data.

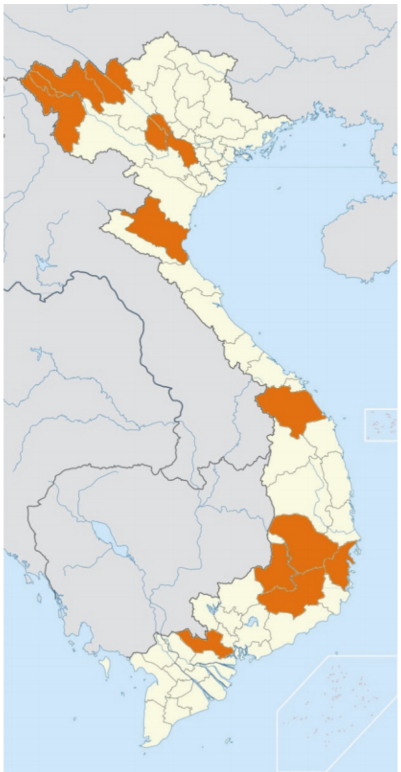


Figure 3.2: Coefficient of variation of commune-level rice production and proportion of land under restriction.

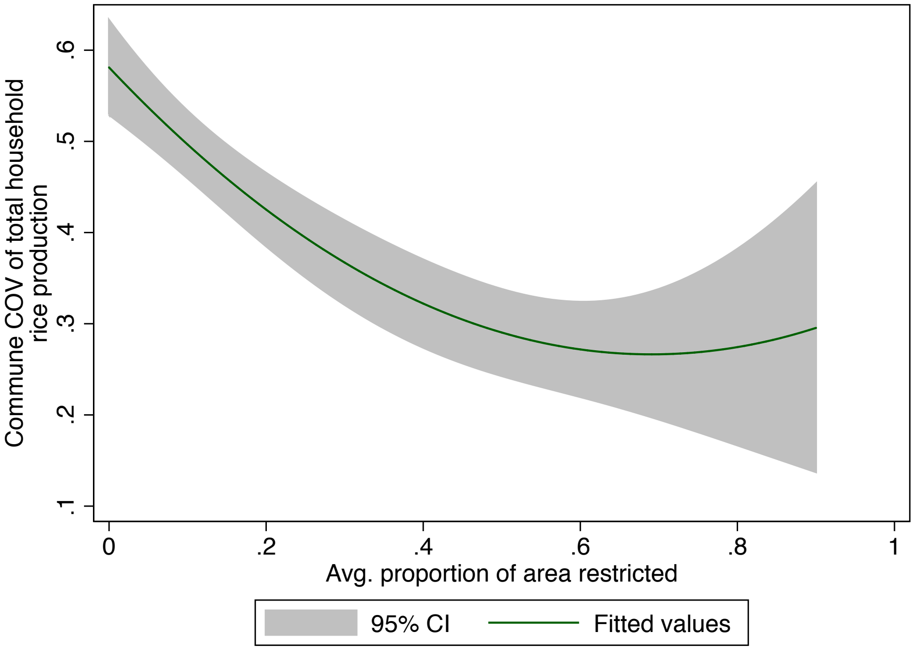


Table 3.1: Household and district summary statistics by year.

	2006	2008	2010	2012	Total
Household					
Household size	4.585	4.558	4.317***	4.236	4.424
	(1.725)	(1.748)	(1.714)	(1.789)	(1.750)
Male head	0.808	0.791	0.789	0.782	0.792
	(0.394)	(0.407)	(0.408)	(0.413)	(0.406)
Head, years of educ.	.	7.854	7.943	7.984	7.927
	(.)	(3.323)	(3.308)	(3.289)	(3.307)
Total area used by household (ha)	0.745	0.740	0.723	0.729	0.734
	(1.201)	(1.176)	(1.192)	(1.228)	(1.199)
Size of used plot (ha)	0.169	0.169	0.171	0.174	0.171
	(0.278)	(0.282)	(0.306)	(0.307)	(0.294)
Number of owned plots	4.881	4.764	4.452***	4.321	4.605
	(3.248)	(3.092)	(2.996)	(2.844)	(3.056)
Number of plots rented in	0.339	0.392***	0.318**	0.298	0.337
	(0.885)	(1.019)	(0.881)	(0.835)	(0.908)
Number of plots rented out	0.259	0.317***	0.403**	0.458	0.359
	(1.048)	(1.129)	(1.238)	(1.386)	(1.209)
Number of plots lost/sold	0.313	0.375***	0.326	0.213***	0.307
	(0.986)	(1.384)	(1.082)	(0.781)	(1.082)
Share of land irrigated	0.583	0.575	0.616***	0.623	0.599
	(0.365)	(0.373)	(0.381)	(0.374)	(0.374)
Share of land with rice	0.465	0.453	0.433*	0.423	0.444
	(0.348)	(0.353)	(0.363)	(0.365)	(0.357)
Rice grown	0.774	0.749*	0.709	0.690	0.731
	(0.418)	(0.433)	(0.454)	(0.463)	(0.444)
Non-rice annual grown	0.658	0.527***	0.613***	0.590	0.597
	(0.475)	(0.499)	(0.487)	(0.492)	(0.491)
Perrenial grown	0.283	0.403***	0.406	0.332***	0.356
	(0.450)	(0.491)	(0.491)	(0.471)	(0.479)
District					
Price of rice (2010 1000VND/KG)	1.683	3.831***	5.335***	7.935***	4.675
	(0.295)	(0.828)	(2.160)	(1.525)	(2.659)
Price of maize (2010 1000VND/KG)	1.446	2.960***	4.603***	7.156***	3.990
	(0.301)	(0.990)	(1.424)	(1.285)	(2.371)

Standard errors in parentheses. Stars indicate statistical significant differences compared to previous year.

Table 3.2: Plot summary statistics by year.

	2006	2008	2010	2012	Total
Plot					
Irrigated	0.737	0.732	0.789***	0.821***	0.770
	(0.440)	(0.443)	(0.408)	(0.383)	(0.421)
Manager is head	0	0.553***	0.497***	0.508	0.390
	(0)	(0.497)	(0.500)	(0.500)	(0.488)
Restr. to grow rice in all seasons	0.200	0.230***	0.0965***	0.320***	0.212
	(0.400)	(0.421)	(0.295)	(0.467)	(0.408)
Restr. to grow rice in some seasons	0.349	0.238***	0.245	0.235	0.267
	(0.477)	(0.426)	(0.430)	(0.424)	(0.442)
Restricted to grow other crop	0.0377	0.0269***	0.0156***	0.0242***	0.0261
	(0.190)	(0.162)	(0.124)	(0.154)	(0.159)
Construction permitted	0.125	0.125	0.101***	0.209***	0.140
	(0.331)	(0.331)	(0.301)	(0.407)	(0.347)
Conversion permitted	0.120	0.122	0.108*	0.216***	0.142
	(0.325)	(0.327)	(0.311)	(0.412)	(0.349)
Rice seasons	1.342	1.351	1.374	1.383	1.362
	(0.873)	(0.874)	(0.874)	(0.876)	(0.874)
Rice yield if >0 (tons/ha)	8.109	8.289**	8.134**	8.861***	8.349
	(3.634)	(3.323)	(3.024)	(3.385)	(3.362)
Maize seasons	0.172	0.181	0.166	0.155	0.168
	(0.466)	(0.464)	(0.470)	(0.464)	(0.466)
Maize yield if >0 (tons/ha)	.	4.012	4.174	4.200	4.118
	(.)	(2.255)	(2.419)	(2.328)	(2.329)

Standard errors in parentheses. Stars indicate statistical significant differences compared to previous year.

Table 3.3: Household summary statistics by restriction status.

	Never-restricted	Restricted
Household		
Household size	4.360	4.445*
	(1.773)	(1.742)
Male head	0.750	0.806***
	(0.433)	(0.395)
Head, years of educ.	8.140	7.859***
	(3.519)	(3.233)
Total area used by household	0.943	0.667***
	(1.390)	(1.123)
Total area used per capita	0.223	0.153***
	(0.353)	(0.273)
Number of plots	3.107	6.007***
	(2.286)	(3.120)
Number of restricted plots	0	2.675***
	(0)	(3.147)
Rice yield if >0 (tons/ha)	6.799	8.535***
	(3.276)	(2.469)
Maize yield if >0 (tons/ha)	4.368	4.848*
	(3.285)	(2.840)

Standard errors in parentheses. Stars indicate statistically significant differences between columns.

Table 3.4: Plot summary statistics by restriction status.

	Never-restricted	Restricted
Plot		
Size (ha)	0.376	0.102***
	(0.596)	(0.295)
Irrigated	0.482	0.865***
	(0.500)	(0.342)
Canal irrigation	0.146	0.743***
	(0.353)	(0.437)
Flat	0.413	0.772***
	(0.492)	(0.419)
Male manager	0.696	0.471***
	(0.460)	(0.499)
Redbook	0.632	0.825***
	(0.482)	(0.380)
Construction permitted	0.452	0.0511***
	(0.498)	(0.220)
Conversion permitted	0.438	0.0584***
	(0.496)	(0.235)
Grows rice	0.312	0.881***
	(0.463)	(0.324)
Grows maize	0.213	0.106***
	(0.410)	(0.308)
Grows other annual	0.214	0.143***
	(0.410)	(0.350)
Grows perennial	0.310	0.0236***
	(0.463)	(0.152)
Rice yield if >0 (tons/ha)	5.539	8.577***
	(3.446)	(2.409)
Maize yield if >0 (tons/ha)	3.474	4.424***
	(2.052)	(2.110)

Standard errors in parentheses. Stars indicate statistically significant differences between columns.

Table 3.5: Predicting restriction status with the Wooldridge method.

	Restricted	Restricted	Restricted	Restricted
Plot restricted$_{t-1}$	0.204***	0.194***	0.152**	0.130*
	(0.0661)	(0.0680)	(0.0693)	(0.0700)
	[0.0547]	[0.0492]	[0.0390]	[0.0331]
Irrigated		0.452***	0.481***	0.495***
		(0.0986)	(0.0994)	(0.0983)
		[0.1167]	[0.1274]	[0.1301]
Redbook		0.460***	0.461***	0.472***
		(0.126)	(0.128)	(0.129)
		[0.1160]	[0.1187]	[0.1208]
Other Crops$_{t-1}$		0.176	0.159	0.154
		(0.123)	(0.125)	(0.126)
		[0.0426]	[0.0396]	[0.0380]
Plot RiceYield$_{t-1}$ (tons per ha)		-0.00288	-0.00361	-0.00327
		(0.00546)	(0.00515)	(0.00501)
		[-0.0012]	[-0.0016]	[-0.0015]
District rice price (log)		0.257	0.262	0.284
		(0.310)	(0.314)	(0.318)
		[0.1104]	[0.1185]	[0.1278]
Natural disaster shock, plot		0.00473	-0.0357	-0.0345
		(0.0674)	(0.0818)	(0.0822)
		[0.0012]	[-0.009]	[-0.0086]
Natural disaster shock, HH			-0.0880	-0.0753
			(0.0860)	(0.0869)
			[-0.0223]	[-0.0189]
HH labor supply			0.0172	0.0167
			(0.0646)	(0.0644)
			[0.0078]	[0.0075]
HH RiceYield$_{t-1}$			0.00329	0.00314
			(0.00565)	(0.00580)
			[0.0015]	[0.0014]
Area used by HH (log)			-0.0329	-0.0171
			(0.149)	(0.149)
			[-0.0149]	[-0.0077]
HH relative/member is gov. official				-0.263**
				(0.105)
				[-0.0665]
Year=2010	-0.503***	-0.594***	-0.617***	-0.617***
	(0.0740)	(0.110)	(0.112)	(0.113)
Year=2012	0.432***	0.247*	0.222	0.183
	(0.0679)	(0.145)	(0.146)	(0.148)
Observations	11452	11335	11071	11071
Mean DV	0.513	0.514	0.523	0.523
Sample	All	All	All	All

SEs in parentheses, APEs in brackets. Standard errors clustered at the household level. Controls for initial condition and each independent variable at each period included as specified in Wooldridge (2005). Flexible controls for plot area, slope, distance from home, household size, way of acquiring the plot, and household head's gender, age, and education level are included but not shown.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.6: Predicting restriction status with the Arellano-Bond method.

	Restricted	Restricted	Restricted	Restricted
Plot Restricted$_{t-1}$	0.0181	0.0241	0.0333**	0.0320**
	(0.0150)	(0.0153)	(0.0159)	(0.0159)
Irrigated		0.134***	0.141***	0.142***
		(0.0155)	(0.0165)	(0.0164)
Redbook		0.124***	0.128***	0.131***
		(0.0199)	(0.0209)	(0.0209)
Other Crops$_{t-1}$		0.0887***	0.0886***	0.0885***
		(0.0182)	(0.0207)	(0.0207)
Plot RiceYield$_{t-1}$ (tons per ha)		-0.00139	-0.00195	-0.00175
		(0.00115)	(0.00122)	(0.00122)
District rice price (log)		0.120***	0.139***	0.141***
		(0.0304)	(0.0359)	(0.0359)
Natural disaster shock, plot		-0.0334***	-0.0337**	-0.0344**
		(0.0108)	(0.0135)	(0.0135)
Natural disaster shock, HH			-0.00833	-0.00706
			(0.0116)	(0.0116)
HH labor supply			-0.0103	-0.0122
			(0.00778)	(0.00780)
HH RiceYield$_{t-1}$			0.00239	0.00247
			(0.00153)	(0.00158)
Area used by HH (log)			-0.0121	-0.00743
			(0.0227)	(0.0225)
HH relative/member is gov. official				-0.0668***
				(0.0136)
Year=2010	-0.105***	-0.138***	-0.156***	-0.154***
	(0.00793)	(0.0114)	(0.0131)	(0.0131)
Year=2012	0.0892***	0.0338**	0.0253	0.0188
	(0.00798)	(0.0148)	(0.0174)	(0.0173)
Observations	9414	9294	8711	8711
A-B AR(1)	-27.81	-26.79	-26.75	-26.76
Sargan	82.91	76.04	58.42	60.27
Hansen	85.96	80.41	62.22	64.12
Mean DV	0.438	0.441	0.467	0.467
Plot, Year	Yes	Yes	Yes	Yes
Sample	All	All	All	All

Standard errors in parentheses. Standard errors clustered at the plot level. GMM style instruments for lagged restriction status, two-step estimation of standard errors with the finite sample Windmeijer correction.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.7: Predicting restriction status with the Arellano-Bond method, robustness checks.

	Restricted	Restricted	Restricted	Restricted
Plot Restricted$_{t-1}$	0.0342**	0.0190	0.0140	0.0193
	(0.0165)	(0.0302)	(0.0297)	(0.0344)
Irrigated	0.135***	0.146***	0.137***	0.140***
	(0.0176)	(0.0272)	(0.0265)	(0.0301)
Redbook	0.141***	0.0768	0.112*	0.137*
	(0.0220)	(0.0561)	(0.0581)	(0.0757)
Other Crops$_{t-1}$	0.0886***	0.0474	0.0769**	0.0934**
	(0.0231)	(0.0377)	(0.0383)	(0.0440)
Plot RiceYield$_{t-1}$ (tons per ha)	-0.00172	-0.00269	-0.00239	-0.00216
	(0.00126)	(0.00168)	(0.00182)	(0.00221)
District rice price (log)	0.151***	0.174**	0.155**	0.210**
	(0.0383)	(0.0686)	(0.0685)	(0.106)
Natural disaster shock, plot	-0.0329**	-0.0353	-0.0283	-0.0315
	(0.0139)	(0.0246)	(0.0230)	(0.0303)
HH labor supply	-0.0159*	-0.00409	-0.0123	0.00231
	(0.00825)	(0.0180)	(0.0171)	(0.0181)
HH RiceYield$_{t-1}$	0.00260	0.00181	0.00362	0.00230
	(0.00178)	(0.00389)	(0.00321)	(0.00321)
Area used by HH (log)	-0.00508	-0.00148	-0.00785	-0.0343
	(0.0235)	(0.0418)	(0.0409)	(0.0412)
Natural disaster shock, HH	-0.00383	-0.00829	-0.00209	-0.00632
	(0.0122)	(0.0256)	(0.0239)	(0.0336)
HH relative/member is gov. official	-0.0692***	-0.0695**	-0.0748***	-0.0552
	(0.0142)	(0.0282)	(0.0282)	(0.0369)
Year=2010	-0.164***	-0.154***	-0.163***	-0.167***
	(0.0137)	(0.0245)	(0.0250)	(0.0351)
Year=2012	0.0131	0.00593	0.00282	-0.00629
	(0.0185)	(0.0327)	(0.0327)	(0.0468)
Observations	8200	8200	8200	8200
A-B AR(1)	-26.33	-16.87	-17.64	-15.20
Hansen-P	1.91e-12	0.0000727	0.00955	0.177
# Instruments	16	26	20	20
Mean DV	0.483	0.483	0.483	0.483
Plot, Year	Yes	Yes	Yes	Yes
Instr. collapsed	No	No	Yes	Yes
Cluster	HH	HH	HH	COM

Standard errors in parentheses. Standard errors clustered at the plot level. GMM style instruments for redbook and lagged restriction status, other crops, plot yield and household yield. Two-step estimation of standard errors with the finite sample Windmeijer correction.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure 3.3: Yield of rice-growing plots by restriction status.

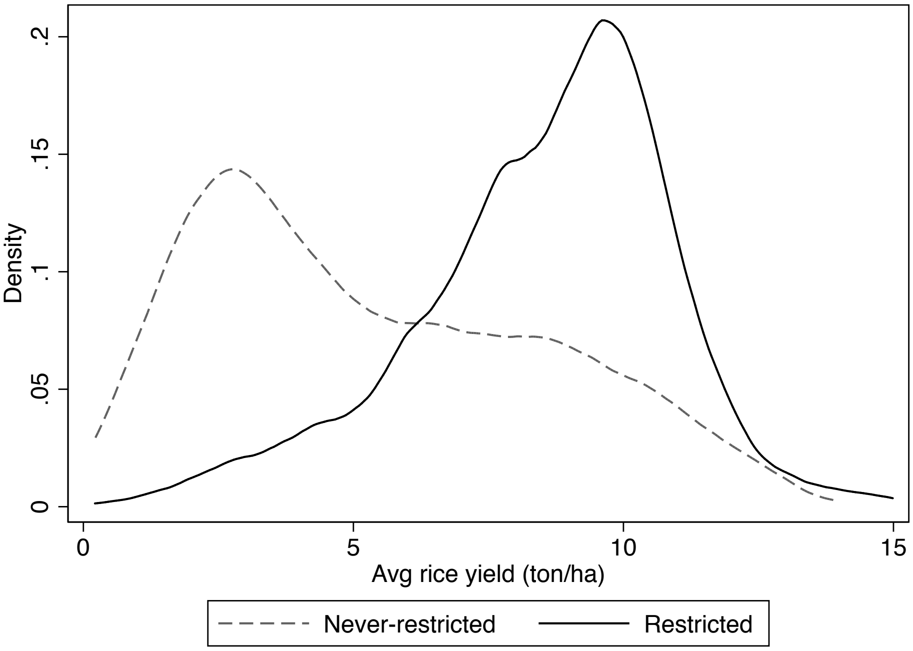


Figure 3.4: Yield of maize-growing plots by restriction status.

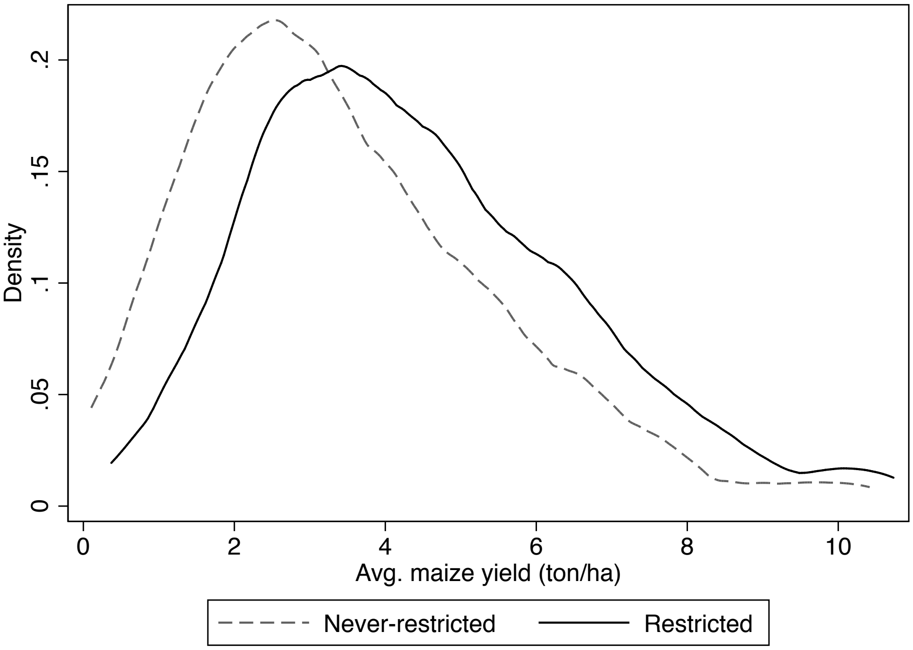


Figure 3.5: Total land restricted at the household and commune levels by year.

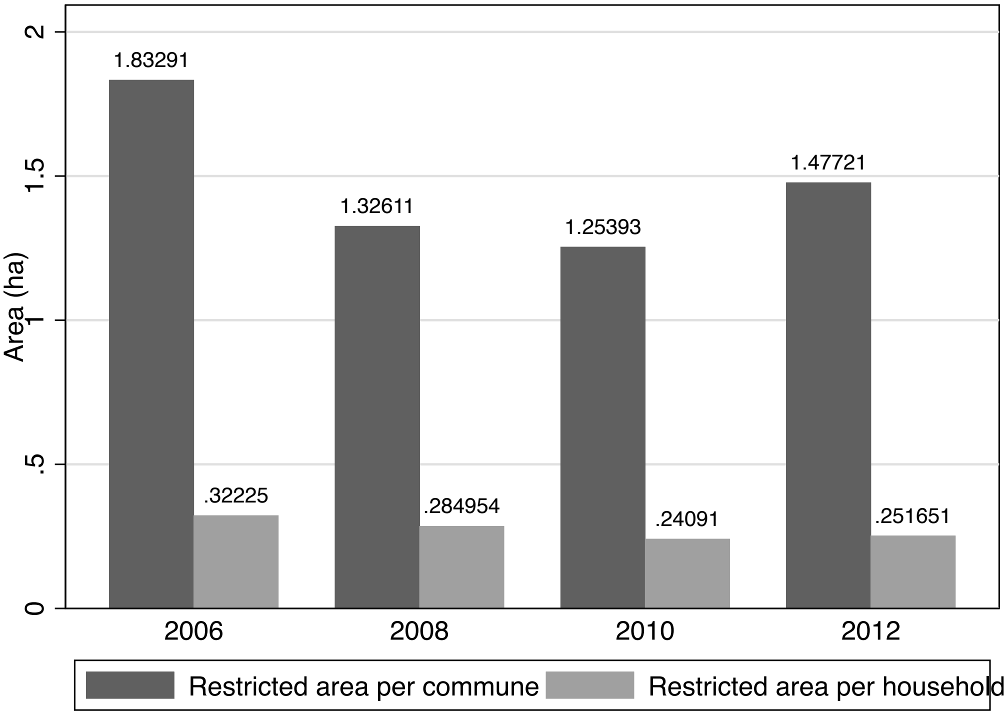


Figure 3.6: Compliance with plot restrictions.

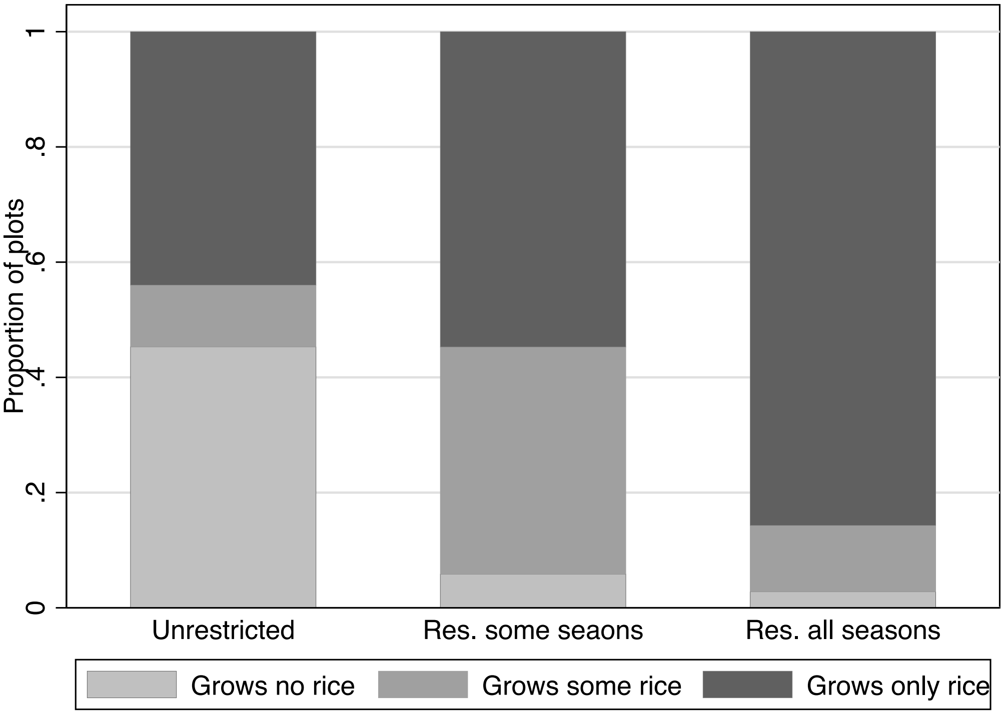


Table 3.8: Changes in restrictions and previous rice cultivation.

Rice_{t-1}	All→None	All→Some	Some→None	None→Some	Some→All	None→All
None	3.25	3.50	4.03	16.50	2.21	14.32
Some seasons	11.53	12.94	37.85	20.00	39.50	16.87
All seasons	85.22	83.56	58.12	63.50	58.29	68.81
N	893	371	1,041	1,000	362	901

Table 3.9: Land restriction and the extensive margins of household rice production.

	Rice=1	RiceSeasons	RiceHa.	ln(RiceHa.)	Rice=1	RiceSeasons	RiceHa.	ln(RiceHa.)
HH Restricted	0.0543***	0.215**	-0.0159	-0.0186	0.0826***	0.252**	-0.0347**	0.00143
	(0.00873)	(0.0989)	(0.00996)	(0.0140)	(0.0117)	(0.119)	(0.0154)	(0.0186)
Total used land, ha. (log)	0.189***	1.785***	0.143***	0.683***	0.184***	1.666***	0.136***	0.699***
	(0.0139)	(0.178)	(0.0206)	(0.0459)	(0.0144)	(0.176)	(0.0214)	(0.0472)
Irrigated land share (std)	0.0419***	0.455***	0.0336***	0.128***	0.0453***	0.398***	0.0369***	0.158***
	(0.00744)	(0.0806)	(0.00656)	(0.0168)	(0.00642)	(0.0730)	(0.00832)	(0.0183)
Redbook land share (std)	0.00332	0.0551	-0.00273	0.00621	0.00643	0.0539	0.00238	0.00488
	(0.00480)	(0.0696)	(0.00557)	(0.0117)	(0.00530)	(0.0507)	(0.00569)	(0.0128)
HH size	0.00594	0.280***	0.00774	0.0238***	0.00528	0.284***	0.00688	0.0261***
	(0.00405)	(0.0556)	(0.00545)	(0.00783)	(0.00417)	(0.0613)	(0.00554)	(0.00876)
Male household head	-0.0181	-0.161	0.00884	0.0164	-0.0141	-0.0528	0.0101	-0.0152
	(0.0226)	(0.268)	(0.0197)	(0.0338)	(0.0228)	(0.258)	(0.0216)	(0.0419)
Natural disaster	0.0211***	0.126	-0.00503	0.00414	0.0180**	0.163	0.0137	0.0265
	(0.00643)	(0.0809)	(0.00986)	(0.0131)	(0.00842)	(0.102)	(0.0128)	(0.0169)
Rice price (log)	-0.00794	-0.317	-0.0852	-0.113				
	(0.0280)	(0.311)	(0.0633)	(0.0887)				
Observations	7960	7960	7960	5152	8032	8032	8032	4808
Mean DV	0.747	5.235	0.303	-1.431	0.734	5.147	0.298	-1.421
HH, Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Commune-Year FE	No	No	No	No	Yes	Yes	Yes	Yes
Sample	All	All	All	AlwaysRice	All	All	All	AlwaysRice

Standard errors in parentheses. Standard errors clustered at the commune level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.10: Land restriction and the extensive margins of household maize production.

	Maize=1	MaizeSeasons	MaizeHa.	Maize=1	MaizeSeasons	MaizeHa.
HH Restricted	-0.0133	0.0338	0.00426	-0.0305**	0.0126	-0.00128
	(0.0142)	(0.0618)	(0.00728)	(0.0135)	(0.0589)	(0.00598)
Total used land, ha. (log)	-0.0238	0.224***	0.0353***	-0.0458***	0.136***	0.0234***
	(0.0178)	(0.0446)	(0.00725)	(0.0123)	(0.0337)	(0.00565)
Irrigated land share (std)	-0.0670***	-0.0814***	-0.0145**	-0.0672***	-0.0474**	-0.0141**
	(0.00984)	(0.0259)	(0.00572)	(0.00939)	(0.0210)	(0.00559)
Redbook land share (std)	-0.0193**	-0.0309	-0.00213	-0.0131	0.00744	0.000429
	(0.00927)	(0.0325)	(0.00518)	(0.00839)	(0.0137)	(0.00355)
HH size	0.0179***	0.0881***	0.00756***	0.0112*	0.0483***	0.00538**
	(0.00654)	(0.0214)	(0.00275)	(0.00573)	(0.0168)	(0.00209)
Male household head	0.0225	-0.123	-0.0153	0.00418	-0.149	-0.00752
	(0.0439)	(0.173)	(0.0114)	(0.0377)	(0.102)	(0.00817)
Natural disaster	-0.0103	0.0343	-0.00706	-0.0247	-0.0137	-0.00528
	(0.0139)	(0.0492)	(0.00833)	(0.0159)	(0.0606)	(0.00653)
Maize price (log)	-0.0201	0.0429	-0.00781			
	(0.0475)	(0.135)	(0.0119)			
Observations	5940	5940	5940	8032	8032	8032
Mean DV	0.438	0.886	0.0951	0.354	0.663	0.0706
Plot, Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Commune-Year FE	No	No	No	Yes	Yes	Yes
Sample	All	All	All	All	All	All

Standard errors in parentheses. Standard errors clustered at the commune level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.11: Household land restriction and rice production and yield.

	RiceProd	RiceYield	RiceYield	RiceProd	RiceYield	RiceYield
Restricted land share (in Std.Dev.)	-0.103	0.376***	0.287***	-0.0911	0.541***	0.447***
	(0.0906)	(0.0677)	(0.0658)	(0.101)	(0.0786)	(0.0745)
Irrig. land share (std)	0.264***	0.459***	0.358***	0.249***	0.373***	0.298***
	(0.0568)	(0.0907)	(0.0777)	(0.0628)	(0.0725)	(0.0669)
Redbook land share (std)	-0.00387	0.0177	0.00606	0.00488	-0.0566	-0.0621
	(0.0373)	(0.0638)	(0.0601)	(0.0341)	(0.0678)	(0.0665)
Total used land (log)	0.996***	1.378***	0.963***	0.988***	1.381***	1.036***
	(0.195)	(0.141)	(0.123)	(0.210)	(0.135)	(0.127)
HH size	0.108**	0.115**	0.0450	0.102***	0.0706	0.00867
	(0.0504)	(0.0534)	(0.0510)	(0.0343)	(0.0549)	(0.0522)
Male household head	-0.0325	-0.346	-0.296	-0.120	-0.344	-0.328
	(0.125)	(0.261)	(0.255)	(0.174)	(0.277)	(0.274)
Natural disaster	-0.122	-0.350***	-0.377***	-0.0386	-0.271**	-0.305**
	(0.0769)	(0.108)	(0.108)	(0.109)	(0.134)	(0.134)
Price of rice (log)	-0.617	-0.0924	-0.00891			
	(0.674)	(0.427)	(0.404)			
# Rice Seasons			0.240***			0.213***
			(0.0332)			(0.0297)
Observations	7652	7652	7652	7696	7696	7696
Mean DV	2.290	6.164	6.164	2.252	6.046	6.046
HH, Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Commune-Year FE	No	No	No	Yes	Yes	Yes
Sample	All	All	All	All	All	All

Standard errors in parentheses. Standard errors clustered at the commune level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.12: Household land restriction and logged rice production.

	ln(Output)	ln(Output)	ln(Output)	ln(Output)	ln(Output)	ln(Output)
HH Restricted	-0.0124			0.0233		
	(0.0186)			(0.0219)		
Restricted land share (in Std.Dev.)		0.0313***	0.00139		0.0596***	0.0184**
		(0.00879)	(0.00756)		(0.0102)	(0.00861)
Total used land (log)	0.559***	0.562***	0.115***	0.601***	0.606***	0.131***
	(0.0437)	(0.0433)	(0.0310)	(0.0484)	(0.0468)	(0.0364)
Irrig. land share (std)	0.154***	0.150***	0.0689***	0.134***	0.126***	0.0252**
	(0.0164)	(0.0161)	(0.0134)	(0.0149)	(0.0144)	(0.0122)
Redbook land share (std)	0.0158	0.0133	0.00730	-0.00406	-0.00706	-0.00892
	(0.0110)	(0.0111)	(0.00895)	(0.0131)	(0.0129)	(0.0104)
HH size	0.0461***	0.0465***	0.0241***	0.0395***	0.0390***	0.0175***
	(0.00814)	(0.00813)	(0.00621)	(0.00803)	(0.00790)	(0.00580)
Male household head	0.0155	0.0110	0.00941	-0.0189	-0.0279	0.00226
	(0.0435)	(0.0425)	(0.0360)	(0.0448)	(0.0430)	(0.0345)
Natural disaster	-0.0797***	-0.0793***	-0.0825***	-0.0511***	-0.0503***	-0.0602***
	(0.0160)	(0.0160)	(0.0144)	(0.0173)	(0.0174)	(0.0145)
Price of rice (log)	-0.0235	-0.0324	0.0100			
	(0.0802)	(0.0817)	(0.0704)			
# Rice Seasons			0.0387***			0.0359***
			(0.00414)			(0.00412)
Rice area (log)			0.485***			0.499***
			(0.0387)			(0.0480)
Observations	4920	4920	4920	4548	4548	4548
Mean DV	0.587	0.587	0.587	0.595	0.595	0.595
HH, Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Commune-Year FE	No	No	No	Yes	Yes	Yes
Sample	AlwaysRice	AlwaysRice	AlwaysRice	AlwaysRice	AlwaysRice	AlwaysRice

Standard errors in parentheses. Standard errors clustered at the commune level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.13: Household land restriction and maize production.

	MaizeOutput	MaizeOutput	MaizeOutput	MaizeOutput	MaizeOutput	MaizeOutput
HH Restricted	0.0118			-0.0229		
	(0.0341)			(0.0240)		
Restricted land share (in Std.Dev.)		-0.00639	-0.000453		-0.0167*	-0.00746
		(0.0124)	(0.00972)		(0.00970)	(0.00715)
HH size	0.0205*	0.0203*	-0.00489	0.0207**	0.0208**	0.00446
	(0.0121)	(0.0121)	(0.0105)	(0.00848)	(0.00850)	(0.00748)
Irrigated land share (std)	-0.0359*	-0.0352*	-0.00355	-0.0450**	-0.0430**	-0.0127
	(0.0206)	(0.0203)	(0.0165)	(0.0194)	(0.0190)	(0.0129)
Redbook land share (std)	-0.00629	-0.00551	0.00166	0.0160	0.0164	0.0151
	(0.0238)	(0.0239)	(0.0179)	(0.0181)	(0.0182)	(0.0149)
Total used land, ha. (log)	0.148***	0.149***	0.0276	0.106***	0.108***	0.0329*
	(0.0334)	(0.0337)	(0.0232)	(0.0286)	(0.0288)	(0.0185)
Natural disaster=1	-0.0358	-0.0360	-0.0301	0.00809	0.00823	0.0191
	(0.0371)	(0.0370)	(0.0310)	(0.0299)	(0.0298)	(0.0228)
Maize price (log)	0.00159	0.00313	0.00889			
	(0.0849)	(0.0848)	(0.0741)			
MaizeSeasons			0.120***			0.106***
			(0.0242)			(0.0206)
Maize area			1.709***			1.804***
			(0.375)			(0.357)
Observations	5488	5488	5488	7300	7300	7300
Mean DV	0.413	0.413	0.413	0.312	0.312	0.312
Plot, Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Commune-Year FE	No	No	No	Yes	Yes	Yes
Sample	All	All	All	All	All	All

Standard errors in parentheses. Standard errors clustered at the commune level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.14: Plot restrictions and household decision to grow rice.

	Rice=1	Rice=1	Rice=1	Rice=1	Rice=1	Rice=1
Plot Restricted	0.129***	0.283***	0.192***	0.301***	0.207***	0.304***
	(0.0135)	(0.0188)	(0.0166)	(0.0191)	(0.0202)	(0.0219)
Other HH plot restricted		-0.204***		-0.193***		-0.202***
		(0.0151)		(0.0156)		(0.0186)
Irrigated	0.250***	0.221***	0.280***	0.254***	0.305***	0.276***
	(0.0227)	(0.0225)	(0.0239)	(0.0235)	(0.0261)	(0.0273)
Redbook	0.0188	0.0194*	0.0308*	0.0263	0.0274	0.0345
	(0.0118)	(0.0113)	(0.0157)	(0.0160)	(0.0214)	(0.0212)
Household size	0.00391	0.00326	0.00277	0.00260	0.00511	0.00269
	(0.00284)	(0.00290)	(0.00364)	(0.00351)	(0.00700)	(0.00610)
Male household head	-0.0306	-0.0295	-0.00881	-0.00756	-0.0256	-0.0188
	(0.0239)	(0.0263)	(0.0234)	(0.0283)	(0.0569)	(0.0563)
Natural disaster, HH	0.00273	0.000185	0.0159*	0.0116	0.00160	0.00431
	(0.00639)	(0.00667)	(0.00867)	(0.00867)	(0.0101)	(0.0114)
Rice price (log)	-0.0514*	-0.0504*				
	(0.0308)	(0.0290)				
Observations	18032	18032	18024	18024	18160	18160
Mean DV	0.746	0.746	0.742	0.742	0.740	0.740
Plot, Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Commune-Year FE	No	No	Yes	Yes	No	No
HH quadratic trend	No	No	No	No	Yes	Yes
Sample	All	All	All	All	All	All

Standard errors in parentheses. Standard errors clustered at the commune level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.15: Plot restrictions and number of rice seasons grown.

	RiceSeasons	RiceSeasons	RiceSeasons	RiceSeasons	RiceSeasons	RiceSeasons
Plot Restricted	0.254***	0.535***	0.364***	0.568***	0.374***	0.570***
	(0.0260)	(0.0341)	(0.0311)	(0.0356)	(0.0401)	(0.0425)
Other HH plot restricted		-0.371***		-0.362***		-0.413***
		(0.0279)		(0.0300)		(0.0365)
Irrigated	0.517***	0.464***	0.551***	0.502***	0.594***	0.536***
	(0.0423)	(0.0414)	(0.0421)	(0.0408)	(0.0442)	(0.0463)
Redbook	0.0256	0.0267	0.0295	0.0211	0.0126	0.0271
	(0.0202)	(0.0200)	(0.0247)	(0.0252)	(0.0339)	(0.0327)
Household size	0.00567	0.00449	0.00215	0.00182	0.000843	-0.00411
	(0.00488)	(0.00484)	(0.00622)	(0.00585)	(0.0139)	(0.0125)
Male household head	-0.0504	-0.0485	-0.0166	-0.0143	-0.0119	0.00183
	(0.0484)	(0.0547)	(0.0454)	(0.0561)	(0.102)	(0.103)
Natural disaster, HH	0.00177	-0.00285	0.0170	0.00893	-0.00826	-0.00270
	(0.0132)	(0.0141)	(0.0197)	(0.0203)	(0.0218)	(0.0245)
Rice price (log)	-0.108	-0.106				
	(0.0677)	(0.0653)				
Observations	18032	18032	18024	18024	18160	18160
Mean DV	1.372	1.372	1.365	1.365	1.362	1.362
Plot, Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Commune-Year FE	No	No	Yes	Yes	No	No
HH quadratic trend	No	No	No	No	Yes	Yes
Sample	All	All	All	All	All	All

Standard errors in parentheses. Standard errors clustered at the commune level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.16: Plot restrictions and households' decision to grow maize.

	Maize=1	Maize=1	Maize=1	Maize=1	Maize=1	Maize=1
Plot Restricted	-0.0474***	-0.113***	-0.0591***	-0.102***	-0.0591***	-0.111***
	(0.0143)	(0.0202)	(0.0147)	(0.0192)	(0.0211)	(0.0244)
Other HH plot restricted		0.0889***		0.0757***		0.103***
		(0.0156)		(0.0134)		(0.0194)
Irrigated	-0.103***	-0.0903***	-0.109***	-0.0986***	-0.115***	-0.0995***
	(0.0166)	(0.0163)	(0.0156)	(0.0153)	(0.0183)	(0.0181)
Redbook	-0.00381	-0.00457	-0.00826	-0.00648	-0.0186	-0.0246
	(0.0123)	(0.0124)	(0.0131)	(0.0130)	(0.0159)	(0.0156)
Household size	0.00833	0.00875*	0.00280	0.00287	0.00670	0.00676
	(0.00506)	(0.00500)	(0.00417)	(0.00408)	(0.0105)	(0.0100)
Male household head	-0.0114	-0.0118	-0.0136	-0.0140	0.00740	0.00882
	(0.0490)	(0.0466)	(0.0321)	(0.0302)	(0.0487)	(0.0472)
Natural disaster, HH	-0.00504	-0.00437	-0.0179	-0.0162	-0.00567	-0.00875
	(0.0106)	(0.0109)	(0.0150)	(0.0151)	(0.0128)	(0.0132)
Maize price (log)	0.0183	0.0151				
	(0.0328)	(0.0331)				
Observations	14600	14600	18024	18024	18160	18160
Mean DV	0.163	0.163	0.133	0.133	0.133	0.133
Plot, Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Commune-Year FE	No	No	Yes	Yes	No	No
Household quadratic trend	No	No	No	No	Yes	Yes
Sample	All	All	All	All	All	All

Standard errors in parentheses. Standard errors clustered at the commune level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.17: Plot restrictions and number of maize seasons grown.

	MaizeSeasons	MaizeSeasons	MaizeSeasons	MaizeSeasons	MaizeSeasons	MaizeSeasons
Plot Restricted	-0.0889***	-0.191***	-0.111***	-0.179***	-0.125***	-0.198***
	(0.0214)	(0.0341)	(0.0248)	(0.0339)	(0.0314)	(0.0420)
Other HH plot restricted		0.138***		0.121***		0.154***
		(0.0258)		(0.0230)		(0.0320)
Irrigated	-0.143***	-0.124***	-0.145***	-0.129***	-0.153***	-0.131***
	(0.0251)	(0.0240)	(0.0241)	(0.0234)	(0.0275)	(0.0265)
Redbook	0.00640	0.00523	-0.00529	-0.00246	-0.0136	-0.0190
	(0.0178)	(0.0181)	(0.0155)	(0.0155)	(0.0188)	(0.0184)
Household size	0.00909	0.00974	-0.000826	-0.000719	-0.000915	0.000931
	(0.00608)	(0.00605)	(0.00526)	(0.00510)	(0.0113)	(0.0106)
Male household head	-0.00788	-0.00848	-0.0190	-0.0198	0.0466	0.0415
	(0.0555)	(0.0512)	(0.0400)	(0.0362)	(0.0655)	(0.0629)
Natural disaster, HH	0.000288	0.00133	-0.0163	-0.0136	-0.00322	-0.00529
	(0.0137)	(0.0141)	(0.0203)	(0.0203)	(0.0168)	(0.0171)
Maize price (log)	0.00517	0.000220				
	(0.0416)	(0.0421)				
Observations	14600	14600	18024	18024	18160	18160
Mean DV	0.206	0.206	0.169	0.169	0.168	0.168
Plot, Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Commune-Year FE	No	No	Yes	Yes	No	No
Household quadratic trend	No	No	No	No	Yes	Yes
Sample	All	All	All	All	All	All

Standard errors in parentheses. Standard errors clustered at the commune level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.18: Plot restrictions and plot rice output.

	RiceOutput	RiceOutput	RiceOutput	RiceOutput	RiceOutput	RiceOutput
Plot Restricted	0.164***	-0.0501	0.190***	-0.0192	0.157***	-0.0329
	(0.0339)	(0.0348)	(0.0387)	(0.0354)	(0.0310)	(0.0350)
Other HH plot restricted	-0.201***	-0.0473	-0.210***	-0.0686	-0.198***	-0.0524
	(0.0527)	(0.0447)	(0.0610)	(0.0546)	(0.0391)	(0.0387)
Irrigated	0.187***	0.00414	0.198***	0.0209	0.202***	0.0295
	(0.0333)	(0.0261)	(0.0341)	(0.0251)	(0.0440)	(0.0329)
Redbook	0.0320*	0.0269*	0.0241	0.0258	0.0263	0.0250
	(0.0171)	(0.0147)	(0.0211)	(0.0184)	(0.0269)	(0.0236)
Household size	0.0137	0.0123	0.0112	0.0109	0.000174	-0.00131
	(0.00939)	(0.00920)	(0.00822)	(0.00800)	(0.0143)	(0.0143)
Male household head	-0.0413	-0.00838	-0.0406	-0.0204	0.0566	0.0564
	(0.0386)	(0.0356)	(0.0468)	(0.0444)	(0.0691)	(0.0635)
Natural disaster, HH	-0.0254	-0.0223	-0.0258	-0.0277	-0.0346	-0.0319
	(0.0227)	(0.0218)	(0.0308)	(0.0300)	(0.0260)	(0.0249)
Rice price (log)	-0.186	-0.147				
	(0.148)	(0.139)				
# Rice seasons		0.502***		0.395***		0.291***
		(0.0981)		(0.0777)		(0.0535)
Rice=1		-0.181		-0.0502		0.0831
		(0.144)		(0.106)		(0.0759)
Observations	16180	16180	16152	16152	16296	16296
Mean DV	0.668	0.668	0.656	0.656	0.664	0.664
Plot, Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Commune-Year FE	No	No	Yes	Yes	No	No
HH quadratic trend	No	No	No	No	Yes	Yes
Sample	All	All	All	All	All	All

Standard errors in parentheses. Standard errors clustered at the commune level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.19: Plot restrictions and plot rice yield.

	RiceYield	RiceYield	RiceYield	RiceYield
Plot Restricted	0.820***	-0.183	2.294***	0.0762
	(0.162)	(0.116)	(0.200)	(0.123)
Other HH plot restricted			-1.926***	-0.325***
			(0.158)	(0.0755)
Irrigated	2.311***	0.207*	2.044***	0.184*
	(0.175)	(0.112)	(0.163)	(0.111)
Redbook	0.0114	-0.0449	0.0206	-0.0424
	(0.136)	(0.0908)	(0.136)	(0.0911)
Household size	0.0858**	0.0661**	0.0820**	0.0657**
	(0.0388)	(0.0300)	(0.0382)	(0.0300)
Male household head	-0.134	0.194	-0.160	0.186
	(0.312)	(0.231)	(0.316)	(0.232)
Natural disaster, HH	-0.349***	-0.338***	-0.370***	-0.342***
	(0.0919)	(0.0751)	(0.0966)	(0.0752)
Rice price (log)	-0.212	0.177	-0.239	0.168
	(0.484)	(0.371)	(0.475)	(0.370)
# Rice seasons		4.352***		4.332***
		(0.123)		(0.122)
Rice=1		-0.169		-0.220
		(0.204)		(0.202)
Observations	16180	16180	16180	16180
Mean DV	6.463	6.463	6.463	6.463
Plot, Year FE	Yes	Yes	Yes	Yes
Commune-Year FE	No	No	No	No
HH quadratic trend	No	No	No	No
Sample	All	All	All	All

Standard errors in parentheses. Standard errors clustered at the commune level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.20: Plot restrictions and maize yields.

	MaizeYield	MaizeYield	MaizeYield	MaizeYield
Plot Restricted	-0.201**	-0.00814	-0.549***	-0.00310
	(0.0796)	(0.0305)	(0.155)	(0.0564)
Other HH plot restricted			0.451***	-0.00648
			(0.141)	(0.0532)
Irrigated	-0.420***	0.0671	-0.360***	0.0663
	(0.116)	(0.0490)	(0.108)	(0.0498)
Redbook	-0.0939	0.00265	-0.103	0.00279
	(0.0862)	(0.0444)	(0.0852)	(0.0443)
Household size	0.0103	-0.00538	0.0114	-0.00539
	(0.0283)	(0.0129)	(0.0278)	(0.0129)
Male household head	-0.126	-0.146*	-0.114	-0.146*
	(0.219)	(0.0871)	(0.201)	(0.0872)
Natural disaster, HH	0.0264	0.00957	0.0256	0.00958
	(0.0635)	(0.0280)	(0.0645)	(0.0281)
Maize price (log)	0.0793	-0.0615	0.0501	-0.0611
	(0.218)	(0.0846)	(0.217)	(0.0845)
# Maize seasons		3.140***		3.140***
		(0.193)		(0.193)
Maize=1		0.463**		0.463**
		(0.233)		(0.233)
Observations	9936	9936	9936	9936
Mean DV	0.622	0.622	0.622	0.622
Plot, Year FE	Yes	Yes	Yes	Yes
Commune-Year FE	No	No	No	No
Household quadratic trend	No	No	No	No
Sample	All	All	All	All

Standard errors in parentheses. Standard errors clustered at the commune level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.21: Household land restriction and agricultural profit.

	AgProfit	AgProfit	AgProfit	AgProfit
Restricted land share (in Std.Dev.)	-557.5***	-526.9***	-521.2***	-450.0**
	(151.0)	(153.8)	(190.6)	(191.8)
Ag. labor supplied (days)	1.471	1.745	1.593	1.894
	(2.037)	(2.022)	(2.482)	(2.466)
# Crop seasons	106.2**	198.3***	83.90*	194.0***
	(41.82)	(52.93)	(50.59)	(61.35)
Total used land (log)	240.8	445.6	460.6	930.9
	(447.2)	(495.5)	(555.0)	(627.2)
Redbook land share (std)	-494.6**	-488.7**	-142.2	-143.6
	(210.3)	(209.4)	(259.4)	(259.8)
Irrig. land share (std)	241.8	317.9	224.5	359.8
	(220.5)	(217.9)	(277.7)	(276.8)
Perennial share of land (std)	733.5**	632.2**	980.0***	742.0**
	(322.2)	(286.7)	(322.1)	(307.5)
Distance to nearest road (km)	-111.7*	-109.2*	-12.39	-12.86
	(65.44)	(65.24)	(101.6)	(101.7)
Natural disaster	-1276.7***	-1275.3***	-741.6*	-739.7*
	(386.5)	(385.0)	(439.5)	(434.4)
HH grows rice		99.12		-1765.2*
		(1178.2)		(1043.3)
# Rice seasons		-183.3**		-168.0**
		(73.42)		(77.43)
Rice area (ha)		-595.9		-1224.9
		(1356.6)		(1344.7)
Year=2008	790.5*	916.3**		
	(419.7)	(415.5)		
Year=2010	-867.1	-745.2		
	(556.7)	(554.7)		
Year=2012	168.6	295.9		
	(578.2)	(568.8)		
Observations	5756	5756	5404	5404
Mean DV	3146.3	3146.3	3164.9	3164.9
HH, Year FE	Yes	Yes	Yes	Yes
Commune-Year FE	No	No	Yes	Yes
Sample	All	All	All	All

Standard errors in parentheses. Standard errors clustered at the commune level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.22: Household land restriction and agricultural profit, by rice and non-rice crops.

	RiceProfit	NonRiceProfit	RiceProfit	NonRiceProfit
Restricted land share (in Std.Dev.)	-459.8**	-115.9	-53.05	-463.8**
	(199.3)	(244.6)	(145.0)	(209.4)
HH grows rice	1739.7***		349.0	
	(618.7)		(693.9)	
Rice labor supplied (days)	1.375		3.085	
	(3.742)		(4.509)	
# Rice seasons	316.1***		291.0***	
	(70.64)		(54.72)	
Rice area (ha)	6978.6***		6331.6***	
	(2156.1)		(1778.7)	
HH grows non-rice		2400.2***		1505.6**
		(840.1)		(663.8)
Non-rice labor supplied (days)		0.942		7.869**
		(3.787)		(3.862)
# Non-rice seasons		504.9***		506.4***
		(97.65)		(90.48)
Non-rice area (ha)		1920.8*		1241.4
		(1122.4)		(1027.8)
Total used land (log)	500.5	-2329.2***	992.0***	-2155.9***
	(356.0)	(795.9)	(367.6)	(817.3)
Redbook land share (std)	30.23	-491.9**	25.82	-183.7
	(155.6)	(222.2)	(181.9)	(243.2)
Irrig. land share (std)	281.4	-249.1	336.9**	-289.4
	(189.4)	(284.0)	(162.8)	(303.6)
Natural disaster	-847.7***	-358.2	-396.6	-364.6
	(309.3)	(462.5)	(266.9)	(532.9)
Distance to nearest road (km)	-0.229	-101.8	78.23	-72.23
	(152.8)	(184.1)	(65.85)	(129.1)
# Crop seasons	78.07**	-466.4***	-9.928	-351.2***
	(38.30)	(96.49)	(36.93)	(77.86)
Perennial share of land (std)	-576.6**	1210.9***	-15.56	1058.5***
	(286.0)	(418.6)	(184.8)	(349.2)
Year=2008	3946.9***	-2991.2***		
	(397.4)	(680.8)		
Year=2010	4381.8***	-5041.4***		
	(442.2)	(853.1)		
Year=2012	8547.0***	-8109.2***		
	(901.9)	(1307.2)		
Observations	5756	5756	5404	5404
Mean DV	5848.2	-2708.1	5924.6	-2763.1
HH, Year FE	Yes	Yes	Yes	Yes
Commune-Year FE	No	No	Yes	Yes
Sample	All	All	All	All

Standard errors in parentheses. Standard errors clustered at the commune level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Bibliography

Ley Agraria. Anaya Editores, Mexico City, 2002.

Acemoglu, D., Johnson, S., and Robinson, J. A. The Colonial Origins of Comparative Development: An Empirical Investigation. *The American Economic Review*, 91(5):pp. 1369–1401, 2001. ISSN 00028282. URL `http://www.jstor.org/stable/2677930`.

Alavi, H. R. *Trusting trade and the private sector for food security in Southeast Asia*. World Bank Publications, 2012.

Alix-Garcia, J. A spatial analysis of common property deforestation. *Journal of Environmental Economics and Management*, 53(2):141–157, 2007.

Alix-Garcia, J., Shapiro, E. N., Sims, K. R., Frey, G. E., Fassola, H. E., Pachas, A. N., Colcombet, L., Lacorte, S. M., Renkow, M., Pérez, O., et al. Forest Conservation and Slippage. *Land Economics*, 88(4), 2012.

Angelsen, A. Agricultural expansion and deforestation: modelling the impact of population, market forces and property rights. *Journal of development economics*, 58(1):185–218, 1999.

Arellano, M. and Bond, S. Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The review of economic studies*, 58(2):277–297, 1991.

Beltramo, T. and Levine, D. I. The effect of solar ovens on fuel use, emissions and health: results from a randomised controlled trial. *Journal of Development Effectiveness*, 5(2): 178–207, 2013.

Besley, T. Property rights and investment incentives: Theory and evidence from Ghana. *Journal of Political Economy*, 103(5):pp. 903–937, 1995. ISSN 00223808. URL `http://www.jstor.org/stable/2138750`.

Borenstein, S. A microeconomic framework for evaluating energy efficiency rebound and some implications. Technical report, National Bureau of Economic Research, 2013.

Bray, D. B., Antinori, C., and Torres-Rojo, J. M. 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, 2006.

Bray, D. B., Duran, E., Ramos, V. H., Mas, J.-F., Velazquez, A., McNab, R. B., Barry, D., and Radachowsky, J. Tropical deforestation, community forests, and protected areas in the Maya Forest. *Ecology & Society*, 13(2), 2008.

Bui, B. B. Rice based food security in Vietnam: Past, present and future. *Vietnam: Fifty years of rice research and development*, Hanoi: Agriculture Publishing House, September 2010. 2010.

CIE. Vietnam's Trade Policies 1998. *Centre for International Economics, Canberra and Sydney*, 1998.

de Janvry, A., Gordillo, G., and Sadoulet, E. *Mexico's Second Agrarian Reform: Household and Community Responses*, volume 30, pages pp. 441–442. Cambridge University Press, 1997. URL `http://www.jstor.org/stable/158554`.

de Janvry, A., Dutilly, C., Muñoz-Piña, C., and Sadoulet, E. Liberal reforms and community responses in Mexico. *Communities and markets in economic development*, pages 318–44, 2001.

de Janvry, A., Emerick, K., Gonzalez-Navarro, M., and Sadoulet, E. Delinking land rights from land use: Certification and migration in Mexico. Working paper, June 2013a.

de Janvry, A., Gonzalez-Navarro, M., and Sadoulet, E. Are land reforms granting complete property rights politically risky? Electoral outcomes of Mexico's certification program. *Journal of Development Economics*, 2013b. ISSN 0304-3878. URL `http://www.sciencedirect.com/science/article/pii/S0304387813000503`.

De Soto, H. The other path: The informal revolution. *New York: Harper and Row*, 1989.

De Soto, H. et al. *Mystery of capital: Why capitalism triumphs in the West and fails everywhere else.* Basic books, 2000.

Deininger, K. and Jin, S. Tenure security and land-related investment: Evidence from Ethiopia. *European Economic Review*, 50(5):1245–1277, 2006.

Deininger, K. W. and Minten, B. Poverty, policies, and deforestation: The case of Mexico. *Economic Development and Cultural Change*, 47(2):313–344, 1999.

Deininger, K. W., Bresciani, F., Association, A. A. E., et al. *Mexico's ejido reforms: Their impact on the functioning of factor markets and land access.* American Agricultural Economics Association, 2001.

Deininger, K. W. et al. *Land policies for growth and poverty reduction.* World Bank Publications, 2004.

Demsetz, H. Toward a theory of property rights. *Law and Economics*, 1:341–353, 1967.

Do, Q.-T. and Iyer, L. Land titling and rural transition in Vietnam. *Economic Development and Cultural Change*, 56(3):531–579, 2008.

Duran-Medina, E., Mas, J.-F., and Velázquez, A. Land use/cover change in community-based forest management regions and protected areas in Mexico. *The Community Forests of Mexico: Managing for Sustainable Landscapes. University of Texas Press, United States of America*, pages 215–238, 2005.

Feder, G. and Feeny, D. Land tenure and property rights: Theory and implications for development policy. *The World Bank Economic Review*, 5(1):135–153, 1991.

Giesecke, J. A., Tran, N. H., Corong, E. L., and Jaffee, S. Rice Land Designation Policy in Vietnam and the Implications of Policy Reform for Food Security and Economic Welfare. *The Journal of Development Studies*, 49(9):1202–1218, 2013.

Gill, G. J., Farrington, J., Anderson, E., Luttrell, C., Conway, T., Saxena, N., and Slater, R. *Food Security and the Millennium Development Goal on Hunger in Asia*. Overseas development institute (ODI), 2003.

Goldstein, M. and Udry, C. The profits of power: Land rights and agricultural investment in Ghana. *Journal of Political Economy*, 116(6):981–1022, 2008.

Government of Vietnam. Decree No. 69/2009/ND-CP of the government additionally providing for land use planning, land prices, land recovery, compensation, support and resettlement. Hanoi 2009.

Gunn, G. C. The Great Vietnamese Famine of 1944-45 Revisited. , 52:81–105, 2011.

Ha, P. V., Nguyen, H. T. M., Kompas, T., Che, T. N., and Trinh, B. Rice production, trade and the poor: regional effects of rice export policy on households in Vietnam. *Journal of Agricultural Economics*, 66(2):280–307, 2015.

Honoré, B. E. and Kyriazidou, E. Panel data discrete choice models with lagged dependent variables. *Econometrica*, pages 839–874, 2000.

Hung, P. and Murata, T. Impacts of reform policies on agricultural sector in Vietnam. *Journal of the Faculty of Agriculture-Kyushu University (Japan)*, 2001.

Ives, M. In Mekong Delta, Rice Boom In Mekong Delta, Rice Boom Has Steep Environmental Cost. Yale Environment 360, 2013.

Knight, B. Endogenous federal grants and crowd-out of state government spending: Theory and evidence from the federal highway aid program. *American Economic Review*, pages 71–92, 2002.

Lichtenberg, E. and Smith-Ramirez, R. Slippage in conservation cost sharing. *American Journal of Agricultural Economics*, page aaq124, 2011.

Liscow, Z. D. Do property rights promote investment but cause deforestation? Quasi-experimental evidence from Nicaragua. *Journal of Environmental Economics and Management*, 65(2):241–261, 2013.

Markussen, T., Tarp, F., and Van Den Broeck, K. The forgotten property rights: Evidence on land use rights in Vietnam. *World Development*, 39(5):839–850, 2011.

Marsh, S. P. and MacAulay, T. G. Land reform and the development of commercial agriculture in Vietnam: policy and issues. *Agribusiness Review*, 10, 2002.

McCarthy, N., de Janvry, A., and Sadoulet, E. Land allocation under dual individual–collective use in Mexico. *Journal of Development Economics*, 56(2):239–264, 1998.

Mendelsohn, R. Property rights and tropical deforestation. *Oxford economic papers, New Series*, 46:750–756, 1994.

Minot, N. and Goletti, F. *Rice market liberalization and poverty in Viet Nam*, volume 114. Intl Food Policy Res Inst, 2000.

Nguyen, H. and Grote, U. Agricultural policies in Vietnam: Producer support estimates, 1986-2002. Technical report, ZEF discussion papers on development policy, 2004.

Nielsen, C. P. Vietnam's rice policy: Recent reforms and future opportunities. *Asian economic journal*, 17(1):1–26, 2003.

Pike, D. Vietnam in 1980: The Gathering Storm? *Asian Survey*, pages 84–92, 1981.

Pingali, P. and Siamwalla, A. Myanmar: Rice policy reforms and the potential for exports. *TDRI Quarterly Review*, 8(4):10–12, 1993.

Pingali, P. L. and Xuan, V.-T. Vietnam: Decollectivization and rice productivity growth. *Economic development and cultural change*, pages 697–718, 1992.

Rossiter, D. Economic land evaluation: Why and how. *Soil use and management*, 11(3): 132–140, 1995.

Rozelle, S. and Li, G. Village leaders and land-rights formation in China. *American Economic Review*, 88(2):433–38, 1998.

The Economist. Losing the plot: Land-grabs in Vietnam, March 16th 2013.

Tien, T. D., Le, N. P., Marsh, S. P., MacAulay, T., Hung, P., et al. Agricultural land use flexibility in Vietnam. *Agricultural development and land policy in Vietnam*, pages 41–68, 2006.

Tu, D. T. Land and water investment in Viet Nam: past trends, returns and future. *Proceedings of the Regional Consultation, FAO*, 2002.

Valsecchi, M. Land property rights and international migration: Evidence from Mexico. *Journal of Development Economics*, 2014.

Vasavakul, T., Marsh, S., MacAulay, T., Hung, P., et al. Agricultural land management under doi moi: policy makers' views. *Agricultural development and land policy in Vietnam*, pages 221–232, 2006.

Wooldridge, J. M. Simple solutions to the initial conditions problem in dynamic, nonlinear panel data models with unobserved heterogeneity. *Journal of applied econometrics*, 20(1): 39–54, 2005.

World Bank. Advancing rural development from vision to action. Report for Consultative Group Meeting for Vietnam, 1998.

Wu, J. Slippage effects of the conservation reserve program. *American Journal of Agricultural Economics*, 82(4):979–992, 2000.

Yates, P. L. Mexico's agricultural dilemma. *Tucson: University of Arizona Press*, 1981.

Young, A. and Goldsmith, P. F. Soil Survey and Land Evaluation in Developing Countries: A Case Study in Malawi. *The Geographical Journal*, 143(3):pp. 407–431, 1977. ISSN 00167398. URL `http://www.jstor.org/stable/634710`.