Delinking land rights from land use: Certification and migration in Mexico

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June 27, 2013

Abstract

We show that removing the link between active land use and ownership through certification can result in increased outmigration. Using the rollout of the Mexican land certification program from 1993 to 2006 we find that households obtaining land certificates were subsequently 28% more likely to have a migrant member. This response was differentiated by initial land endowments, land quality, outside wages, and initial land security, as predicted by our model. Effects on land under cultivation were heterogeneous: in high land quality regions land under cultivation increased while in low quality ones it declined.

JEL Codes: Q15, O15

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1 Introduction

Well-defined and secure property rights over land have long been recognized as essential for economic development (Demsetz, 1967; North and Thomas, 1973; De Soto, 1989). There are however different ways in which these rights can be established. Contrary to the norm in developed countries in which rights are established with land tiles, in many developing countries rights are established by contingent use. In the latter case, security of access requires evidence of active use (production); i.e., leaving land idle implies a risk of reallocation without compensation. This can be inefficient as it imposes restrictions on the amount of labor used on the land by requiring that it be kept in production at an accepted standard of use, ignoring the return to labor in other activities. With a focus on improving the security of access to land and stimulating investment, land certification and titling programs have been proposed (De Soto, 2000), resulting in the implementation of large-scale certification programs sponsored by national governments and international development agencies (Heath, 1990). While the focus has been on land productivity, little attention has been given to the potentially large effects on the spatial reallocation of labor. The importance of this effect becomes clear once one considers that in developing countries value added per worker is on average four times higher in the non-agricultural sector than in agriculture (Gollin et al., 2012). For the specific case of Mexico, in the early 1990s agriculture represented only 3.8% of GDP while 34.4% of the population lived in rural areas.

In reviewing the literature, Galiani and Schargrodsky (2011) find that the benefits from well-defined and secure property rights over land can materialize through four channels: enhanced investment incentives (Alchian and Demsetz, 1973; Lin, 1992), facilitation of land trades (Besley, 1995; Deininger, 2003), increased use of land as collateral to access credit (Feder, Onchan, and Chalamwong, 1988; De Soto, 2000), and improved intra-household labor allocations (Field, 2007). There is no clear distinction, however, as to whether rights are established by use or by certification/titling, for as long as they are well defined and secure. Yet, the difference on labor and land use can be very important: use-based rights can restrain migration out of agriculture and keep inferior land in production (Feder and Feeny, 1991).

The classic economic argument regarding the impact of weak property rights on migration is based on treating insecurity as a tax on output. Improving property rights is then predicted to increase the marginal products of agricultural land and labor, decreasing incentives to migrate. In this paper, we argue that a pre-title regime where use-based property rights require presence of the owner on the land and his active use of the land, creates a distortion working in the opposite direction, inefficiently tying labor to the land.[1] We use a simple household model to show that

[1] There are many examples of use-based property rights with implications on the efficiency of land use. In Brazil, cultivation of more than 50% of the potentially productive area in large farms is required by the constitution of 1988 as a "social obligation" of land ownership, with the right to expropriate at the demand of occupants if deemed under-used (Navarro, 2009). By contrast, occupants making active use of the land cannot be removed as long as they are growing crops. In China, under the household responsibility system introduced in 1978, land belongs to the community and individual farmers have usufruct rights that can be subject to expropriation. Households engaging in off-farm employment are more likely to see part or all of their land reallocated (Rozelle and Li, 1998). In Ghana, Goldstein and Udry (2008) find that individuals with more secure property rights due to their political position can

implementation of a land certification program delinking land rights from land use can lead to increased outmigration. In the model, the inefficient labor tying result rests on two main conditions: a preexisting suboptimal farm size and the land use requirement.

We test the model's predictions using data from Mexico's large-scale land certification program (Programa de Certificación de Derechos Ejidales y Titulación de Solares, or Procede). The program was rolled out nationwide from 1993 to 2006 to issue certificates of ownership over ejido land. Ejidos are agrarian communities that were created over the 1914 to 1992 period as part of an ambitious land reform program in which community members (ejidatarios) were granted use and residual claimant rights over individual agricultural plots. Security of access for individuals was closely linked to usage. Any land that was left fallow for more than two years could be granted to another beneficiary. Procede revoked this pattern of property rights. It gave ejidatarios land certificates specifying the name of the owner of each agricultural plot alongside with a GIS-based map of the plot. Similar documents were provided for residential plots, while a certificate was issued to each ejidatario giving ownership of a share of common use lands. Procede was massive in scale, providing certificates to over 3.6 million families by the end of the program. We use this large-scale land certification experiment to assess the migration and land reallocation impacts of redefining property rights from use-based to title-based.

Because the program provided certificates to the entire community simultaneously, selection concerns are minimized.[2] We use a fixed-effects econometric specification that compares changes in migration between households in early certified and later certified ejidos.[3] We establish the migration result using three independent datasets with the following results. First, using panel data on rural households, we find that households in certified ejidos were subsequently 28% more likely to have a migrant household member. Second, using locality level data from two successive population censuses, we find that certification led to a 4% reduction in population. Third, we use a nationwide ejido census to confirm that certification led to more young people leaving the ejido for work reasons. Our estimates imply that about 70,000 people–or some 20% of the total number of migrants from these communities–can be attributed to the certification program.

With this main result established, we proceed to test other predictions of the model. First, we document heterogeneity in migration responses, with larger effects for households with ex-ante weaker property rights (associated with border conflicts and gender of the household head) and with more attractive off-farm wage opportunities. Second, we document that migration effects are smaller where land is more productive, consistent with labor tying being more onerous in less productive land. Third, we find evidence of sorting at the community level regarding who migrates based on differential land endowments. Farmers with more land were less likely to migrate than smaller landholders as a result of the program. The model predicts this differential effect, as the use restriction in the previous property rights regime was more binding for farmers with smaller landholdings. Finally, the model suggests that the difference in migration responses between large

reduce land use, leaving it idle over longer fallow periods to restore soil fertility.

[2]Typically, distribution of land titles is demand driven. See for example, Alston, Libecap, and Schneider (1996).

[3]The robustness checks section provides evidence for the parallel trend assumption necessary for identification.

and small landholders should be sharper in areas with higher land productivity. We find clear evidence of this in the data. The overall effect of certification for land-rich households in high productivity areas is not statistically different from zero. In contrast, in low land productivity regions the migration effect is statistically significant for large and small landholders and of about the same magnitude.

The focus of the empirical analysis in the first part of the paper is on the labor reallocation effects. The second part of the paper explores the effects of certification on farm consolidation and land use. By allowing consolidation of farm units, the certification program could help resolve the suboptimal farm size problem. Of course, frictions in the land market in spite of certification can also lead to less cultivation if migrants decide to keep the land fallow - but preserve ownership due to its option value or as a retirement activity. We test for this effect using a Herfindahl land concentration index, but cannot reject that there was no consolidation over a four year period, although the coefficient is positive and the magnitude economically significant. Land concentration effects may of course take a longer time to emerge and we only have data on this outcome in a four year window.

The second question regarding land use we focus on is whether the certification program actually led to reductions in cultivated area. Less labor inputs are naturally expected to decrease total output. However, there are two countervailing forces that make this an empirical question. The first is land consolidation in a context of increasing returns to land, while the second is the enhanced investment effect traditionally argued for in the property rights literature. Investments that are complementary to agricultural land could help expand cultivated area after the program. We use three rounds of satellite land use data to determine that, on average, farmland in ejidos did not decrease after introduction of the program in spite of large population losses. We also find that the impact of certification on land area under cultivation depends on land quality: ejidos in high land productivity areas saw an increase in farmland after the certification program was introduced compared to those in low productivity areas where there was a slight reduction.

An alternative explanation for the increased migration result is that the certification program attracted funds from outside the community through land transactions which helped finance migration by relaxing liquidity constraints.[4] We test and reject that this alternative mechanism is explaining the increased migration after certification. We assess the role of credit constraints by comparing the effect of the certification program between randomly assigned Progresa (a conditional cash transfer program) and non-Progresa localities. Because the former experienced substantial exogenous cash inflows *before* certification, thereby mitigating liquidity constraints, the migration response should be smaller in Progresa localities once certification occurred. We do not find evidence of this in the data.[5]

[4] Angelucci (2012b) shows that conditional cash transfer programs alleviate credit constraints and allow for migration of household members.

[5] Previous research has failed to document a credit access effect from banks using land as collateral after titling (Galiani and Schargrodsky, 2010; Field and Torero, 2006). The Mexican certification program was explicitly designed to limit mortgages (hence the term certification, not title) so we ignore this alternative in the paper. Early evidence on Procede also failed to find any credit access effects (Deininger and Bresciani, 2001).

Our paper relates to a new literature on the effects of property rights on migration in rural areas. In the context of China, a recent working paper by Giles and Mu (2011) shows that tenure insecurity caused by periodic land reallocations, based in part on household land use, has caused farmers to reduce outmigration. Work by Chernina et al. (2013) studies rural to rural migration in the Russian Empire during the early 1900s and argues that increased land liquidity was an important component of the Stolypin titling reform. The authors use a difference-in-differences strategy to show that migration increased significantly after the titling reforms. It is however difficult to attribute the effects of the Stolypin reforms to land liquidity since the reforms occurred concurrently with a large number of government programs designed to incentivize migration to rural Siberia, including giving away land at destination and paying for transportation costs.[6] In a recent paper, Valsecchi (2012) studies the effect of Procede on international migration to the U.S. using a triple differences estimator. However, an important complication arises from his use of posesionarios/avecindados[7] as a non-eligible household control group, since these were often formally recognized as ejidatarios during administration of the program or hired as laborers following the opening of the labor market. Because the program had indirect effects on non-eligible households, this creates identification concerns for triple difference estimates. Land rights and migration in Africa have been studied by de Brauw and Mueller (2012) who show that changes in self-reported perceived transferability of land rights was not significantly correlated with changes in probability of labor out-migration in Ethiopia. That null result of course must be considered as taking place in a context in which the land remains state-owned, and sales, mortgages and land exchanges are still illegal, making it unclear how perceived land transferability can impact migration.

Other work on property rights and labor allocation has focused on urban areas. Field (2007) finds that providing land titles to urban squatters in Peru resulted in an increase in the amount of labor allocated to work away from home, in essence due to a reduction in the need for guarding labor. In contrast, Galiani and Schargrodsky (2010) find that the provision of land titles to squatters in urban Argentina had no effect on labor market outcomes, possibly due to unconstrained labor supply prior to the reform.

Our paper complements this literature by providing theory and empirical analysis suggesting a different explanation for why households may migrate after rural land titling programs. Requirements to use land productively put households in a constrained optimum where too much labor was being used in agriculture, particularly in the least productive areas and on the smaller farms. Our model has clear predictions about what types of families should be most likely to send migrants following reform. The household-level microdata that we use allows us to test these theories. The prediction that some families should send migrants and others should not has implications for the aggregate impacts of the reform. Particularly, sorting according to land productivity suggests that average productivity could indeed increase due to migration rather than to increased investment.

[6] The authors also show that the main effects of the reform on migration persisted conditional on land sales, suggesting that other mechanisms are potentially contributing to the results.

[7] Avecindados are families living in the ejido without formal access to ejido land. Posesionarios are fringe members of ejidos that had voting rights in ejido assemblies, but did not have formal access to ejido land.

The remainder of the paper is organized as follows. In Section 2 we provide further details on Procede. Section 3 develops a basic household model and derives testable implications. Section 4 discusses the data and the identification strategy. Section 5 presents the results. Section 6 provides robustness checks and section 7 concludes.

2 The *Procede* Land Certification Program

During the period from 1914 to 1992, Mexico's first land reform consisted in government expropriation of large private landholdings and redistribution of these tracts of land to groups of peasant farmers organized in agrarian communities called ejidos (Sanderson, 1984).[8] Once awarded, the land was managed by the assembly of farmers under the guiding hand of the state. Beneficiaries received usufruct rights to a land plot for individual cultivation, access to common-use land (for forests, pastures, and surface water), and a residential lot. With the objective of limiting land concentration, ejidatarios faced strict legal restrictions on rentals and sales of land.[9] Furthermore, the Constitution itself ruled that any individual land that was not cultivated in two consecutive years was to be reassigned to a member of the community willing and able to cultivate the land, imposing a permanent "use it or lose it" restriction.

Giving access to land with obligation to use it productively has been an important instrument of land redistribution programs. For example, the United States Homestead Act of 1862 and the Reclamation Act of 1902 only awarded title to the landholder after five years of actual and continuous residence in order to guard against "dummy filings, speculation, and the accumulation of large estates" (Coman, 1911). In the Mexican ejido, the use requirement was permanent. Political scientists have argued that granting incomplete property rights with use requirements was purposefully done to create a clientelistic relationship between farmers and the party in power, in spite of the economic inefficiencies it entailed (Magaloni, 2006).[10]

This first land redistribution program, one of the largest in the world (Yates, 1981), eventually resulted in low agricultural productivity and high levels of poverty among beneficiaries (de Janvry, Gordillo, and Sadoulet, 1997). With the impending advent of NAFTA (the free trade agreement between Mexico, the United States, and Canada), the Mexican government introduced a major constitutional reform in 1992 to improve efficiency in the ejido by certifying individual land plots to current users. The reform was clearly intended to improve security of access to land in the ejido by delineating individual property boundaries within the ejido, thus encouraging long-term productive investments by ejidatarios (Heath, 1990). The reform created Agrarian Tribunals to resolve conflicts over the issuance of certificates, established an ejido National Land Registry where individuals would be assigned parcels in the ejido, allowed land rental and sales between ejidatarios,

[8]The program also certified land in indigenous communities. In the remainder of the paper we do not differentiate ejidos from indigenous communities.

[9]Although there is evidence that a black market for ejido lands existed in some parts of the country (Cornelius and Myhre, 1998).

[10]In a recent paper, we find evidence of voting behavior consistent with that hypothesis (de Janvry, Gonzalez-Navarro, and Sadoulet, 2013).

and established a well defined procedure to turn ejido certificates into full titles that could be sold to non-ejidatarios.[11] By issuing land certificates, the program effectively delinked property rights from use requirements.

The program was national in scope and took 13 years to complete. The registration process began with officials from the Agrarian Attorney's Office (PA) approaching ejido officials and providing information about Procede. An ejido assembly was called to approve initiation of the certification process. Except for a few conflict zones, the program progressed remarkably smoothly. After the first assembly, government officials from the National Institute of Statistics and Geography (INEGI) worked with the ejido to identify owners of plots and to produce GIS maps of the ejido. Any disputes over property ownership had to be resolved during this stage of the process by the agrarian courts especially created to resolve such conflicts (Deininger and Bresciani, 2001). After all conflicts had been resolved, the maps showing individual ownership were submitted for approval at a final ejido assembly. Final approval resulted in issuance of ownership certificates by the National Agrarian Registry (RAN) *simultaneously* to all rights-holders in the ejido.

de Janvry, Gonzalez-Navarro, and Sadoulet (2013) investigate the correlates of the Procede rollout, showing that ejidos where the program was initiated earlier were on average smaller, had more land in parcels, were closer to large cities, were wealthier, had fewer posesionarios, and were more likely to be in municipalities that were politically aligned with the party of the state governor. The differences between early and late certified ejidos are not a threat to our identification strategy as long as the differences are largely time invariant or uncorrelated with changes over time in migration. As a first robustness check to address this concern we verify that changes over time in migration *prior to the program* were not correlated with the year of program completion. In our main analysis, we also interact fixed ejido characteristics with time effects to account for the possibility that migration changed over time due to these fixed characteristics that were correlated with timing of land certification.

3 Theory

The traditional land insecurity model treats insecurity of property rights as a tax on production. Because improving property rights in the canonical model generates a higher expected output, this naturally leads a household to optimally allocate more labor to the farm, thus reducing the equilibrium level of outmigration. Note that this result is based on the critical assumption that the household is always efficiently allocating labor between uses.

The main innovation in our model is to introduce use requirements as a condition to maintain property rights. In a context of small plot sizes (due to the prohibition of land transactions), this leads to spatial labor misallocation. The model makes clear how these two conditions can cause inefficient tying of labor to land, and how relaxing the use restriction can provoke increased outmigration. Once this is established, the model is used to generate predictions about heterogenous

[11] See Appendini (2002) and de Ita (2006) for a description of the reforms.

effects which can be taken to the data.

3.1 Setup

We use the standard agricultural production model in which farm labor h_e produces expected output Y_e according to $Y_e = \gamma A^\alpha h_e^\beta$, where $0 < \alpha, \beta < 1$, A is land, and γ is a total factor productivity parameter. We incorporate migration as households having the option of supplying labor h_m in the non-farm labor market at the wage w_m, from which they earn $w_m h_m$. Household utility is quasi-linear:

$$u(C, \ell) = C + v(\ell),$$

where C is consumption, ℓ is leisure, and utility of leisure is concave ($v' > 0,\ v'' < 0$). Households are endowed with time T which is spent working on the farm, on wage labor off the farm, and on leisure, so that $T = h_e + h_m + \ell$ is the time constraint. The household's budget constraint is $C = \gamma A^\alpha h_e^\beta + w_m h_m + I$, where I is non-labor income.

3.2 Traditional land insecurity model

Insecure property rights are usually modeled as reducing the expected product that the household reaps from farm labor (for instance Besley and Ghatak, 2010). In particular, expected farm production becomes $Y_e = (1-\tau)\gamma A^\alpha h_e^\beta$, where $\tau \in [0, 1]$ reflects the degree of insecurity in property rights.

Obtaining the first order conditions of the household's problem and differentiating with respect to τ provides the following prediction:

$$\frac{\partial h_e}{\partial \tau} = \frac{-h_e}{(1-\tau)(1-\beta)} < 0.$$

Thus, in the standard setup, improving property rights results in an increase in farm labor and a corresponding decrease in migration.

3.3 When land use preserves property rights over the land

In line with the nature of property rights in Mexican ejidos, we instead incorporate land insecurity as a required minimum production level per unit of land:

$$\frac{Y_e}{A} \geq \frac{\pi_m}{s},$$

where π_m is the minimum yield, and $s \in (0, 1)$ is a parameter representing the household's specific strength of property rights. The parameter s captures the idea that households with weaker property rights have to maintain a higher production level to keep their land (Goldstein and Udry, 2008). Because we do not have stochastic output, the minimum yield requirement can alternatively be thought of as a minimum labor requirement per unit of land. However, in deference to the principal-agent literature, we use the minimum yield requirement as it is more realistic.

In line with use-based ownership, there is neither a rental nor a sales markets for land, and farmers are not allowed to hire workers. Hence A is the exogenously allotted land to the household during the initial phase of land reform, and h_e can only be family labor. Lack of land markets and farm sizes below the optimal scale generate non-decreasing return to scale ($\alpha + \beta \geq 1$). Non-decreasing returns to scale can arise out of small landholdings or production indivisibilities. In any case, there is evidence for this assumption in Mexican ejidos.[12]

Without constraint, the optimal allocation of labor to farm production would be:

$$h_e^* = \left(\frac{\gamma\beta}{w_m}\right)^{\frac{1}{1-\beta}} A^{\frac{\alpha}{1-\beta}}, \tag{1}$$

which is an increasing and convex function of A. The minimum yield constraint requires the household to allocate a minimum amount of labor ($\underline{h_e}$) to agricultural production

$$\underline{h_e} = \left(\frac{\pi_m}{s\gamma}\right)^{\frac{1}{\beta}} A^{\frac{1-\alpha}{\beta}}, \tag{2}$$

or else lose its land. This minimum labor requirement is an increasing and concave function of A. The restriction will bind for farm sizes that are smaller than the threshold A_0 defined by $h_e^* = \underline{h_e}$:

$$A_0 = \left[\frac{1}{\gamma}\left(\frac{\pi_m}{s}\right)^{1-\beta}\left(\frac{w_m}{\beta}\right)^{\beta}\right]^{\frac{1}{\alpha+\beta-1}}. \tag{3}$$

At the constrained labor allocation, the average on-farm return to labor is:

$$\frac{Y_e}{\underline{h_e}} = \gamma A^{\alpha} \underline{h_e}^{\beta-1} = \gamma^{\frac{1}{\beta}} \left(\frac{\pi_m}{s}\right)^{1-\frac{1}{\beta}} A^{\frac{\alpha+\beta-1}{\beta}},$$

When the restriction binds, although households allocate more time to the farm than under unrestricted optimization, it is still advantageous to allocate $\underline{h_e}$ to the farm as long as the average return to farm labor is as large as the off farm wage, i.e., $Y_e/\underline{h_e} \geq w_m$. This defines a threshold A_1 below which households will prefer to relinquish their land and fully work off-farm:

$$A_1 = \left[\frac{1}{\gamma}\left(\frac{\pi_m}{s}\right)^{1-\beta} {w_m}^{\beta}\right]^{\frac{1}{\alpha+\beta-1}} = \beta^{\frac{\beta}{\alpha+\beta-1}} A_0 \tag{4}$$

Equilibrium Labor Allocation. *The labor allocation solution to this restricted optimization is*

[12] The 1994 ejido survey was administered to around 1300 ejido households by the World Bank. We estimated a production function of the form $ln(production_{is}) = \beta_0 + \beta_1 ln(hectares_{is}) + \beta_2 ln(labor_{is}) + \alpha_s + \varepsilon_{is}$, where i indexes households and s indexes states. Standard errors were conservatively clustered at the state level. The estimates from this regression are $\hat{\beta}_1 = 0.933$ and $\hat{\beta}_2 = 0.176$. The sum of the two coefficients is significantly larger than 1 with a p-value of 0.048. While these estimates certainly cannot be interpreted causally, the results provide suggestive empirical evidence consistent with non-decreasing returns to scale in this context. See also Adamopoulos and Restuccia (2013) for estimates of the efficiency cost of small farms in developing countries.

represented in Figure 1 and summarized as follows:

- Leisure is determined by: $w_m = v'(\ell)$
- On farm labor is given by:

  (i) $h_e = h_e^*$, if $A \geq A_0$

  (ii) $h_e = \underline{h_e}$, if $A_1 \leq A \leq A_0$

  (iii) $h_e = 0$, if $A \leq A_1$,

  where A_0 is defined by $h_e^* = \underline{h_e}$, and A_1 is defined by $Y_e/h_e = w_m$

- Migrant/off-farm labor is given by:

$$h_m = T - h_e - \ell \tag{5}$$

The results have simple interpretations since land is the key complementary input to farm labor. Households with a sufficiently small land endowment cannot obtain their opportunity cost by staying and cultivating land; they choose to surrender their land and work off-farm. Households with a large land endowment have a high marginal product of labor and are thus unaffected by the production constraint. These households optimally allocate all their labor to agriculture while at the same time producing enough output to keep their land. Only households with intermediate levels of land find themselves allocating more labor than would be optimal under unrestricted optimization.

We argue that in the context of Mexican ejidos one can think of most households as belonging to this intermediate range. First, consider that the objective of the original Mexican land redistribution program was to provide land to as many landless peasants as possible. This gave the government an incentive to minimize plot size subject to providing the household a livelihood (the opportunity cost in the model). Second, because land transactions were not allowed prior to the Procede program, farm sizes were maintained at the originally allocated size without allowing for adjustments in response to the advent of mechanization in agriculture, which is thought to increase the optimal farm size. Third, further evidence of excess labor in ejidos comes from the 1991 agricultural census which indicates that the number of workers per hectare of land in the Mexican private sector (non-ejido) was 0.041, whereas in the ejido sector it was 0.052.

3.4 Land certificates and migration

Procede certificates can be interpreted as allowing farmers to move from the restricted optimization situation to the unrestricted situation. If the minimum labor allocation restriction was binding (regime (ii) with $A_1 \leq A \leq A_0$), farm labor *decreases with land certificates*:

$$\Delta h_e = h_e^* - \underline{h_e}$$

And migrant labor increases by the opposite amount:

$$\Delta h_m = \underline{h_e} - h_e^* = \left(\frac{\pi_m}{s\gamma}\right)^{\frac{1}{\beta}} A^{\frac{1-\alpha}{\beta}} - \left(\frac{\gamma\beta}{w_m}\right)^{\frac{1}{1-\beta}} A^{\frac{\alpha}{1-\beta}}. \tag{6}$$

In Figure 1, certification is represented by a vertical move from the restricted to the unrestricted on-farm labor schedule. Leisure is unaffected because it is solely determined by the outside wage w_m.

3.5 Heterogeneity in migration response to certification

This simple framework can be used to obtain comparative statics predictions resulting from household level heterogeneity. Note that, while the level of migration h_m of a household depends on family size (equation 5), this is not the case for the out-migration Δh_m induced by the land certificate (equation 6). Our unitary model also does not generate predictions on which household members should migrate as a response to the program. Ejidos did not have rules on which household members should cultivate land and therefore any household member could be used to meet minimum production requirements.[13] The predicted migration response however varies with strength of the use-based property rights previously enjoyed, outside wages, farm size, and land productivity. All comparative statics results are obtained by simple differentiation of equation (6).

Degree of security under use-based property rights

Heterogeneity in the degree of land insecurity under the use-based regime can be thought of as heterogeneity in the s parameter. More insecure property rights are reflected as a lower s and a higher required farm activity $\underline{h_e}$. Differentiating (6) with respect to s:

$$\frac{\partial \Delta h_m}{\partial s} = \frac{\partial \underline{h_e}}{\partial s} < 0$$

shows that, *ceteris paribus*, this generates a higher migration response the more insecure property rights were in the use-based regime.

Off-farm wages

Higher wages commanded higher levels of migration h_m through lower optimal leisure. They also induce a higher migration response to the land certificate:

$$\frac{\partial \Delta h_m}{\partial w_m} = -\frac{\partial h_e^*}{\partial w_m} > 0$$

Because the unrestricted on-farm labor schedule is lower the more attractive outside opportunities (w_m) are, the regime change leads to larger migration responses from households with better off-

[13] In results not reported here we find marginally significant heterogeneity in program effects according to the number of young males in the household at baseline. These effects could be interpreted as either related to household size (T) or to greater potential off-farm wages (w_m).

farm opportunities.

Land productivity

Differing farmland quality in the model can be understood as heterogeneity in the productivity parameter γ. Higher land quality reduces the minimum labor necessary to reach the required yield under use-based rights and increases the optimal labor that the household should allocate to the farm. Both effects contribute to a reduction in the excess labor imposed by use-based property rights:

$$\frac{\partial \Delta h_m}{\partial \gamma} = \frac{\partial \underline{h_e}}{\partial \gamma} - \frac{\partial h_e^*}{\partial \gamma} < 0$$

This suggests that farms with lower land productivity have more outmigration when moving from a use-based to a title-based property rights regime.

Farm size

Differentiation of (6) with respect to A gives:

$$\frac{\partial \Delta h_m}{\partial A} = \frac{\partial \underline{h_e}}{\partial A} - \frac{\partial h_e^*}{\partial A} = \left(\frac{\pi_m}{s\gamma}\right)^{\frac{1}{\beta}} \frac{1-\alpha}{\beta} A^{\frac{1-\alpha-\beta}{\beta}} - \left(\frac{\gamma\beta}{w_m}\right)^{\frac{1}{1-\beta}} \frac{\alpha}{1-\beta} A^{\frac{\alpha+\beta-1}{1-\beta}}$$

This expression can be shown to be negative for land size A greater than a threshold A_2 where the two curves $\underline{h_e}$ and h_e^* have parallel slopes.

$$A_2 = A_1 \left[\frac{(1-\alpha)(1-\beta)}{\alpha\beta} \beta^{\frac{-1}{1-\beta}}\right]^{\frac{\beta(1-\beta)}{\alpha+\beta-1}}$$

The first term in the square brackets is smaller than 1, while the second term is greater than 1, meaning that A_2 can either be greater or smaller than A_1. Hence, migration induced by relaxing the yield constraint decreases with farm size, except possibly for the smallest farms still operating with $A \in [A_1, A_2]$, if it is the case that $A_1 < A_2$. The case where $A_2 < A_1$ is depicted in Figure 1. In this case the vertical distance between the two curves is clearly decreasing in A. This expression suggests that if there is heterogeneity in land holding size (A) within ejidos, the larger landholders should migrate less in response to certification. This can be thought of as a sorting effect in which the larger farmers are more likely to stay behind while the smaller more marginal farmers migrate.

It is also straightforward to see that this expression implies that the differential induced migration across farm sizes is sharper in areas with higher land quality:

$$\frac{\partial^2 \Delta h_m}{\partial \gamma \partial A} < 0.$$

This prediction is economically important. It can be interpreted as saying that the migration response of larger landholders in high productivity areas is lower than the migration response of larger landholders in low productivity areas. An equivalent interpretation is that in low productivity areas, the difference in migration response between small and large landholders is not as different as that which arises in high productivity ones.

In summary, we expect that delinking property rights from use requirements allows households to allocate the optimal amount of labor to their farm activity instead of the inefficiently high level required by the "use-it or lose-it" restriction. The out-migration response is expected to be larger for households that had weaker property rights under the prior regime of incomplete property rights, that have better outside opportunities, smaller farms, and lower land quality. We also expect that the differential migration response between small and large farms is stronger in areas with better land. These are the results taken to the data in sections 5.2 to 5.5.

Before moving to the data, we should explicitly acknowledge that the model focuses on the use constraint and its effects in an environment of small landholdings (increasing returns to scale). In doing so, it leaves out many other factors that, while relevant, cannot explain the migration responses we are interested in. The first factor left out in this model is land consolidation. Procede can be expected to allow farmers to consolidate their operations (by rentals or sales of land) in order to achieve a more efficient scale. We test for this effect when we explore land use outcomes, but note that it cannot explain increased outmigration. By increasing the productivity of labor, land consolidation works to increase labor demand. The second factor we leave out is labor markets. If Procede allowed for more efficient labor markets, we expect moving towards a separation equilibrium (as in Benjamin, 1992). We test for this in Section 5.7, but note that it would not explain increased outmigration either.

Finally, the view we take in this model is that credit constraints were not restricting migration. Some have argued that the existence of wage differentials between urban and rural areas may be explained by credit constraints to migration (Levy and Van Wijnbergen, 1995), and this is a definite alternative mechanism. By allowing land transactions to take place, certification could have alleviated credit constraints and allowed for more migration. We investigate this alternative mechanism empirically in section 5.7, but fail to find evidence for it.

4 Data

Our source of information on the rollout of Procede is a set of ejido digital maps created during the certification process by INEGI and managed by RAN. GIS ejido boundaries are available for the 26,481 ejidos that completed the program during the period from 1993-2006.[14] The rollout of the program was quite rapid. Nearly half of all ejidos were fully certified by 1997 while all but a small subset of ejidos had completed the program by 2006. The curve in Figure 2 gives the share of these ejidos that had completed the program each year from 1993 to 2006. Figure 2 also shows the dates of the other datasets used: the Progresa surveys (ENCEL), the population censuses, the ejido censuses, and the land use maps. Figure A1 in the online appendix maps the rollout of Procede at

[14]These data also include 246 ejidos that were in the process of certification but had not yet completed the program during 2007. They do not include the remaining 2500 ejidos that were left to a special program after Procede closed in 2006.

the national level, helping visualize the extensiveness and national scope of the program.

We use the 1998-2000 Encuesta Evaluacion de los Hogares (ENCEL) surveys administered in the evaluation of the anti-poverty program Progresa to study individual migration behavior.[15] The ENCEL data consist of a panel of approximately 25,000 households from 506 poor localities that qualified for the program in the states of Guerrero, Hidalgo, Michoacan, Puebla, Queretaro, San Luis Potosi, and Veracruz. We matched the localities to ejidos using the coordinates of the centroid of the locality. We considered the locality to match an ejido if the centroid of the locality was located inside the boundaries of one of the ejidos in the GIS database. This process matched 200 localities to 195 different ejidos. Of these ejidos, 68 were certified in 1993-1996, 51 in 1997-1999, and 76 after 1999. Our final data consist of an unbalanced panel of 7,577 households from ejidos that were certified after 1996.[16] Approximately 2.2% of these households had a migrant leave during 1997. Between 1998 and 2000 an additional 5.9% of households sent a migrant.

For the community level analysis, we use the 1990 and 2000 population censuses at the locality level from INEGI. Figure 2 shows that approximately 75% of ejidos completed the program between the two censuses. We matched locality centroids to ejidos using the spatial matching technique mentioned above. The final data used in the regressions is a balanced two year panel of population and certification status for 17,328 localities.[17] These data cover all states of Mexico and therefore have broader geographic coverage than the panel of Progresa households. Approximately 62% of the localities in ejidos experienced a decline in population during the period from 1990-2000.

The fourth dataset we use is the Ejido Census (Censo Ejidal) from INEGI that was administered to all ejidos in Mexico in the years 1991 and 2007. The 1991 and 2007 matched surveys are not publicly available and were merged by INEGI specifically for this study. Because the census data that were made available to us did not identify the ejido by name, we created a matching algorithm that builds on common variables in the two censuses and the ejido GIS maps to construct a matched dataset of 19,713 ejidos. The details of the matching algorithm are given in the online appendix.

Finally, we use INEGI GIS land use maps for the whole country. The data consist of Series II, III, and IV of the INEGI land use/land cover maps. The data are based on a combination of Landsat imagery taken during 1993, 2002, and 2007 and a series of field verifications by INEGI. The digital ejido boundaries were overlaid on the land use maps to create a panel of land use at the ejido level for the years 1993, 2002, and 2007. The median amount of agricultural land during 1993 in the ejidos certified in 1993-2006 is roughly 240 hectares, while the median share of total ejido area that is in agriculture is 27%. These figures rose slightly to 275 hectares and 32% in 2007.

[15] Progresa is the Mexican conditional cash transfer program started in 1997. The program is now referred to as Oportunidades. Progresa localities were selected to have more than 50 but less than 2,500 inhabitants and have a high marginality index as computed from the 1990 population census and the 1995 population count information. We use the 1998, 1999, and 2000 ENCEL surveys. The 1997 migration data were derived from recalls in the 1998 ENCEL survey. The 1997 ENCASEH baseline survey did not have comparable migration information.

[16] The panel is unbalanced due to attrition as well as addition of a small number of households to the sample in 1999 and 2000. Our migration result is robust to estimation with a fully balanced panel of households.

[17] All regressions at the community level exclude localities that had population of 20 or less individuals in 1990. Small localities often disappear or are regrouped over time and we therefore drop them from the analysis.

5 Results

5.1 The impact of land certification on migration

We establish our basic result that rural land certification leads to increased outmigration in three independent datasets. First, we consider the panel of households from Progresa, which contains detailed demographic variables and migration status of household members over the four years 1997-2000. The unit of analysis is the household and the dependent variable is an indicator for whether the household has a permanent migrant that left the ejido since the onset of our observations. The main estimating equation is:

$$y_{ijt} = \delta Certif_{jt} + \gamma_j + \alpha_t + x_{ijt}\beta + \varepsilon_{ijt}, \tag{7}$$

where y_{ijt} is an indicator for whether household i in ejido j has a permanent migrant by year t, $Certif_{jt}$ is an indicator for whether ejido j was certified at the beginning of year t, γ_j is an ejido fixed effect, α_t is a time fixed effect, x_{ijt} is a vector of household level covariates, and ε_{ijt} is a random error term. Standard errors are clustered at the ejido level for estimation. This is a standard fixed effects regression where identification is coming from changes in migration behavior correlated to changes in certification status. Any time-invariant ejido characteristic that is correlated with the program rollout is accounted for by the ejido fixed effects. The identifying assumption is therefore that any time-varying ejido characteristic that affects migration trends is uncorrelated with the distribution of certificates. We provide support for the validity of this identification assumption in the next section, focusing first on the results.

The first column in Table 1 gives the basic result with no household controls. In this specification, the probability of a household having a migrant increases by 0.015 after being reached by Procede. The average rate of migration during the sample period is 5.3%, indicating that the effect of the program was to increase permanent migration by 28%. The second column shows that the estimated program effect is almost identical when household level covariates are included in the regression. This minimal change is consistent with the fact that certificates were distributed to all ejidatario households in the ejido. The third column shows that the estimated coefficient is robust to replacing ejido fixed effects by household fixed effects. A key concern for our identification strategy is the possibility of differential time trends that would be correlated with the timing of certification. In columns (4)-(6) we show that the results are robust to controlling for specific time trends more flexibly. In column (4) we allow the time effects to be specific by state. Column (5) includes interaction terms between each time effect and the household-level covariates. In column (6) we include interactions between time effects and some ejido-level characteristics that are shown in de Janvry, Gonzalez-Navarro, and Sadoulet (2013) to be correlated with the rollout of Procede. The purpose of this robustness check is to control for the possibility that the program was initiated earlier in certain types of ejidos that experienced differential changes in migration after the program due to reasons other than land certification. For example, the program was completed on average earlier in ejidos that are located closer to large cities. The fixed effects in our specification obviously account for time invariant differences due to proximity to major cities. Allowing the time effects to depend on proximity to cities further controls for differences in migration over time that are due to earlier program areas being closer to cities rather than certification. Our main result remains economically large and statistically significant after introducing several additional controls for differential time trends. Overall, the behavior of households in the Progresa dataset firmly points to land certificates increasing the probability that a household member migrates.

Second, we study migration behavior at the locality level using the matched 1990 and 2000 population censuses. The locality level analysis captures both migration of individuals and entire families. Three key characteristics of this alternate dataset are its inclusion of localities of all sizes and levels of income, its geographical coverage (nationwide), and its longer time span (up to 7 years with a certificate). By the year 2000, 73% of the ejidos had been awarded a certificate, while the other ejidos were still in the pre-certification regime. We first compare the evolution of locality population over time in a standard two-period fixed effects regression:

$$Pop_{jt} = \gamma_j + \beta I(t = 2000) + \delta I(Certified\ by\ 2000_j = 1)I(t = 2000) + \varepsilon_{jt}. \tag{8}$$

We then allow for a linear effect of certification over time by estimating:

$$\begin{aligned} Pop_{jt} = \gamma_j + \beta I(t = 2000) + (\delta_0 + \delta_1 Years\ Certified_j) I(Certified\ by\ 2000_j = 1) I(t = 2000) \\ + \varepsilon_{jt}. \end{aligned} \tag{9}$$

We finally partition the ejidos certified between the two censuses into early certified and late certified groups and estimate separate effects for the two groups:

$$\begin{aligned} Pop_{jt} = \gamma_j + \beta I(t = 2000) + \delta_1 I(Certified\ before\ 1997_j = 1) I(t = 2000) + \\ \delta_2 I(Certified\ from\ 1997 - 1999_j = 1) I(t = 2000) + \varepsilon_{jt}. \end{aligned} \tag{10}$$

The dependent variable is the total population (or logarithm) of locality j in year t (1990 or 2000). The first specification (8) is a simple fixed effect regression where δ identifies the average effect of the ejido getting certification on the change in locality population. The second specification (9) takes into account the number of years since certification, allowing the migration response to take effect over several years in a linear way. The third specification (10) estimates a separate certification effect for localities in ejidos certified in 1993-1996 (δ_1) and localities in ejidos certified in 1997-1999 (δ_2).

Regression results are reported in Table 2, where standard errors are clustered at the ejido level. The first row in the table shows that ejido localities lost around 9.6 persons or 21% of their population between 1990 and 2000 (the time effect in the first row). The coefficients on the interaction term in the second row indicate that Procede was associated with an *additional reduction* in population of approximately 3-4 individuals, in a setting where the average locality has 99 individuals (column (1)), or 4% of its population (column (2)). While results are less statistically precise, column (3) suggests that the loss of population is progressive over time, with a decline of approximately 0.54% of the population per year after Procede certification. In column (4) we estimate separate effects for early certified ejidos (before 1997) and late certified ejidos (1997-1999). The estimated effect of certification is a 5.9% decrease in population for early certified ejidos and a 2% decrease for later certified ejidos. The difference between early and late certified ejidos is statistically significant. The large difference is consistent with certification leading to initial migration and further migration after migrant networks have been established in destination communities, as in Munshi (2003) who shows that migration networks take approximately 3-4 years to develop. As a specification check we use 12,455 localities with available population in 1980 to estimate a version of (8) for the period 1980-1990. The estimate in column (5) indicates that the difference in population change in the 1980-1990 decade between early and late certified localities was very small and not significant. This similarity in pre-program population trends suggests that our estimate is not driven by pre-1990 differences in population change between early program and late program areas.

Ubiquity of the emigration effect across the whole distribution of change in population is illustrated in Figure 3. The solid black line represents the empirical distribution function for the change in population from 1990 to 2000 for localities in ejidos that were certified between the two censuses. The dashed line represents localities in ejidos certified in 2000 or later.[18] The distribution for localities in ejidos not certified by 2000 stochastically dominates that for certified localities. This indicates that the effect of certification on migration is not a feature of some specific localities but occurs throughout the distribution of population changes.

How does this estimated effect of Procede on the locality population compare to what was revealed in the selected Progresa communities? We cannot simply directly compare effects between datasets because the time periods differ. We also must be careful to measure migration effects annually, rather than over a period of several years. The Progresa data document annual emigration from 1997 to 2000, in localities that were certified from 1997 onwards. The most direct comparison can thus be drawn with column (4) of Table 2 where we also estimate the program effect during this time period. The time effect shows a baseline migration of 20.7% of the population over 10 years, which corresponds to an average annual rate of 2.3% (=$0.793^{0.1}$-1). The certification effect for those ejidos certified in 1997-99 is an additional effect of 1.96% over these 3 years, or an average annual effect of 0.7%. Hence Procede led to an increase of the annual loss of population of 29% (=0.7/2.3). Recall that the average annual effect in the Progresa dataset was an increase in migration by 28%. So while we looked at different measures of migration in the two datasets (households sending off one permanent migrant in the Progresa dataset and population change in the locality dataset), we find that Procede has had the same relative effect of increasing migration by an additional 28-29%.

Third, we analyze migration behavior using the 1991 and 2007 ejido censuses. By 2007, all the ejidos in our dataset had been certified. Hence we can only identify the effect of certification coming from the differential number of years an ejido has been certified in 2007. Furthermore, because

[18]The top and bottom 5% of observations were removed for the graph.

the migration question was not asked in the first round, we can only perform a cross sectional regression. Our dependent variable is the response to a question from the 2007 census asking if the majority of young people leave the ejido. We estimate a cross-sectional regression of the form:

$$Y_{js} = \alpha + \gamma_s + \delta \, Years\ Certified_{js} + x_{js}\beta + \varepsilon_{js}. \tag{11}$$

where γ_s are state fixed effects and x_{js} is a vector of ejido level covariates in 1991 (before Procede). The dependent variable Y_{js} is an indicator variable for whether the majority of young people are said to emigrate from the ejido.

This is obviously a less well identified regression than those reported using the previous two datasets. However, this specification is justified by the result in Table 2 suggesting that the effect of certification is increasing over time. Second, the ejido census has the advantage that the unit of observation coincides perfectly with the population of interest, because questions are asked about the group of ejidatarios in each particular ejido. Finally, this is the only dataset we use that does not necessitate a geographical merge. Hence, we see this as an important verification of the results presented in the previous two tables.

Results are reported in Table 3. Column (1) shows a positive association between the years since certification and the probability that the majority of young people migrate from the ejido. Certified ejidos are 0.35% more likely to respond that a majority of their young people emigrate from the ejido for every year since certification. This result is robust to the addition of ejido covariates measured in 1991 (column (2)). Columns (3) and (4) suggest that most of this effect is driven by increased migration to the United States. The average ejido had been certified 9.5 years in 2007, meaning that for the average ejido, the probability that a majority of young people would be leaving the ejido increased by 7.8 percentage points due to the Procede program.

By presenting results from three independent datasets, we seek to credibly establish that delinking property rights from use requirements generated by the assignment of land certificates led to increased migration from agrarian communities. The number of households having a migrant increased by 28%, the locality population declined by 4%, and ejidos were 0.35% more likely to report that a majority of their youth were leaving the community for every year they had been certified.

Applying these migration effects to the 1.7 million population of the localities matched to ejidos (17,328 localities with average population of 99.1 as reported in Table 2 column(1)) suggests that Procede would have been responsible for an outmigration of about 4% of them or almost 70,000 people. This should be compared to the natural trend of a loss of 20.7% or 350,000 people in these communities over 10 years.

These results should not be interpreted as suggesting a reduction in welfare. On the contrary, as the model suggests, we interpret this as evidence that inefficient amounts of labor had been allocated to the land under the use-based property rights regime. By delinking property rights from use, the program merely allowed households to adjust from an inefficient equilibrium with too much farm labor to an efficient equilibrium with less farm labor.

5.2 Heterogeneity in pre-reform property rights security

The model predicts that the migration response to land certification should be larger when pre-reform property rights were weaker ($\frac{\partial \Delta h_m}{\partial s} < 0$). As a measure of *between ejido* security, we use a question from the 1991 ejido census on the presence of boundary problems within the ejido. Column (1) of Table 4 shows that the point estimate of the migration effect of certification is more than double for households in ejidos where boundary problems were present. A concern with this specification is that migration could increase over time in ejidos with boundary problems independent of certification. We control for differential time effects in column (2). The difference between ejidos with and without boundary issues becomes larger with the addition of specific time effects. The effect of certification on the probability of having a migrant household member increases from 0.008 for households in ejidos without boundary problems to 0.036 for households in ejidos with problems. This difference is significant at the 10% level.

Next, as a measure of *within ejido* insecurity, we use an indicator for a female headed household. Work by social observers indicates that, prior to Procede, female ejidatarias held low status inside the ejido (Stephen, 1996; Deere and Léon, 2001; Hamilton, 2002). For example Stephen (1996, p.291) quotes an ejidataria from Oaxaca as stating, "Women don't participate in ejido assemblies. The men in our community don't let us participate in meetings." Based on interviews conducted in four ejidos in northern and central Mexico, Hamilton (2002) points out that women were susceptible to expropriation by male relatives or friends of high-level ejido officials. This anecdotal evidence prompted the use of a female-headed household dummy as a proxy for weaker ex-ante property rights. We must however interpret our result with caution since female headed households are almost certainly different for reasons other than s in our model.

Columns (3) and (4) show that indeed the effect of certification on migration of household members is significantly larger for female headed households. The magnitude of the coefficient is quite large. The subset of households with female heads is small but not trivial, consisting of around 10% of the population. The marginal effect of certification for these households represents an approximate doubling in the probability that the household has a migrant (marginal effect of Procede of 0.065 compared to the mean value of 0.056). These effects contrast with the smaller impact for male-headed households.

These results are consistent with improvements in property rights brought about by land certificates having much larger effects for households with weaker rights prior to certification. In terms of the model, we interpret this as individuals with weaker property rights (lower s) being more constrained prior to the program and thus having to dedicate more labor to the farm to maintain their land. Hence, receipt of land certificates resulted in a larger migration response for these households.

5.3 Heterogeneity in off-farm wages

We derive an empirical measure of off-farm wage opportunities by using the 1994 Encuesta Nacional de Ingresos y Gastos de los Hogares (ENIGH) household survey to estimate off-farm wages as a function of gender, years of education, the interaction between gender and years of education, a quadratic function of age, and a state fixed effect. We limit this estimation to wage earners that were 18-50 years old since this population is more representative of the population of potential migrants. We then used the wage equation to predict wages for each adult in the set of Progresa households matched to ejidos. The maximum predicted off-farm wage amongst adults 18-50 was taken as the household's off-farm wage opportunity.[19] In columns (5) and (6) of Table 4 we estimate a separate certification effect for households above and below median values of off-farm wage opportunity. The difference in migration response to certification between households with high and low wage opportunities is statistically significant at the 10% level. Using the results from column (6), the estimated increase in the certification effect for male headed households that have above median off-farm wage opportunities is 0.026 and is statistically significant at the 10% level. These results are consistent with the theoretical prediction that the migration response should be larger for households that have higher wage opportunities outside of agriculture ($\frac{\partial \Delta h_m}{\partial w_m} > 0$).

5.4 Heterogeneity in land productivity

The theory predicts that certification leads to a smaller migration response in places with higher land productivity ($\frac{\partial \Delta h_m}{\partial \gamma} < 0$). A common measure of land productivity in Mexico is rainfed corn yield. This measure has the advantage of its geographical coverage, as corn is the staple food grown all over the country. However it is only systematically available at the municipality level and since 2002 from SAGARPA (Ministry of Agriculture). We use the average corn yield over the period 2002-2008 as the measure of land productivity, and partition agricultural land as high or low productivity at the median yield of 1.29 tons/ha. Columns (1) and (2) of Table 5 show that, as predicted, the migration response to certification is weaker (and almost null) in ejidos where land is more productive.

5.5 Heterogeneity in land endowments

The model predicts a smaller migration effect for farmers with more land. Column 3 in Table 5 shows evidence that this holds in the data. The coefficient for relatively large landholders[20] is only 1/5 of that for small landholders.

The final prediction derived in the model is that large farmers in productive regions are expected to respond the least to certification with labor re-allocation ($\frac{\partial^2 \Delta h_m}{\partial \gamma \partial A} < 0$). We test for this by splitting the sample into low and high productivity areas (using the maize yield variable defined above) and estimating the effect of the program for large and small landholders (using the large landholder variable defined above). The results are striking. In low productivity areas, columns (6) and (7), larger landholders are not significantly less likely to migrate than land poor farmers. The coefficient is negative but insignificant. In contrast, in high productivity areas, columns (4) and (5),

[19] Predicted wage was set to 0 if the household did not have any individuals in the 18-50 years old range.

[20] We use an indicator variable which is equal to one if a family has more land per adult than the median in the ejido in 1997.

larger landholders increase their migration *significantly less* than land poor farmers. In fact, the overall effect of certification for land-rich households in high productivity areas is not statistically different from zero. In sum, these results are consistent with the prediction of the model that households are sorted according to their landholdings: larger, more productive farmers stay on the farm, whereas smaller more marginal farmers respond to the removal of use requirements by having more members migrate.

5.6 Certification and land use

The model we presented considered an autonomous household deciding how to allocate labor on and off the farm. According to the model, the freedom provided by certification makes constrained households allocate less labor to the farm. A logical byproduct of this phenomenon would be that less agricultural labor should be reflected in more land being left fallow. In reality, Procede also made land rental and sales transactions legal[21] and there are two reasons why land reallocation after Procede can be expected: first, it alleviates the inefficiently small farm size problem by allowing consolidation of production units in a context of increasing returns to scale; second, if some farmers are more productive than others, certification can allow for gains from trade through land markets to be realized.

We first test whether certification led to increased land concentration using a Herfindhal index of land concentration in ejidos using the Progresa data to estimate an ejido fixed-effect specification that allows us to assess changes in land concentration arising from Procede in a four year window. Column (1) in Table 6 reports results from a regression in which the Herfindahl index is the dependent variable. While the point estimate is positive (and reflects a 23% increase in land concentration) it is not statistically significant, possibly due to the small number of observations.[22] Given the large standard errors, we take away from this exercise that the evidence from household surveys points towards an increase in land concentration but the data is not conclusive.

Our second strategy to assess changes in land use is to test for aggregate changes in the amount of cultivated land in the ejido using objective data and a longer time horizon. If the certificates were used by families to simply leave the land fallow without risk of loss, we would observe a reduction in cultivated land in the ejido. Alternatively, if land was rented out or sold to other community members by households with migrants, we would observe no changes in cultivated land. Finally, if the certification program provided better incentives to invest in agriculture, we could actually observe increases in cultivated acreage in spite of population reductions.

We test for this using panel data from Landsat providing cultivated area in 1993, 2002, and 2007.[23] At each of the three points in time we observe the amount of land allocated to agriculture, pasture, forest, jungle, and thicket in the ejido. We estimate the reduced form impact of certification on the logarithm of cultivated area in a standard fixed effects framework:

[21] Deininger and Bresciani (2001) report observing an increase in land rentals in 1997 compared to 1994.

[22] The small number of observations is due to the index being calculated using information from all households in a given ejido year.

[23] INEGI GIS land use series II, III and IV.

$$\log(Agland_{jt}) = \gamma_j + \alpha_t + \delta Certified_{jt} + \varepsilon_{jt}, \tag{12}$$

where j indexes ejidos and t refers to the year of the land use observation. Results reported in column (2) of Table 6 show that certification had no significant effect on the total area used for agriculture within the ejido. The coefficient is actually positive but very small (0.1%). This is a surprising result given the reduction in labor induced by Procede. If marginal farmers were abandoning land in order to migrate, then we would have observed a decrease in agricultural land after certification. Columns (3) and (4) however show a rich pattern of heterogenous effects by land quality. Column (3) shows that cultivated land actually increased with certification in agriculturally favorable regions but decreased in lower land quality areas. In column (4), we add controls for differential time trends in high and low yield areas. The estimated coefficient shows that certification is associated with an insignificant decline of cultivated land in low-yield regions. Point estimates range from -0.8 to -1.8%. In contrast, agricultural land increases with certification in high agricultural productivity areas. The point estimate ranges from 1.3 to 1.6%, and the difference between favorable and non-favorable areas is significant.[24]

We conclude our land use analysis by verifying that there is a correlation between population changes and cultivated area changes. In order to do this, we consider the overall change in log agricultural land between 1993 and 2007 using the Landsat data. The median change in log of agricultural land in these data is .0001 while the mean is 0.111. To limit the influence of outliers, we use the rank of the ejidos in the distribution of change in cultivated land.[25] The first two columns of Table 7 repeat the fixed effects regression of locality population on whether the ejido has been certified separately for the localities with agricultural land use change below and above the median value. The table shows that the negative effect of certification on population size is much stronger in localities that also saw the largest decreases in agricultural land. Column (3) shows that localities with the most pronounced declines in agricultural land ($rank$ =0) experienced a decline in population of 9.2% in response to certification, while ejidos with the largest increases in agricultural land saw no significant effect of certification on population.

In summary, in areas of low land quality, certification induced a strong migration response accompanied by a decline in cultivated land. In more favorable land quality regions, only the less well endowed households responded with migration, while the larger farmers did not migrate, and total land in agriculture increased slightly.

5.7 Alternative mechanisms from certification to migration

While the view taken in this paper has been that the increased migration caused by land certification is a result of relaxing the land use constraint, there is an alternative mechanism that would also

[24] As a robustness check on the resolution of the Landsat images, we ran all the regressions in Table 6 after dropping the smallest 5% of ejidos. The coefficients change only minimally and statistical significance is unaffected (results not reported).

[25] The value of the variable Rank corresponds to the empirical distribution function of the change in the logarithm of agricultural land.

be consistent with increased migration. Namely, land certification could have relaxed liquidity constraints by allowing poor households to sell or rent their land and use those funds to finance migration.[26] While this would not invalidate the link between certification and migration, it refers to a completely different cause of increased migration. In particular, it would imply that credit constraints were the critical factor holding people in agriculture, not the land use requirement.

One way to distinguish between these two competing explanations is by taking advantage of the Progresa experiment. Progresa randomly allocated cash transfers across villages in our sample to poor households equivalent to 140% of monthly food consumption per adult (Angelucci and De Giorgi, 2009). Because the cash payments were awarded to the poorest families, Progresa would have alleviated liquidity constraints in households where the restriction was more likely to be binding. Crucially, because these large cash inflows to poor families were occurring *before* certification, liquidity constraints would have been less binding in Progresa treatment villages when Procede arrived. Hence if the liquidity constraint story is correct, we should observe *smaller* effects of certification in Progresa treatment villages. We test for this by estimating the following regression:

$$y_{ijt} = \delta_1 Certif_{jt} + \delta_2 Certif_{jt} * Progresa_j + \gamma_j + \alpha_t + \varepsilon_{ijt}. \tag{13}$$

The specification is similar to our main specification in Table 1. The only difference is that in this specification we test whether the migration response is differentiated according to Progresa treatment status. Note that the because of the ejido fixed effects, the specification allows for Progresa to have a direct effect on migration (these are explored in Stecklov et al. (2005) and Angelucci (2012a)).[27] The specification does impose the same time trends for both groups. We relax this assumption by also showing a specification which adds Progresa-treament specific time trends.

$\delta_2 < 0$ would be evidence that liquidity is the mechanism causing certification to increase migration. The results in columns (1) and (2) of Table 8 do not support this story. If anything, the migration effect is *larger* in Progresa treatment villages. In Column 1, the certification effect in Progresa control villages is .006 and that in treatment villages is .021. The difference between control and treatment villages is economically large, *positive*, but not statistically significant (p =0.25). The same story holds in column (2) where we allow for differential time trends in Progresa treatment villages. We hence reject the hypothesis that liquidity was the factor holding back households in ejidos.

5.8 Rural labor markets

Hiring outside labor was technically illegal prior to Procede. It is possible then that ejido households substituted hired labor for family labor, thus allowing family members to migrate. However, recall

[26] In the context of Mexico, McKenzie and Rapoport (2007) have shown that migration to the U.S. is related to wealth.

[27] We use ejido fixed effects to maintain consistency with our previous specification. The direct effect of Progresa on migration is fully absorbed when locality fixed effects are used. Since the match between localities and ejidos is near one to one, the results of these two specifications are very similar.

that the estimates from the locality level regressions (which correspond to net migration) were of similar order of magnitude to the individual household estimates. This suggests that substituting hired labor for family labor was not an important phenomenon in the data.

We can nonetheless inquire whether Procede led to more efficient rural labor markets. Benjamin (1992) shows that frictions in rural labor markets generate non-separation between production and consumption decisions. In our context, the correlation between household size and the amount of land cultivated can be expected to decrease after the completion of Procede. The intuition is that a large labor endowment was necessary to cultivate a large amount of land prior to the program. If the program had a significant impact on the labor market, then this correlation should decrease after completion of Procede. We estimate:

$$Hectares_{ijt} = \beta_0 Certif_{jt} + \beta_1 Adults_{ijt} + \beta_2 Adults_{ijt} * Certif_{jt} + \gamma_j + \mu_t + x_{ijt}\alpha + \varepsilon_{ijt}, \quad (14)$$

where $Hectares_{ijt}$ is land cultivation and $Adults_{ijt}$ is the time-varying number of adults in the household. A negative and significant estimate of β_2 would suggest an increased separation between the household as a firm and the household as a consumer, which would be interpreted as working through rural labor markets. The estimate in Column (3) of Table 8 shows that the correlation between household size and cultivation does not decrease significantly after program completion. Thus the data are consistent with the certificates liberating family labor from the farm, but not with hiring in of workers to substitute for family labor.

6 Internal validity checks

We present several tests that support the validity of the identifying assumptions of the paper. The main threat to identification in the Progresa dataset is correlation between the timing of Procede and the time-path of migration in the ejido. The estimated average program effect would be biased if completion of Procede were correlated with pre-program changes in migration. To investigate the possibility of bias in program timing, we use a standard regression of *pre-program* changes in ejido level migration rates on indicators for the year Procede was completed:

$$\Delta y_{jt} = \gamma + \alpha_t + \sum_{k \geq t} \delta_k I(Procede\ Year_j = k) + \varepsilon_{jt} \quad \forall t \leq Procede\ Year_j. \quad (15)$$

The dependent variable Δy_{jt} is the change in the average level of the migrant indicator in ejido j from year $t-1$ to year t. The key independent variables are a set of dummy variables, $Procede\ Year_j = k$, for the year in which the program was completed in the ejido. Since the data cover the years 1997 to 2000, only three such variables are necessary for the ejidos certified in 1999, 2000, or after 2000.[28] *Procede Year* effects that are jointly significant would indicate that year of program completion was correlated with pre-program changes in migration. The results

[28]The base group is composed of ejidos certified in 1998 since we require the ejido to be certified at the start of the year to be considered as certified for that year.

are reported in the online appendix in Table A1 where we report results separately for changes in migration from 1997-1998, 1997-1999, and 1997-2000. Year of program completion does not significantly explain pre-program changes in migration in either of the three regressions. Lack of a significant correlation between the year of Procede completion and changes in ejido level migration rates over time provides evidence that pre-program time trends in migration were not correlated with completion of the program.

Another possibility is that the timing of Procede is correlated with sharp changes in migration prior to the program. If Procede was rolled out in response to sharp declines in migration prior to the program, then our estimate would simply reflect reversion to mean migration levels. Perhaps more likely, if households anticipated the program and reduced migration to oversee the certification process, then post-program returns to normal migration rates would confound our estimate. We estimate the following specification to consider this potential Ashenfelter dip effect (Ashenfelter, 1978):

$$y_{jt} = \gamma_j + \alpha_t + \beta_0 \cdot \textit{(Year of)}_{jt} + \beta_1 \cdot \textit{(Year before)}_{jt} + \beta_2 \cdot \textit{(2 Years before)}_{jt} + \varepsilon_{jt}, \tag{16}$$

where y_{jt} is average migration at the ejido level, and other variables are indicators for the year of, year before, and two years before program completion. The β coefficients indicate whether migration levels were significantly different than average in the ejido during the years directly before the program. Column (4) of Table A1 gives the results of estimating (16). The point estimates are very small and statistically insignificant (the smallest p-value is 0.84), yet the standard errors are large. An ideal result of the regression would be a set of precisely estimated zeros on the three indicator variables. While we cannot reject large coefficients, it is reassuring that there are no obvious significant changes in migration in the years leading up to completion of the program. We interpret the combined results in the table as providing no clear evidence that our identification strategy is biased by correlation between program completion and pre-program migration.

A similar concern with our identification strategy is that anticipation of being certified in the future would lead to a decrease in migration in uncertified ejidos. Our observed increase in migration would then reflect an anticipation effect and not a true migration effect. The results in column (4) of Table A1 are not consistent with a large decrease in migration during the years immediately prior to the program.

Finally, another potential issue of concern is attrition of households from the ENCEL survey. 11.2% of households with an interview completed in 1998 did not have an interview completed in 1999. The percentage rose slightly to 12.7% in 2000.[29] In Table A2 we run the basic regression used to identify the role of Procede on migration, equation (7), on attrition. The coefficient of the certified variable is both insignificant and very small. There is therefore no evidence that the migration effect we estimate could be due to selective attrition.

[29]We define attrition as the interview not being conducted for any purpose.

7 Conclusions

Delinking land rights from land use has been the focus of a number of large land certification programs. In this paper, we showed that if property rights were tied to land use requirements in the previous regime, these policy reforms can induce increased outmigration from agricultural communities. We provided evidence on this phenomenon by analyzing the Mexican ejido land certification program which, from 1993 to 2006, awarded ownership certificates to farmers on about half the country's farm land.

We used three independent datasets to document a strong migration response in agricultural communities where certificates were issued. Families that obtained certificates were subsequently 28% more likely to have a migrant household member and the locality's overall population fell by 4%. The estimated effect increased over time. We documented heterogeneity in migration response according to the ex-ante level of property rights insecurity, level of off-farm opportunities, initial plot size, and land quality.

There is also evidence of sorting within the community: larger farmers stayed, whereas land-poor farmers left, and this effect was starker in high productivity areas. This prompts the question of whether total acreage under cultivation decreased with the program. We found that, on average, cultivated land was not reduced because of the program. However, this masks an interesting heterogeneity. While in low land quality regions agricultural land was reduced, in high land quality regions the certification program led to increases in agricultural land, which we attribute to gains in agricultural labor productivity or increased incentives to invest. Overall, the evidence shows that certification of ownership increases the efficiency of labor allocation across space by inducing low productivity farmers to migrate, while leaving higher productivity farmers in place and allowing them to consolidate land. Because smallholder farmers are the ones most likely to leave after certification, efficiency gains are accompanied by immediate benefits for them. These results are most consistent with a model where the key constraint imposed by insecure property rights is the requirement of continued presence. The empirical evidence is not consistent with alleviation of liquidity constraints being the mechanism explaining the increase in migration.

The literature on property rights focuses on investment and increased access to credit as key pathways between rural land reform and economic growth (Galiani and Schargrodsky, 2011). Outmigration from rural areas has only recently received attention. Our results suggest that the permanent reallocation of labor between sectors of the economy can be an equally important pathway resulting in the effects of agricultural land reform extending beyond rural areas. The importance of low agricultural labor productivity in explaining low aggregate output across countries suggests that enhancing agricultural labor productivity can possibly have large effects (Restuccia, Yang, and Zhu, 2008). Removing the barriers to migration through property rights reforms is one way to achieve this. An important policy implication of our results is thus that improvement of property rights through formal land certification can have not only direct effects on investment, land markets, and land use patterns but also indirect effects on the spatial performance of labor markets, resulting in particular in large flows of rural migrants.

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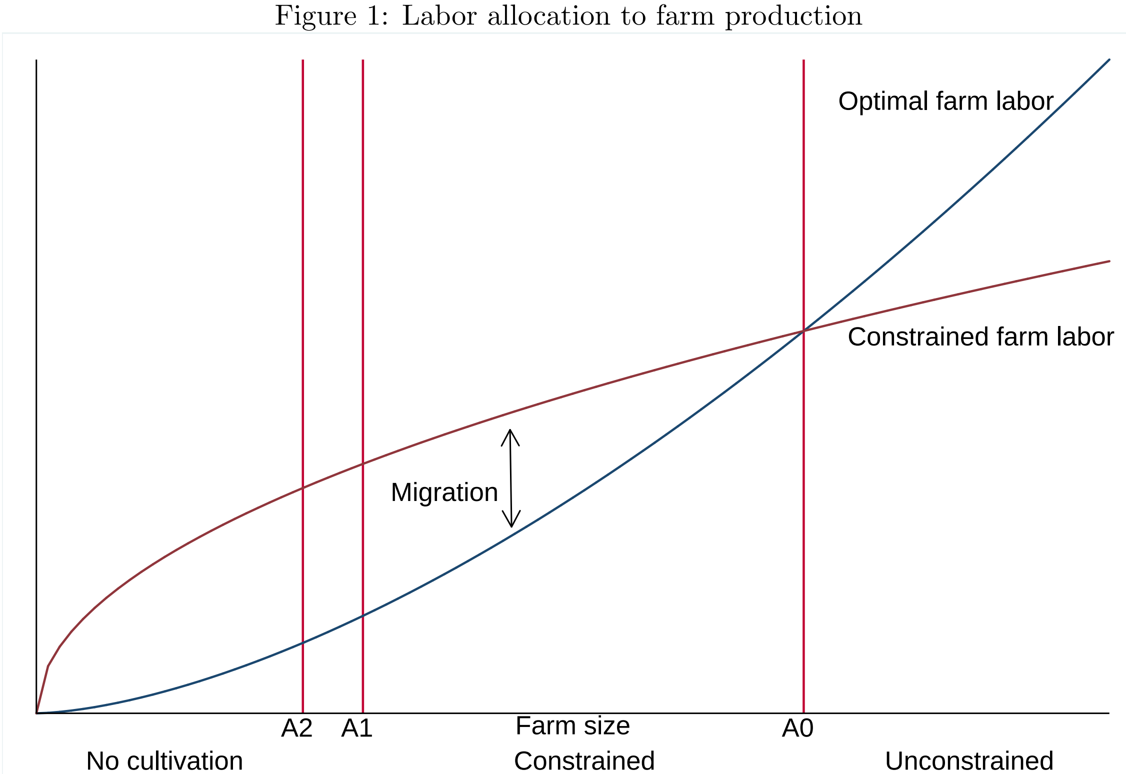
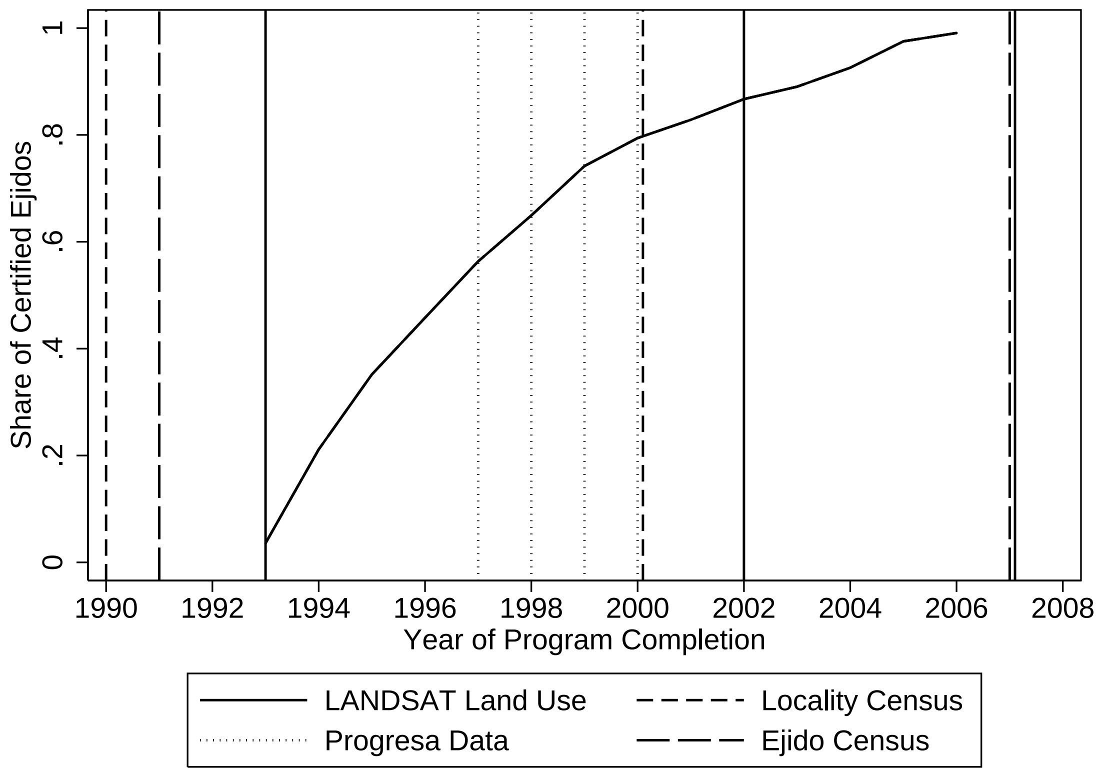
Figures and Tables

Figure 1: Labor allocation to farm production



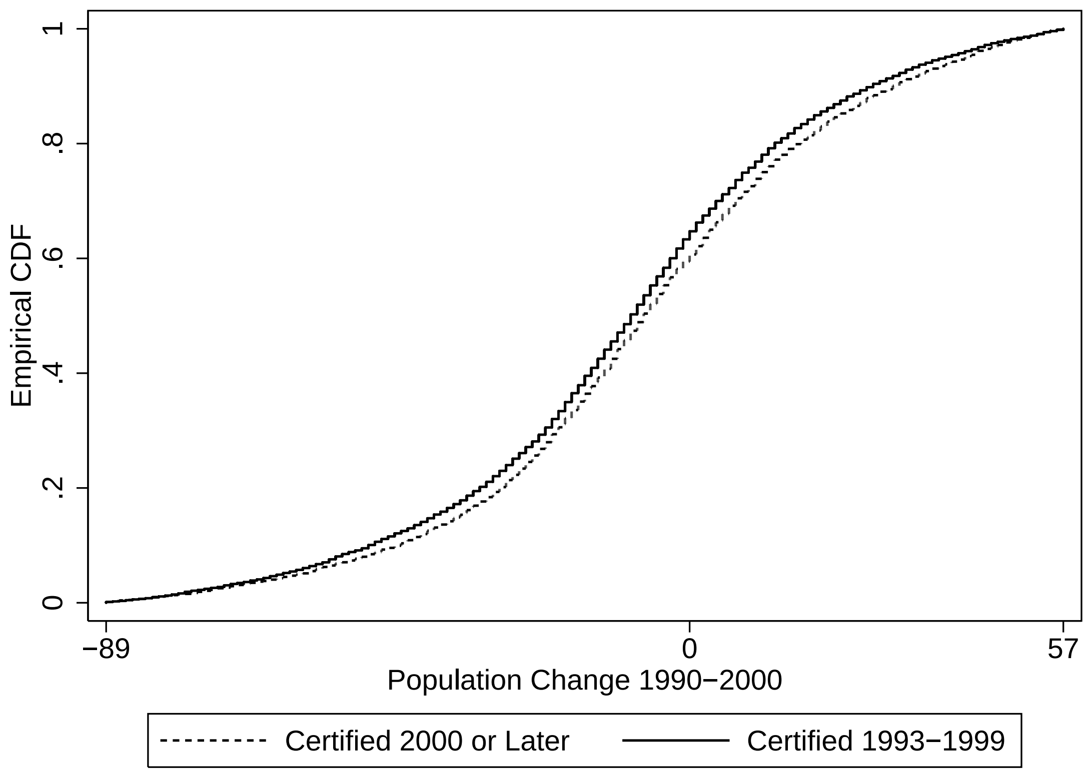
Notes: Figure shows the optimal agricultural labor schedule as a function of farm size. *Optimal farm labor* is labor use under the title-based regime. *Constrained farm labor* is labor use under the minimum production constraint. See Section 3 for other details on theoretical model.

Figure 2: Correspondence between data and rollout of Procede



Notes: Figure shows cumulative share of ejidos certified over time. Vertical lines represent observations for each of the datasets used in the analysis. The Progresa ENCEL data are from 1998-2000. Migration recall data were used for 1997. Locality level census data are from 1990 and 2000. Ejido level census data are from 1991 and 2007. LANDSAT land use data are from 1993, 2002, and 2007.

Figure 3: Cumulative distribution of population change, 1990-2000, by certification date



Notes: Figure displays empirical CDF of population change (in levels) from 1990-2000. Data used are the 1990 and 2000 locality-level population censuses.

Table 1: Effect of Procede on household migration behavior

	Progresa Households Matched to Ejidos					
	(1) Has Migrant	(2) Has Migrant	(3) Has Migrant	(4) Has Migrant	(5) Has Migrant	(6) Has Migrant
Certified	0.0149^{**}	0.0158^{**}	0.0153^{**}	0.0172^{***}	0.0157^{**}	0.0130^{**}
	(0.0061)	(0.0064)	(0.0062)	(0.0059)	(0.0063)	(0.0062)
HH is Landholder		0.0136^{***}			0.0048	
		(0.0044)			(0.0053)	
Number Males 17-30 in HH		0.0195^{***}			0.0088^{**}	
		(0.0046)			(0.0037)	
HH Head is Female		0.0127			0.0092	
		(0.0101)			(0.0082)	
Age of HH Head		0.0009^{***}			0.0004^{***}	
		(0.0002)			(0.0001)	
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Ejido Fixed Effects	Yes	Yes	No	Yes	Yes	Yes
HH Fixed Effects	No	No	Yes	No	No	No
State x Time Effects	No	No	No	Yes	No	No
HH Characteristics x Time Effects	No	No	No	No	Yes	No
Ejido Characteristics x Time Effects	No	No	No	No	No	Yes
Mean of Dep Variable	0.053	0.056	0.053	0.053	0.056	0.053
Number of Observations	27189	24533	27189	27189	24533	27189
R squared	0.047	0.058	0.043	0.048	0.059	0.048

Standard errors that allow for clustering at the ejido level are reported in parentheses. Asterisks indicate statistical significance at the 1% ***, 5% **, and 10% * levels. Data include observations on all households in ejidos that completed the Procede process after 1996. All regressions are linear probability models. The dependent variable is 1 if the household had a migrant leave during the year or any previous sample year. Certified indicator = 1 if ejido was certified at the start of the year. Ejido characteristics in column 6 are distance to nearest large city (population > 100,000), number of ejidatarios, number of posesionarios + avecindados, total size of the ejido, share of ejido land in parcels, locality marginalization index, longitude, and latitude.

Table 2: Effect of Procede on locality-level population

	Census Localities Matched to Ejidos				
	(1) Population	(2) ln(Population)	(3) ln(Population)	(4) ln(Population)	(5) ln(Population),1980-1990
Year=2000	-9.6309***	-0.2069***	-0.2069***	-0.2069***	
	(1.0014)	(0.0105)	(0.0105)	(0.0105)	
Certified 1993-1999*Year=2000	-3.6893***	-0.0404***	-0.0206		
	(1.1485)	(0.0128)	(0.0195)		
Years Certified in 2000*Certified 1993-1999*Year=2000			-0.0054		
			(0.0039)		
Certified Before 1997*Year=2000				-0.0592***	
				(0.0144)	
Certified 1997-1999*Year=2000				-0.0196	
				(0.0151)	
Year=1990					-0.2094***
					(0.0125)
Certified 1993-1999*Year=1990					-0.0082
					(0.0148)
Ejido Fixed Effects	Yes	Yes	Yes	Yes	Yes
Mean of Dep Variable	99.111	4.271	4.271	4.271	4.416
Number of Observations	34656	34656	34656	34656	24910
R squared	0.014	0.035	0.036	0.036	0.033

Standard errors that allow for clustering at the ejido level are reported in parentheses. Asterisks indicate statistical significance at the 1% ***,5% **, and 10% * levels. Regressions in columns 1-4 based on 17,328 localities that were matched to ejidos, had population data in both the 1990 and 2000 censuses, and had a population of more than 20 individuals in 1990. Regression in column 5 is based on 12,455 localities with available population data in 1980 and with a population larger than 20 in 1980.

Table 3: Effect of Procede on ejido-level migration of young people

	Matched Ejidos in 1991 and 2007 Ejido Census			
	(1) Migrate	(2) Migrate	(3) Migrate US	(4) Migrate US
Years Certified in 2007	0.0035***	0.0039***	0.0037***	0.0031***
	(0.0013)	(0.0013)	(0.0012)	(0.0012)
Using Improved Seeds in 1991		-0.0178*		0.0009
		(0.0100)		(0.0095)
Using Tractors in 1991		-0.0048		0.0123
		(0.0105)		(0.0104)
Electrical Lighting in 1991		0.0384***		0.0514***
		(0.0108)		(0.0110)
Log of Distance Between Ejido and PA Office		0.0528***		0.0110
		(0.0113)		(0.0113)
State Fixed Effects	Yes	Yes	Yes	Yes
Mean of Dep Variable	0.426	0.426	0.297	0.297
Number of Observations	19670	19600	19670	19600
R squared	0.086	0.092	0.128	0.131

Standard errors that allow for clustering at the municipality level are reported in parentheses. Asterisks indicate statistical significance at the 1% ***, 5% **, and 10% * levels. The question in the 2007 census identifies the ejidos where a majority of young people are integrated in the activities of the ejido or remain in the ejido but work in nearby localities. If neither of the prior conditions was true, the destination of the majority of the young people is identified. The variable "migrate" takes on a value of 1 if neither of the first two conditions was true. The dependent variable in column 3 and 4 takes on a value of 1 only if the answer to the location of the majority of young people was the United States.

Table 4: Heterogeneous effects of certification on migration

	Progresa Households Matched to Ejidos					
	(1) Has Migrant	(2) Has Migrant	(3) Has Migrant	(4) Has Migrant	(5) Has Migrant	(6) Has Migrant
Certified	0.0138	0.0081	0.0102	0.0096	-0.0028	-0.0041
	(0.0088)	(0.0086)	(0.0063)	(0.0064)	(0.0085)	(0.0093)
Certified*Ejido Had Boundary Problems in 1991	0.0164	0.0278*				
	(0.0142)	(0.0145)				
Certified*HH Head is Female			0.0596**	0.0648**	0.0649**	0.0702**
			(0.0247)	(0.0277)	(0.0252)	(0.0282)
Certified*Above Median Predicted Wage					0.0247*	0.0262*
					(0.0139)	(0.0155)
Above Median Predicted Wage					0.0015	0.0010
					(0.0056)	(0.0056)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Ejido Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Time Effects*HH Head is Female	No	No	No	Yes	No	Yes
Time Effects*Ejido Had Boundary Problems in 1991	No	Yes	No	No	No	No
Time Effects*Above Median Predicted Wage	No	No	No	No	No	Yes
Mean of Dep Variable	0.057	0.057	0.056	0.056	0.056	0.056
Number of Observations	21090	21090	24533	24533	24513	24513
R squared	0.060	0.060	0.059	0.059	0.059	0.060

Standard errors that allow for clustering at the ejido level are reported in parentheses. Asterisks indicate statistical significance at the 1% ***, 5% **, and 10% * levels. Data include observations on all households in ejidos that completed the Procede process after 1996. All regressions are linear probability models. Dependent variable = 1 if the household had a migrant leave during the year or any previous sample year. Certified indicator = 1 if ejido was certified at the start of the year. All regressions include landholder indicator, age of household head, indicator for female household head, and number of males between 17 and 30 as controls. *Ejido had boundary problems* is an indicator variable for response of yes to this question during the 1991 ejido survey. *Above Median Predicted Wage* = 1 if the household's predicted maximum off-farm wage is above the median in the sample.

Table 5: Heterogeneity in certification effect according to baseline land

	All Municipalities			High Yield Municipalities		Low Yield Municipalities	
	(1) Has Migrant	(2) Has Migrant	(3) Has Migrant	(4) Has Migrant	(5) Has Migrant	(6) Has Migrant	(7) Has Migrant
Certified	0.0298***	0.0312***	0.0234***	0.0159*	0.0201**	0.0351***	0.0370***
	(0.0097)	(0.0101)	(0.0076)	(0.0090)	(0.0099)	(0.0129)	(0.0127)
Certified*High Maize Yield Municipality	-0.0232*	-0.0256**					
	(0.0124)	(0.0126)					
Certified * (Land per Adult > Median in Ejido [1997])			-0.0187*	-0.0240*	-0.0339**	-0.0095	-0.0145
			(0.0097)	(0.0122)	(0.0157)	(0.0157)	(0.0164)
Land per Adult > Median in Ejido [1997]	0.0061	0.0061	0.0098*	0.0134*	0.0035	0.0038	-0.0007
	(0.0051)	(0.0051)	(0.0051)	(0.0073)	(0.0057)	(0.0058)	(0.0045)
Ejido Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Effects*Land per Adult > Median in Ejido	No	No	No	No	Yes	No	Yes
Time Effects*High Maize Yield Municipality	No	Yes	No	No	No	No	No
Mean of Dep Variable	0.056	0.056	0.056	0.057	0.057	0.054	0.054
Number of Observations	24372	24372	24372	14533	14533	9839	9839
R squared	0.058	0.058	0.058	0.052	0.052	0.068	0.068

Standard errors that allow for clustering at the ejido level are reported in parentheses. Asterisks indicate statistical significance at the 1% ***, 5% **, and 10% * levels. Dependent variable in all regressions is 1 if the household is a migrant household. All regressions are linear probability models. Certified indicator = 1 if ejido was certified at the start of the year. All regressions include age of household head, indicator for female household head, and number of males between 17 and 30 as controls. Columns 1, 2 and 3 are for all matched ejidos in the Progresa sample. Columns 4 and 5 are for ejidos in municipalities with average maize yields above 1.293 tons/hectare. Columns 6 and 7 are for ejidos in municipalities with average maize yields below 1.293 tons/hectare.

Table 6: Effect of Procede on agricultural land use

	Progresa Data	LANDSAT Satellite Data		
	(1)	(2)	(3)	(4)
	Herfindahl	Log(Area Ag.)	Log(Area Ag.)	Log(Area Ag.)
Certified	0.0268	0.0013	-0.0080	-0.0175
	(0.0320)	(0.0093)	(0.0108)	(0.0136)
Certified * High Yield Municipality			0.0209**	0.0332*
			(0.0093)	(0.0182)
Ejido Fixed Effects	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes
Time Effects*High Yield Mun	No	No	No	Yes
Mean of Dep Variable	0.116	5.718	5.714	5.714
Number of Observations	506	63392	58763	58763
R squared	0.547	0.012	0.012	0.012

Standard errors that allow for clustering at the ejido level are reported in parentheses. Asterisks indicate statistical significance at the 1% ***, 5% **, and 10% * levels. The dependent variable is the log of the area in agriculture in the ejido. *High Yield* is 1 if average maize yield in the municipality of the ejido is larger than 1.293 tons/ha.

Table 7: Population regressions by change in agricultural area

	Rank>0.5	Rank<0.5	All
	(1)	(2)	(3)
	ln(Population)	ln(Population)	ln(Population)
Year=2000	-0.2285***	-0.1936***	-0.1765***
	(0.0143)	(0.0195)	(0.0239)
Certified 1993-1999*Year=2000	-0.0230	-0.0760***	-0.0924***
	(0.0183)	(0.0232)	(0.0292)
Rank of Ag Change * Year=2000			-0.0705*
			(0.0368)
Rank of Ag Change * Certified 1993-1999 * Year=2000			0.0876*
			(0.0461)
Ejido Fixed Effects	Yes	Yes	Yes
Mean of Dep Variable	4.240	4.324	4.278
Number of Observations	15200	12420	27624
R squared	0.035	0.041	0.038

Dependent variable in all regressions is log of locality population. Standard errors that allow for clustering at the ejido level are reported in parentheses. Asterisks indicate statistical significance at the 1% ***,5% **, and 10% * levels. Data come from the 1990 and 2000 locality population censuses. Localities located in ejidos with no agricultural land during either 1993 or 2007 are excluded from the regressions, thus explaining the difference in observations from Table 2. The first column limits to localities in ejidos that experienced above the median change in log agricultural area from 1993-2007. The second column limits to localities in ejidos that experienced below the median changes. The final column is for all localities in ejidos that had nonzero agricultural land area in both 1993 and 2007.

Table 8: Alternative explanations of migration effect of land certification

	(1) Migration	(2) Migration	(3) Hectares
Certified	0.0065	0.0056	-0.1135
	(0.0085)	(0.0086)	(0.1670)
Certified*Progresa locality	0.0143	0.0153	
	(0.0123)	(0.0123)	
Adults in HH			0.4314***
			(0.0393)
Certified*Adults in HH			0.0296
			(0.0414)
HH Head is Female			-0.4606***
			(0.0741)
Age of HH Head			0.0268***
			(0.0027)
Ejido Fixed Effects	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes
Time Effects*Progresa Locality	No	Yes	No
Time Effects*Adults in HH	No	No	Yes
Mean of Dep Variable	0.054	0.054	2.121
Number of Observations	26690	26690	24211
R squared	0.047	0.047	0.288

Standard errors that allow for clustering at the ejido level are reported in parentheses. Asterisks indicate statistical significance at the 1% ***, 5% **, and 10% * levels. Column 3 drops the top 1% of observations with hectares cultivated of 25 or more.

Appendix - For Online Publication

In this section we provide additional details on construction of some of the data used in the analysis.

Progresa Data

Household level migration was taken from the 1998-2000 fall versions of the ENCEL survey. The survey was conducted each fall from 1998-2000 in the 506 localities that were part of the experimental evaluation of Progresa. Since no ejido identifiers were included in these data, we matched the 506 localities to ejidos using a spatial join in ARCGIS. We only observe the coordinates of the centroid of each locality and therefore match localities to ejidos if the center of the locality is located inside the boundaries of the ejido. The digital maps of all ejidos certified from 1993-2006 were obtained from RAN. The spatial merge resulted in 234 of the localities falling into one of 219 different ejidos.[30] The number of households from the 1998 survey that fell inside ejidos as a result of this process is 13,212. Another 4,893 households were removed from the sample as a result of being in ejidos that were certified before 1997. Since permanent migration is being measured, trends in migration are unlikely to be the same in ejidos certified prior to 1997 as those certified later. These ejidos are removed for this reason. It is also important to note that the spatial matching approach does not result in a perfect match between households and ejidos. It is possible that while the centroid of a locality falls into a particular ejido, the outskirts of the locality fall into a different ejido. This is more likely to be an issue in localities that are large. We used census population data to construct the ratio of the population of the locality to the number of ejidatarios in the matched ejido. The matching is more likely to be inaccurate when the locality is large relative to the ejido. We therefore retained only the 200 localities with the lowest values of this metric. This amounted to removing an additional 742 households from the sample. The total number of ejidos in the sample is 127.

1991 and 2007 Ejido Census

The 1991 and 2007 ejido censuses consist of a set of 28,752 ejidos that were surveyed in both 1991 and 2007. We were unable to obtain the name of each ejido due to confidentiality concerns. Further, the 2007 census did not contain information on the time of completion of Procede. A matching process was therefore necessary to make these data usable. The key information used were the state, municipality, and name of the locality where the majority of the ejidatarios live. We used this information along with some common key variables between the census data and the GIS database from RAN to match ejidos based on a 4-step process:

1. There were 22,473 ejidos for which the locality where a majority of the ejidatarios live is located inside the boundaries of the ejido. For these ejidos we were able to use our spatial

[30] This number is roughly consistent with half of Mexico's land being in ejidos. The large number of localities that were not matched to ejidos is therefore not a concern. The matching rate of 46% is actually in line with 50% of land being in ejidos.

merge between localities and ejidos to identify the corresponding ejido in the GIS database. There are of course numerous instances where the boundaries of an ejido contain more than one locality centroid. We were unable to include these ejidos in this matching round. This round matched a total of 14,128 ejidos.

2. The second round of matching is meant to partially correct for the fact that matching localities to ejidos in the previous step using only the centroid of the locality is imperfect. The reason for this is that the centroid of the locality could fall outside of the boundaries of the ejido even if there is substantial overlap between the locality and ejido. Further, ejidos with multiple disjoint patches of land pose problems to matching based on locality centroids and ejido boundaries. The distance between the locality centroid for each unmatched census ejido and the center of each unmatched ejido from the GIS database was calculated using a simple distance calculation in ARCGIS. An ejido from the GIS data was matched to an ejido from the census data if the locality where the majority of the ejidatarios live was the closest locaelity to the center of the ejido. Since this match is not perfect, we attempt to minimize errors by only retaining matches where the percentage difference between the number of ejidatarios in the 1991 census and the GIS database was between -46.8% and 29%.[31] This round generated an additional 1,787 matches.

3. In this round we considered the remaining unmatched ejidos for which the locality where the majority of the ejidatarios live is located inside the boundaries of the ejido. We defined a potential candidate match from the GIS database as an unmatched ejido that was located in the same state and municipality. For each of these potential matches we considered 4 metrics of comparison. The first was the similarity between the name of the locality where the ejidatarios live and the name of the ejido in the GIS database.[32] We generated a spelling similarity index using a combination of the COMPARE and SPEDIS functions in SAS. A match was identified for sufficiently low values of this index. The second metric was the distance between the centroid of the locality and ejido. The ejidos were considered to match if the distance was less than 5.1 kilometers.[33] The third metric was the number of ejidatarios. A match was determined using the same cutoffs as in the previous round. The final metric was the difference between the size of the ejido (in hectares) in the two datasets. The percentage cutoffs were -32.4 and 41.6. We required at least two of these criteria to be satisfied to identify a match between the ejidos. For each census ejido we selected the ejido from the GIS database which matched on the most of these criteria (from 2 to 4). In order to break ties we used the percentage difference in the number of ejidatarios. This round generated a total of 1,878 matches.

4. The fourth round of matches considers the census ejidos where it was stated that the locality

[31] These numbers were chosen as the 10th and 90th percentiles of the percentage difference from the ejidos matched in the previous round.

[32] It is common for ejido names to be the same as locality names in Mexico.

[33] This value was chosen since it was the 10th percentile in the list of candidate matches.

where the majority of ejidatarios live is *not* inside the boundaries of the ejido. We used a similar process as in the previous round with only two modifications. First, similarities between the name of the locality and the ejido were not used. Second, the distance requirement was relaxed to 8.6 kilometers (25th percentile). This round generated 1,920 matches.

Table A1: Relationship between Procede and pre-program migration

	Progresa Households Matched to Ejidos, Pre-Program Period			
	(1) Δ Migration,97-98	(2) Δ Migration,97-99	(3) Δ Migration,97-00	(4) Migration,97-00
Procede Completed in 1999	-0.0011			
	(0.0113)			
Procede Completed in 2000	-0.0040	-0.0087		
	(0.0110)	(0.0092)		
Procede Completed After 2000	-0.0131	-0.0102	0.0015	
	(0.0090)	(0.0086)	(0.0046)	
Year Procede Completed (0/1)				0.0018
				(0.0150)
Year Before Procede (0/1)				-0.0021
				(0.0107)
2 Years Before Procede (0/1)				-0.0015
				(0.0089)
Time Fixed Effects	No	Yes	Yes	Yes
Ejido Fixed Effects	No	No	No	Yes
Mean of Dep Variable	0.022	0.020	0.018	0.050
Number of Observations	111	187	225	406
Number of Ejidos	111	94	76	127
R squared	0.047	0.019	0.002	0.774
Pvalue of joint test	0.190	0.493		

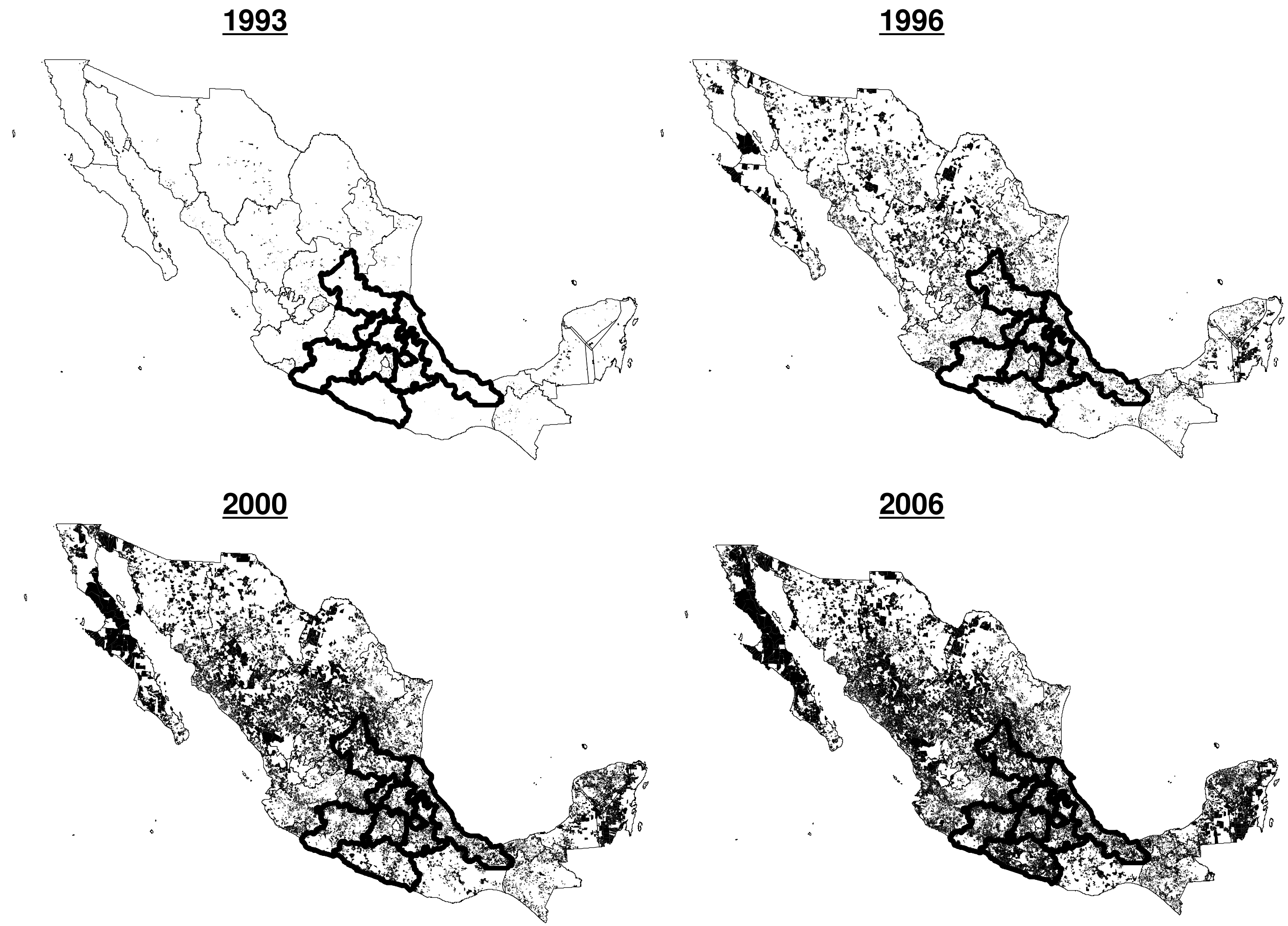
Standard errors are reported in parentheses. Robust standard errors are used in column 1. In columns 2-4, standard errors are clustered at the ejido level. Asterisks indicate statistical significance at the 1% ***, 5% **, and 10% * levels. The dependent variable in columns 1-3 is the change in ejido migration rate. The dependent variable in column 4 is the ejido migration rate. Both regressions are for the pre-treatment period. Columns 1 is for for 1998. Column 2 is for 1998-1999. Column 3 is for 1998-2000. Column 4 is for 1997-2000.

Table A2: Regressions of attrition on certification status and household covariates

	(1) Attrition
Certified	-0.003
	(0.025)
HH is Landholder	-0.043***
	(0.010)
Number Males 17-30 in HH	0.005
	(0.004)
HH Head is Female	0.030**
	(0.012)
Age of HH Head	-0.000
	(0.000)
Ejido Fixed Effects	Yes
Time Fixed Effects	Yes
Mean of Dep Variable	0.112
Number of Observations	12895
R squared	0.115

Standard errors that allow for clustering at the ejido level are reported in parentheses. Asterisks indicate statistical significance at the 1% ***, 5% **, and 10% * levels. Data are for all households that were surveyed in the Fall 1998 ENCEL survey. Observations are from 1999 and 2000. Dependent variable = 1 if household did not have survey completed. Certified indicator = 1 if household had a certificate at the start of the year. 446 households attrited in 1999 but not in 2000. 331 households attrited in both 1999 and 2000. 554 households attrited in 2000 but not in 1999.

Figure A1: Rollout of Procede across time and space



Notes: Shaded ejidos are those that completed the Procede program during or before the listed year. States with bold outlines are 7 Progresa states for which we have migration outcomes (Guerrero, Hidalgo, Michoacan, Puebla, Queretaro, San Luis Potosi, and Veracruz).