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Gabriel Ivan Fuentes Cordoba

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Center for Data Science and Service Research
Graduate School of Economic and Management
Tohoku University
27-1 Kawauchi, Aobaku
Sendai 980-8576, JAPAN

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Gabriel Ivan Fuentes Cordoba†

Abstract

This study estimates the effects of land property rights on agricultural productivity in Panama. By using district-level panel data from 1990 to 2010, I find that land privatization increases rice yield in agricultural labor-intensive districts, but does not have any significant impact in non-agricultural labor-intensive districts. Then, by using household-level data, I find that households with registered land titles are more likely to obtain an agricultural loan and undertake land-attached and land mobile investment.

(JEL O13, O15)

Keywords: Property rights, agricultural productivity, Panama, panel data, investment

1 Introduction

Land property rights are key to improving the use of land resources, encouraging higher levels of investment and credit, and maximizing allocative efficiency. Empirical evidence suggests that land tenure affects productivity through three main channels: investment, borrowing, and land transfer. The idea that tenure security can positively affect agricultural output is hardly controversial. Previous studies dealing with the effects of land property rights have offered insight into how secure land rights can affect the agriculture sector.[1]

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†Tohoku University, Graduate School of Economics and Management, Address: 27-1 Kawauchi, Aoba-ku, Sendai, Miyagi 980-8576 JAPAN, gfuentescordoba@gmail.com

[1]See Deininger and Feder (2009) for a review of the impact of land registration on investment and productivity.

First, secure land rights provide incentives to farmers to invest and use land productively, as farmers believe that investment in and the proper use of land give rise to significant benefits. Second, land can be used as collateral in the formal credit market, depending on the existence of a formal credit market in the first place. Finally, land rights can be transferred, resulting in a more efficient land allocation. Brasselle et al. (2002) refer to these channels as the "assurance," "collateralizability," and "realizability" effects, suggesting that they are the key reasons why complete land rights should encourage investing.

Formal land titling is a common way in which to ensure land tenure rights; however, in the majority of cases, this is expensive and difficult to carry out. The most common way in which to insure land rights is through land titling programs and land reforms, which have been introduced in almost every country in Latin America since the 1960s. Although land reforms have failed to alleviate land inequality and address the lack of land titles in rural households,[2] national governments and international development agencies extensively sponsor land titling programs to improve the use of land in developing countries. Atwood (1990) argues that in Africa there is sufficient evidence to counter the conventional view of land registration because the cost of titling might be high and without the expected effects. However, more recent studies have found evidence that increasing land rights in African countries may indeed improve land tenure security and land-related investment (Fenske, 2010, 2011).

This study focuses on formal land property rights and their effect on agricultural productivity in Panama. I analyze the impact of land title registration to explore the main channels through which property rights affect productivity in the agriculture sector. As in other Latin American countries, agrarian reform and land certification programs have been common in Panama since the 1960s. The first agrarian code was introduced by Law 37 of 1962 and it has since been modified multiple times. This code aims to incorporate people from rural areas into the economic growth process and increase the efficiency of land through land titling. Certification programs are also common in Panama; however, they tend to be highly bureaucratic and without remarkable results. For example, in 1960, 27% of the land used for agriculture purposes was completely titled, whereas in 2010, 49% of this land was titled. In other words, after 50 years of intense struggle as well as different regulations and land authorities, less than half of the land used for agriculture remains improperly registered.

[2]See De Janvry and Sadoulet (1989) for an explanation of the lack of success of land reforms in Latin America.

The impact of land registration programs and land property rights on agricultural productivity and investment incentives has been vastly researched. According to Besley (1995), there are four reasons why complete rights should affect economic activity: property rights strengthen claims to the fruits of investment, improve access to capital, facilitate gains from trade, and reduce unproductive costs. On agricultural productivity, for example, Chankrajang (2015), using partial land rights that cannot be transferred, finds that land security affects labor productivity but has no effect on yields in Thailand.

The empirical findings on land rights and investment have yielded contradictory results. Fenske's (2011) meta-analysis in Western Africa points out that econometric techniques using binary investment measures and studies that control for household-level heterogeneity are unlikely to find an impact of land rights on investment. However, the author finds a strong relationship between land rights and fallowing. Similarly, Goldstein and Udry (2008), using the social and political characteristics of farmers as instrumental variables, find that secure land tenure is associated with higher levels of investment in Ghana. In the case of Latin America, Deininger and Chamorro (2004) estimate the impact of land formalization on investment in Nicaragua. Their findings suggest that properly registered land titles have a significant investment-enhancing impact and that land title registration is associated with an increase in land value, which might have a positive distributional effect. Land titling is also associated with higher levels of investment in Peru (Fort, 2008).

Empirical evidence suggests that an improvement on land rights increases access to credit in countries with formal credit markets. In Thailand, Feder et al. (1988) find evidence that farmers with more secure land rights are able to borrow more than their counterparts. However, studies focused on African countries could not find the same evidence; instead, Migot-Adholla et al. (1991) find that farmers with individual land tenure did not have better access to credit than those with other types of tenure systems. In Central America, better access to credit does not necessarily follow land reforms. In Honduras and Nicaragua, for example, the expansion of land titling reforms did not lead to better access to formal credit. Smallholders have lower credit market participation after titling reforms in Honduras, while in Nicaragua rural financial markets are insufficiently evolved to improve credit access (Boucher et al., 2005).

Higher levels of land security should improve land markets by reallocating land to more efficient users. Boucher et al. (2005), using a descriptive analysis, suggest that land titling reforms activate land rental markets. However, the authors also mention that land rental markets do not affect operated farmland distribution in Central American countries. Another study focusing

on Nicaragua found that large landowners are more likely to purchase land and that this could be for unproductive reasons (Deininger et al., 2003). Further, households without land titles are less likely to rent out land. In other words, the lack of a title is a disincentive to participate in land market activity because of the danger of losing land (Deininger et al., 2003).

The literature on land formalization and registration on investment, access to credit, and land transfer shows that the body of evidence is far from conclusive and even contradictory in some cases. This research therefore aims to contribute to the literature on land rights and agricultural productivity with new empirical findings, exploiting two levels of regionally aggregated data and household-level data. The main findings of this research are as follows. First, land privatization increases rice yield per hectare in agricultural labor-intensive districts in Panama, but has no significant impact in non-agricultural labor-intensive districts. Second, an increase in privately owned land per district is not associated with a rise in labor productivity. Lastly, households with land title deeds that are properly registered are more likely to obtain an agricultural loan as well as undertake land-attached and land mobile investment. To the best of my knowledge, no similar study has evaluated the impact of land registration on agricultural productivity in Panama.

The rest of the paper is organized as follows. Section 2 provides the background. Section 3 describes the data sources, empirical strategy, and descriptive statistics. Section 4 presents the results of land rights and agricultural productivity in Panama. Finally, Section 5 concludes the study.

2 Land reform and privatization movements

Small-scale farmers tend to suffer from land tenure insecurity in Latin America. To solve this issue, land reforms were introduced in a plethora of Latin American countries including Panama. The majority of these reforms were implemented at the beginning of the 1960s under the Inter-American Committee of Agricultural Development, which was created by the United States' Alliance for Progress plan. In the case of Panama, the agrarian reform was institutionalized by Law 37 of 1962. Law 37 of 1962, coupled with more recent acts, aimed to incorporate farmers and people from rural areas of Panama into the economic growth process, with a more equal distribution of land, better access to agricultural credit, and technical assistance to improve their productivity and standards of living.

Law 37 of 1962 explained in detail the role of the Agrarian Reform Commission and encouraged peasants to register their land to increase tenure

security and have easier access to credit. Although the reform was unsuccessful, five years after Law 37 came into force, there was growing demand for land certification. However, only a small number of the land titles requested were granted. In fact, the certification and registration process was highly bureaucratic and it discouraged farmers from obtaining and formally registering their land titles. As in other Latin American countries, the agrarian reform failed to make the structural change needed to improve the agriculture sector, raise the living standards of farmers, and distribute land more equally.

In Latin America, agricultural land distribution is unequal. Lipton (2009) constructs a table of the Gini coefficients of operated farmland to measure household-level farmland inequality for 49 developing countries. According to this table, Panama's farmland Gini coefficient in 1950 was 0.72, whereas by 1990 it had increased to 0.87. In other words, farmland distribution inequality increased after the land reform movements. Only Chile, Paraguay, and Venezuela had larger farmland inequality according to Lipton's table and Panama had the largest land inequality of all Central American countries.

Land reforms have had mixed results according to many studies. Recently, the focus changed towards land titling and certification programs, sponsored by national governments and international development agencies. The main goal of these types of programs is to foster agricultural productivity and provide land property rights to farmers. Panama has received loans from international agencies to implement registration policies, and the percentage of agricultural land with registered titles drastically increased from close to 30% to almost 50% from 1990 to 2010. This rise in land privatization occurred during a period when Panama was politically and economically stable. Furthermore, labor in the agriculture sector decreased sharply from 27% in 1990 to close to 13% in 2010. However, in rural areas of Panama, agriculture remains the most important activity for the majority of households. In fact, the agriculture sector is the second largest employer in the country and it is the most important economic sector in a great number of districts in Panama. However, agricultural productivity is low, specifically seven times lower than productivity in the other sectors in Panama (Hausmann et al., 2016).

Land legislation continues to change in Panama. In 2010, a new land authority was established to administer and regulate land property rights. ANATI (the National Authority of Land), among its many other functions, is in charge of mediating land-related disputes, dictating policies on indigenous peoples' land, and improving the cadastral system. The most updated change that the Agrarian Code suffered was in 2011, regulating agrarian activities, contracts, and sustainable land use. Hence, land regulations are constantly

changing and they are still a polemic topic in Panama.

3 Data and empirical strategy

3.1 Data

The main dataset is taken from Panama's Agricultural Census of 1990, 2000, and 2010, compiled by the National Institute of Statistics and Census of Panama (INEC), the governmental institution that collects, processes, and prepares Panamanian statistics. I also use data from the National Census of Population and Housing of 1990, 2000, and 2010 collected by INEC. The first Agricultural Census in Panama took place in 1950, and the most updated Agricultural Census was held in 2010. The data used in this study are aggregated at the district and corregimiento levels. Panama is divided into provinces, districts, and corregimientos. Figure 1 shows the administrative political division of Panama at the corregimiento level.

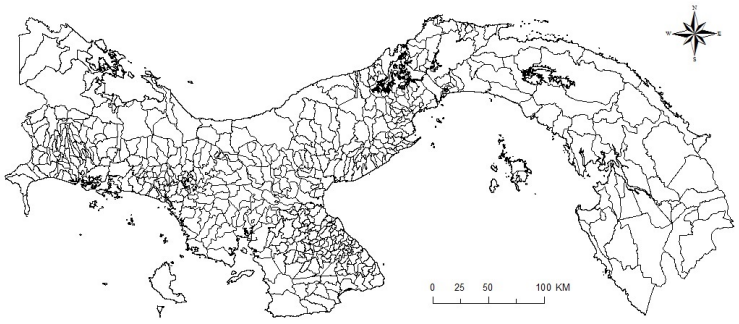
The Agricultural Census offers aggregated data on the number of plots and hectares by province, district, and corregimiento. There were some political changes at the district level during the study period. First, in 1997, Comarca Ngobe Bugle, an indigenous peoples' province, was created. Such provinces are called "Comarcas" in Panama. I omit Comarca districts and all districts that suffered political changes from the creation of the Comarcas because of their special landholding system.[3] Then, in 2001, the district of Montijo was split into two districts. I added the results of the two districts to use them in the panel data analysis.

From 1990 to 2010, Panama suffered a great amount of political change at the corregimiento level. For this reason, only corregimiento-level data are used in the cross-sectional analysis in this research. In 2012, Panama was divided in 621 corregimientos. I drop all corregimientos that do not produce rice and from the metropolitan areas of Colon and Panama.

This study uses the Living Standards Measurement Study (LSMS) to analyze the mechanisms at the household level from 1997 and 2008. The LSMS is a household survey organized by the World Bank and the Ministry of Economy and Finance in Panama. Three independent rounds have been held in Panama, in 1997, 2003, and 2008. The data are pooled cross-sectional data.

[3]Comarcas are the indigenous areas in Panama. The main land tenancy system in these areas is collective landholdings; therefore, they are not included in this research.

Figure 1: Townships in Panama



Note: Panama at the township level in 2010. Panama had 621 townships according to the Statistics Bureau of Panama.

3.2 Empirical strategy for the baseline analysis

To investigate the impact of privately owned land on agricultural productivity, this study uses district-level panel data with fixed effects from 1990 to 2010 in Panama.

To measure the impact of land property rights on agricultural output, the specification is

$$y_{dt} = \alpha_d + \beta_t + \gamma x_{dt} + \varphi z_{dt} + \varepsilon_{dt} \tag{1}$$

where y_{dt} is the log of agricultural yield. α_d is the district fixed effect and β_t represents the year fixed effect. x_{dt} is complete land rights, defined as the share of privately owned land to the total land used for agricultural activities and z_{dt} represents the time-variant control variables.

The main variable used to capture the effect of land property rights at the district level is the share of privately owned land. I define this as the share of land used for agricultural purposes by district where the owner possesses the title deed formally registered to the legal authority (Registro Publico de Panama). I use two proxies for agricultural productivity: rice land yield and labor productivity. Rice yield is defined as rice harvested (in hundredweight) divided by the area of net rice sown (in hectares) per

district. Labor productivity is defined following Chankrajang (2015) as rice harvested (in hundredweight) divided by the number of farmers by district. Not all farmers are rice producers, but this variable is created under the assumption that the percentage of rice producers is constant over time.[4] Rice is a staple grain in Panama and is produced in every district. No other crop is cultivated in every district. Then, the share of privately owned land measures the impact of land certification and registration on agricultural productivity.

This study's empirical strategy could be argued to suffer from endogeneity such as reverse causality. For example, districts that are poor, less productive, or with lower levels of investment may attract government attention to implement land registration policies. However, these are, to some extent, time-invariant characteristics; thus, using fixed effects at the district level mitigates this concern. Another issue of the strategy adopted in this study is that land registration may correlate with unobservable district-specific characteristics that also affect agricultural outcomes. I deal with this endogeneity concern by including important district-specific control variables at the district level.

The specification might also suffer from within-district heterogeneity. To solve this issue, I use cross-sectional data at the corregimiento level. Using data from 2010 permits the inclusion of more control variables.[5] The cross-sectional corregimiento specification is as follows:

$$y_i = \alpha + \beta x_i + \gamma z_i + \varepsilon_i \tag{2}$$

where y_i is the log of rice yield. As before, rice yield is defined as rice harvested (in hundredweight) divided by the area of net rice sown (in hectares) per corregimiento. x_i is complete land rights, defined as the share of privately owned land to the total land used for agricultural activities and z_i represents the time- variant and -invariant control variables.

A more disaggregated level of data than the household level is arguably preferred to study the impact of land certification and registration. Therefore, I use household-level data to explore some of the possible mechanisms

[4]Chankrajang (2015) argues that rice cultivation requires a specific skill, fixed investment, and long-term preparation. Then, the share of rice farmers in a district could be constant. Using the logarithmic form and fixed effect,
$\log\left(\frac{riceproduction_{it}}{ricefarmers_{it}}\right) = \log(riceproduction_{it}) - \log(ricefarmers_{it})$
$\log\left(\frac{riceproduction_{it}}{ricefarmers_{it}}\right) = \log(riceproduction_{it}) - \log(\phi_i farmers_{it})$
$\log\left(\frac{riceproduction_{it}}{ricefarmers_{it}}\right) = \log(riceproduction_{it}) - \log(\phi_i) - \log(farmers_{it})$
where $\log(\phi_i)$ is captured as the district fixed effects.

[5]More data are available in 2010 than in 1990.

Table 1: Descriptive statistics

			District level 1990–2010		
	Rice yield (cwt per ha)	Share of privately owned land	Total land (ha)	Farmers	Rice produced per farmer
Mean	36.11	0.42	43063.13	2646.52	34.67
Standard deviation	23.72	0.22	48624.38	2205.83	67.69
Maximum	103.34	0.87	497746.6	10519	554.34
Minimum	5.65	0.01	384.53	103	0.17
Mean in:					
1990	32.71	0.32	46634.44	3121.16	23.61
2000	35.86	0.38	43869.38	2505.84	39.32
2010	39.74	0.54	38685.57	2312.57	41.07
	Log of rice yield	Pop. density	Illiteracy %	Log of labor productivity	Workers in agriculture %
Mean	3.38	88.27	13.47	2.50	45.1
Standard deviation	0.64	309.83	9.25	1.46	22.96
Maximum	4.64	2771.7	50.4	6.32	83.99
Minimum	1.73	2.4	1.6	-1.79	1.25
			Corregimiento level 2010		
	Rice yield (cwt per ha)	Share of privately owned land	Total land (ha)	Farmers	Rice produced per farmer
Mean	32.46	0.54	4781.02	375.90	50.38
Standard deviation	34.26	0.26	5830.53	352.53	172.35
Maximum	420.46	0.99	58430.34	2546	2219.44
Minimum	0.12	0	112.17	14	0.01
	Log of rice yield	Pop. density	Illiteracy %	Rainfall	Log of labor productivity
Mean	3.16	87.06	10.28	33406.55	1.96
Standard deviation	0.79	268.04	6.73	1930.47	1.94
Maximum	6.04	3734.2	33.26	33836	7.70
Minimum	-2.09	0.3	1.08	1280.4	-4.95

through which land registration affects agricultural productivity: loans, land-attached and mobile investment, and low cost investment. I explain the empirical strategy at the household level in Section 4.2.

3.2.1 Descriptive statistics

Table 1 shows the summary statistics of the main variables at the district and corregimiento levels. The upper part of Table 1 shows the summary statistics for the district-level data from 1990 to 2010, while the lower part indicates the descriptive statistics at the corregimiento level in 2010. At the district level, between 1990 and 2010, mean rice yield was 36.11 cwt per hectare. The district with the highest productivity yielded 103.34 cwt per hectare, while the least productive one yielded 5.65 cwt per hectare. From 1990 to 2010, rice productivity steadily increased and so did the share of privately owned land at the district level. The corregimiento-level data show similar patterns to the district-level data; however, the dispersion of the results tends to be higher.

4 Results

4.1 Effects of land title registration on agricultural productivity

This section presents the results of the empirical specification in equation (1) and equation (2). Table 2 shows the baseline results, using the district-level panel data. The coefficient of the share of privately owned land in Column 1 indicates that an increase in land privatization raises rice land yield after including the year and district fixed effects that control for year shocks, time-invariant geographical characteristics, and labor market opportunities that might affect the results. The coefficient of privately owned land loses its significance in Column 2 when I include important time-variant district characteristics as population density, illiteracy percentage, and median income. The population density coefficient is positive but not statistically significant. Illiteracy measures human capital and the coefficient is negative and statistically significant. Lastly, median income measures the income status of an average household in a district and it does not have a significant effect in Column 2.

In Column 3, I repeat the analysis in Column 2, but this time I restrict the sample to agricultural labor-intensive districts. I divide the aggregated data into two groups, agricultural labor-intensive and non-agricultural labor-intensive districts. In the dataset, the median value of the share of workers in the agriculture sector is around 45% and 42% per district and corregimiento, respectively. For this reason, I define agricultural labor-intensive areas as those areas where farmers represent 40% or more of the total working population. The coefficient of the share of privately owned land is positive and statistically significant in Column 3, indicating that an increase in land privatization raises rice land yield in agricultural labor-intensive districts. In Column 4, I use non-agricultural labor-intensive districts and the coefficients are negative but not statistically significant. In sum, Panel A of Table 2 implies that agricultural labor-intensive districts with a higher share of complete land rights show a greater improvement in rice output per cultivated area.

Panel B of Table 2 shows the effects of land rights on labor productivity. The coefficient of the share of privately owned land in Column 5 is positive, but not statistically significant after including the fixed effects. In Column 6, I add the time-variant control variables to the fixed effects and again the coefficient of the share of privately owned land is not statistically significant. Similarly, in Column 7, the coefficient of the share of privately owned land is not significant in agricultural labor-intensive districts. In Column 8, I

restrict the sample to non-agricultural labor-intensive districts and, similar to Column 4, the coefficient is negative and not statistically significant. These results indicate that there is not a statistically significant impact of land privatization on labor productivity.

Table 2: Effects of land titling on log yield, 1990–2010

	A: Log rice yield				B: Log labor productivity			
	Whole dataset	Whole dataset	Farmers>40%	Farmers<40%	Whole dataset	Whole dataset	Farmers>40%	Farmers<40%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Share of privately owned land	0.401*	0.427	0.481*	-0.539	0.193	0.08	0.265	-0.539
	(0.237)	(0.277)	(0.254)	(0.585)	(0.381)	(0.468)	(0.393)	(0.585)
Population density		0.0003	0.005	0.0001		-0.001***	0.004	0.000
		(0.0003)	(0.021)	(0.0004)		(0.0003)	(0.034)	(0.0004)
Log median income		-0.154*	-0.135	-0.137		-0.553***	-0.457***	-0.137
		(0.092)	(0.106)	(0.421)		(0.026)	(0.17)	(0.421)
Illiteracy percentage		-0.021*	-0.012	-0.081		-0.092***	-0.063***	-0.081
		(0.011)	(0.012)	(0.065)		(0.026)	(0.019)	(0.065)
District FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	171	171	101	70	171	171	101	101
Adjusted R-squared	0.144	0.01	0.077	0.07	0.001	0.031	0.005	0.07

Note: Robust standard errors are in parentheses.
***, **, and * stand for significance at 1%, 5%, and 10%. FE means fixed effects.

Panel A and Panel B of Table 2 measure different types of rice productivity. The results in Table 2 indicate that in agricultural labor-intensive districts with a higher share of land security measured by land registration, land productivity is statistically significantly higher but labor productivity is not. It might seem baffling that land registration affects land yield but has no effect on labor productivity in agricultural labor-intensive districts. However, this difference indicates that in agricultural labor-intensive districts, land registration changes land allocation to more productive farmers, promotes land reallocation to different activities, and increases investment that makes land more productive.

4.2 Robustness check: Land privatization on land yield

While the share of privately owned land has a statistically significant positive relationship with rice yield in agricultural labor-intensive districts, the relationship is not statistically significant in non-agricultural labor-intensive districts. To provide a robustness check of these results, I explore the effect of the share of privately owned land per corregimiento on rice yield. Corregimiento is a less disaggregated level of data than district, allowing us to control for within-district heterogeneity. As this is a cross-sectional analysis, the results of these estimations have to be taken with caution because of endogeneity concerns related to time-variant and -invariant unobservable characteristics. I mitigate this issue by including variables that control for meteorologic, demographic, and income characteristics in each corregimiento. I also include variables that indirectly control for soil characteristics.

The results in Column 1 of Table 3 show that the coefficient of the share of privately owned land is positive and significant at the 1% level, highlighting that an increase in land privatization is associated with a rise in rice yield. Column 1 also shows that an increase in rainfall by corregimiento decreases rice yield. Furthermore, the coefficient of the share of irrigated land is negative and statistically significant, indicating that an increase in the share of irrigated land by corregimiento decreases rice productivity. The most common type of rice cultivation in Panama is upland rice. Upland rice is highly dependent on the weather conditions and type of soil. In Panama, corregimientos with higher shares of irrigated rice might have less suitable characteristics for rice production. Another statistically significant control variable in Column 1 is the share of mechanized land: an increase in the share of mechanized land is associated with a rise in rice yield.

Column 2 restricts the sample to agricultural labor-intensive corregimientos. The median share of workers in the agriculture sector corregimiento is 42%. Hence, as before, I define as agricultural labor-intensive areas those

Table 3: Effects of land privatization on log rice yield, OLS 2010

	A: Log rice yield		
	Whole dataset	Farmers>40%	Farmers<40%
	(1)	(2)	(3)
Share of privately owned land	0.26***	0.249**	0.199
	(0.101)	(0.108)	(0.195)
Pop. Density	-0.0001	-0.003*	-0.002*
	(0.0001)	(0.002)	(0.0001)
Illiteracy %	0.003	-0.0001	-0.009
	(0.006)	(0.006)	(0.014)
Sex ratio	-0.001	0.002	-0.011**
	(0.004)	(0.006)	(0.005)
Rainfall	-0.00002*	-0.00003*	-0.00001
	(0.00001)	(0.00001)	(0.00003)
Share of irrigated land	-1.095***	0.172	-1.102***
	(0.241)	(0.174)	(0.198)
Share of mechanized land	1.761***	1.781***	1.686***
	(0.068)	(0.108)	(0.095)
Log median family income	0.121*	0.055	0.107
	(0.074)	(0.089)	(0.185)
Observations 498	498	266	232
R-squared 0.038	0.496	0.52	0.525

Note: Robust standard errors are in parentheses.
***, **, and * stand for significance at 1%, 5%, and 10%.

areas where farmers represent 40% or more of the total working population. The coefficient of the share of privately owned land in Column 2 is positive and statistically significant after controlling for a number of variables. This finding shows that an increase in land privatization is associated with a rise in rice yield in agricultural labor-intensive corregimientos. I repeat the same analysis in Column 3, restricting the sample to non-agricultural labor-intensive corregimientos. This time, the coefficient of the share of privately owned land is positive but has no statistical significance, indicating that an increase in land privatization in non-agricultural labor-intensive corregimientos is not statistically related to a rise in land productivity.

The results in the previous tables suggest that improving property rights in agricultural labor-intensive areas in Panama affects allocative efficiency, limits expropriation, and improves market transactions as in Besley and Ghatak (2010). In both the corregimiento and the district cases, in agricultural labor-intensive areas, a higher share of complete land rights is associated with an increase in rice yield, while the relationship is not statistically significant in non-agricultural labor-intensive areas. In agricultural labor-intensive areas, land privatization incentivizes farmers to be more productive. There might be better access to credit, higher incentives to invest in land improvements, land reallocation to more efficient activities and farmers, and the reallocation of labor to other markets.

4.3 Mechanisms

I have shown that an increase in the share of privately owned land is associated with a rise in land productivity in agricultural labor-intensive districts. The purpose of this section is to explore the possible mechanisms through which complete land rights affect productivity. I use household-level data to analyze the effect of land regularization on access to credit as well as on land-attached, land mobile, and low cost investment.

I use pooled cross-sectional data from 1997 and 2008 at the household level. This dataset comes from the LSMS, which surveyed 4,945 and 7,045 households in 1997 and 2008, respectively. I only use households working either full- or part-time in the agriculture sector that considered themselves to be landowners. The LSMS asks the following question: "Have you used your own land for agricultural purposes in the last 12 months?" I restricted the sample to households that answered yes to this question.

To measure the impact of land property rights on access to credit and investment, the specification is

$$y_{it} = \beta x_{it} + \delta z_{it} + \gamma_t + \varepsilon_{it} \tag{3}$$

where y_{it} is a dummy variable that takes the value of one if the household received an agricultural loan or undertook an investment, and zero otherwise. x_{it} is a dummy variable that takes the value of one if the household possesses a land title deed that is properly registered, and zero otherwise. z_{it} controls for household and plot characteristics and γ_t represents the year fixed effect.

I use probit and linear probability models. The previous specification has two typical endogeneity concerns found in the literature on land rights and investment. The most common concern in this literature is reverse causality. Sjaastad and Bromley (1997) argue that land insecurity may incentivize land-attached investment to strengthen security. This would lead to overestimated and biased coefficients. The best way in which to solve this issue is by using instrumental variables. Common instruments include previous investment (Besley, 1995; Brasselle et al., 2002), historic characteristics (Banerjee and Iyer, 2005), and modes of plot acquisition (Fenske, 2010). I deal with this issue by restricting the sample to households that considered themselves to be landowners. This means that all households have high levels of land security and that investment in land is not related to the certification and registration of the land title. Another endogeneity concern is unobserved household-specific characteristics. Deininger and Chamorro (2004) argue that farmers with better access to credit or in a better investment environment are more likely to register their land. I mitigate this concern by adding district and year dummy variables into the specifications, under the assumption that households in the same district have similar access to credit and investment.

Although all the households used in the analyses considered themselves to be landowners, only around 35% had a registered title and 10% had a possession rights certificate (derecho posesorio). Possession rights certificates are land use rights in Panama. These certificates can be exploited for agricultural purposes and transferred, but they cannot be used as collateral in the formal credit market. To obtain a possession rights certificate, the occupier has to meet a number of requirements such as proving that the person has settled the land for a long period of time and has low income.

4.3.1 Credit access

Land titling and privatization might increase access to credit, as farmers can use their land as collateral for loans. This subsection explores the effect of holding a registered title on applying for and obtaining loans. In Column 1 of Table 4, I use a dummy variable that takes the value of one if the household applied for an agricultural loan in the past 12 months as the dependent variable. The variable of interest in Table 4 is registered title. In Column 1, the coefficient of registered title is positive and statistically significant,

Table 4: Probability of applying for and obtaining agricultural loans

	Applying for loans		Obtaining loans	
	(1): Probit	(2): OLS	(3): Probit	(4): OLS
Registered title deed	0.037***	0.037***	0.038***	0.041***
	(3.60)	(0.012)	(3.83)	(0.012)
Possession rights	0.026	0.022	0.021	0.017
	(1.63)	(0.17)	(1.31)	(0.015)
Area	0.001***	0.001***	0.001***	0.001***
	(6.04)	(0.0002)	(5.85)	(0.0002)
Area squared	-2.22E-06***	-3.39E-07***	-1.98E-06***	-3.03E-07***
	(-3.79)	(1.06E-07)	(-3.70)	(1.02E-07)
Years of possession	-0.0005	-0.0002	-0.0005	-0.0002
	(-1.59)	(0.0003)	(-1.62)	(0.0003)
Log household consumption	0.021***	0.026***	0.019***	0.024***
	(4.25)	(0.007)	(4.01)	(0.007)
Year fixed effect	No	Yes	No	Yes
District fixed effect	No	Yes	No	Yes
Observations	2129	2129	2129	2129
(Pseudo) R-squared	0.128	0.085	0.132	0.083

Notes: Probit regression coefficients are average marginal probabilities and robust z-statistics are in parentheses. For the linear probability model, robust standard errors are in parentheses. ***, **, and * stand for significance at 1%, 5%, and 10%, respectively.

Table 5: Probability of having made land-attached and machinery investment

	Sheds		Trucks		Agricultural sprayers		Tractors	
	1: Probit	2: OLS	3: Probit	4: OLS	5: Probit	6: OLS	7: Probit	8: OLS
Registered title deed	0.027**	0.036**	0.017**	0.022*	0.076***	0.085***	0.002	0.006
	(2.29)	(0.015)	(2.01)	(0.11)	(3.62)	(0.024)	(0.43)	(0.006)
Possession rights	-0.029	-0.019	0.002	-0.006	-0.021	-0.015	0.003	0.003
	(-1.25)	(0.016)	(0.14)	(0.010)	(-0.63)	(0.033)	(0.43)	(0.007)
Area	0.0003***	0.001***	0.0004***	0.0005**	0.004***	0.001***	0.0002***	0.0003*
	(3.43)	(0.0002)	(3.24)	(0.0002)	(7.87)	(0.0003)	(2.67)	(0.0002)
Area squared	-2.27E-07***	-3.51E-07***	-5.05E-07**	-2.44E-07***	-7.39E-06	-5.63E-07***	2.20E-07	-1.44E-07*
	(-2.81)	(-1.13E-07)	(-1.96)	(1.02E-07)	(-5.85)	(1.76E-07)	(-1.74)	(7.52E-08)
Years of possession	0.001*	0.0001	-0.0005*	-0.0005**	-0.0002	0.0005	-0.0002	-0.0002
	(1.69)	(0.0004)	(-1.78)	(0.0003)	(-0.37)	(0.001)	(-1.15)	(0.0002)
Log household consumption	0.066***	0.058***	0.046***	0.049***	0.114***	0.102***	0.016***	0.019***
	(10.24)	(0.008)	(8.19)	(0.007)	(11.20)	(0.013)	(4.47)	(0.006)
Year fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
District fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Observations	2129	2129	2129	2129	2129	2129	2129	2129
(Pseudo) R-squared	0.151	0.172	0.288	0.183	0.105	0.189	0.269	0.097

Notes: Probit regression coefficients are average marginal probabilities and robust z-statistics are in parentheses. For the linear probability model, robust standard errors are in parentheses. ***, **, and * stand for significance at 1%, 5%, and 10%, respectively.

using the probit model. Column 1 controls for plot-specific and household characteristics, and the statistically significant control variables are area, area squared, and consumption. I repeat the analysis by using the linear probability model and fixed effects in Column 2. The coefficient of registered title is statistically significant, indicating that farmers with registered titles are 3.7% more likely to apply for an agricultural loan than their counterparts without titles.

I use a dummy variable that takes the value of one if the household obtained an agricultural loan in the past 12 months as the dependent variable in Columns 3 and 4 of Table 4. In Column 3, the coefficient of registered title is significant, using the probit model. Using the linear probabilities in Column 4 confirms that the propensity to obtain agricultural credit is higher for households with registered titles. Deininger and Chamorro (2004) point out that farmers with better access to credit are more likely to formally register their land; hence, household-specific unobservable characteristics might affect the results in Table 4. I mitigate this issue by including the district and year fixed effects in the linear probability model and adding plot-specific and household-specific control variables.

These results contrast with the evidence from other Latin American countries in which land tenure security improvements do not translate into better access to credit. For example, Carter and Olinto's (2003) findings suggest that there are no credit supply effects of tenure security on small farmers in Paraguay. Similarly, Jansen and Roquas (1998) find that land titles are not used as collateral; instead, producers mortgage their houses or their pro-

Table 6: Probability of having made investment

	Seeds	Natural fertilizers	Other fertilizers	Pesticides
	(1)	(2)	(3)	(4)
Registered title deed	-0.013	-0.008	0.014	0.044**
	(-0.83)	(-0.55)	(0.70)	(2.02)
Possession rights	0.019	0.010	-0.013	-0.027
	(0.81)	(-0.45)	(-0.42)	(-0.80)
Area	0.0002	-0.0001	-0.0005**	0.0004
	(0.83)	(-0.50)	(-2.14)	(1.35)
Area squared	-2.49E-07	4.57E-08	2.53E-07**	-5.41E-07**
	(-1.63)	(0.62)	(2.10)	(-2.00)
Years of possession	-0.001*	0.0001	-0.0006	-0.0005
	(-1.92)	(0.22)	(-1.08)	(-0.81)
Log household consumption	0.057***	0.055***	0.121***	0.079***
	(7.19)	(8.06)	(13.53)	(7.71)
Observations	2129	2129	2129	2129
Pseudo R-squared	0.042	0.048	0.077	0.033

Notes: Probit regressions. Average marginal probabilities. Robust z-statistics are in parentheses. ***, **, and * stand for significance at 1%, 5%, and 10%, respectively.

duction in Honduras. In fact, the authors argue that few farmers actually receive credit from formal institutions. In my specification, the data have no information on whether households use their land as collateral or use their houses or production. Nonetheless, according to Columns 3 and 4 in Table 4, households with registered titles are around 3.8% more likely to obtain an agricultural loan. This might be one of the mechanisms through which complete land rights improve rice yield.

4.3.2 Investment

Complete land rights might incentivize farmers to invest in machinery, land improvements, and land conservation. Deininger and Chamorro (2004) find that the registration of land titles increases the propensity to undertake investment in Nicaragua. I explore different types of investment that might be associated with land privatization, using the probit and linear probability models. First, I explore the probability of investing in different types of land-attached and land mobile investment when households have complete land rights. The dependent variables are dummy variables that take the value of one if the household undertakes an investment, and zero otherwise. The result in Column 1 of Table 5 shows that the coefficient of registered title deed is positive and statistically significant. In Column 1, the dependent variable is investment in sheds (a type of land-attached investment). The propensity to undertake this investment increases by 2.7% when the title is

properly registered. Column 2 confirms the investment-enhancing impact of land registration on sheds, including the fixed effects. The possession rights certificate coefficients are negative in Columns 1 and 2. Although farmers with possession rights certificates have a higher degree of security than farmers lacking any certification, possession rights holders are no more likely to invest in land-attached investment than title-less farmers.

Then, I focus on other types of investment, namely trucks, agricultural sprayers, and tractors, which are all types of land mobile investment. The coefficient of registered title is positive and statistically significant in Column 3, indicating that households with a registered title are around 1.7% more likely to invest in trucks. Using the linear probability model in Column 4 confirms the results, but the effect is stronger. In Column 5, the coefficient of registered title indicates that households with complete land rights are 7.6% more likely to invest in sprayers. The coefficient of registered title in Column 6 corroborates this result. Interestingly, the propensity to invest in tractors does not increase for households with complete land rights, according to the coefficients of registered title in Columns 7 and 8, which are not statistically significant.

In Table 5, the coefficients of area and household consumption are statistically significantly in all estimations. This finding indicates that farmers with larger plots and with a higher wellbeing status have a higher propensity to undertake land-related investment. These results indicate that farmers have high incentives to invest when they own the land title, knowing that the returns on investment will be earned by them.

Higher levels of land security may motivate farmers to invest in low cost investment that improves land yield. Then, I focus on the following low cost investment: seeds, natural fertilizers, other fertilizers, and pesticides. Column 1 of Table 6 suggests that having a registered title does not have any statistical significance on the probability of investing in high yield seeds and plants. The coefficient of registered title in Column 2 is negative, but not statistically significant. This finding indicates that registering the title does not increase the propensity to invest in natural fertilizers. The dependent variable of Column 3 is other fertilizers and, again, the coefficient of registered title is not statistically significant. This result confirms that households with a registered title are not necessarily more likely to invest in fertilizers than their counterparts without such a title. The coefficient of registered title is positive and statistically significant in Column 4, indicating that households with complete land rights are 4.4% more likely to use pesticides. The coefficients of registered title in Columns 1, 2, and 3 are not statistically significant. Household consumption is always significant, which shows that a household's wellbeing increases the probability of buying low cost inputs.

The results of this section suggest that the main channels through which land registration affects agricultural productivity are loans, investment in machinery, land-attached investment, and the higher use of pesticides.

5 Concluding remarks

This study empirically investigated the impact of land property rights on agricultural productivity in Panama. The findings show that an increase in land rights in agricultural labor-intensive districts is associated with a rise in land productivity. Then, it used LSMS household-level data to explore potential mechanisms through which property rights affect productivity, finding that households with registered land titles are more likely to obtain agricultural credit, undertake land-attached and land mobile investment, and use pesticides. Owing to data constraints, this study could not investigate the impact of more secure property rights on land transfers, which could be a significant mechanism.

The impact of property rights or land titling programs on the agriculture sector in Latin America has been repeatedly studied; however, these studies have found different results. In line with this research, other studies also find a positive impact of land titling on agricultural outcomes in Latin America. For example, in Nicaragua, a land titling and registration program resulted in an increase in land-attached investment (Deininger and Chamorro, 2004). Further, the lack of a land title is a strong disincentive to participate in the rental market in Nicaragua (Deininger et al., 2003). In Mexico, De Janvry et al.'s (2015) findings suggest that land certification allows for more efficient land and labor allocation, while in Paraguay, tenure security has a strong effect on demand for land-attached capital. However, these effects might only benefit large-scale producers (Carter and Olinto, 2003).

Some studies have not found a positive effect of titling in the agriculture sector. For example, Jansen and Roquas (1998) argue that a land titling program in Honduras has not led to an increase in investment and productivity, instead exacerbating land-related conflicts. Further, the major expansion of land titles in Nicaragua and Honduras did not increase formal credit market participation (Boucher et al., 2004). There might be two reasons why the results of these two previous studies are different from the findings of the present study. First, in Panama, land registration increases tenure security, while in Honduras, according to Jansen and Roquas (1998), the title program was poorly implemented and did not increase land security. Second, in the majority of Central American countries, rural credit markets are insufficiently evolved and thus property rights do not improve credit access.

However, Panama has a well-functioning financial system, and there might be access to formal credit in rural areas. Indeed, in Panama, agricultural credit has increased in recent years. This fact, along with an investment-friendly environment, might be why an increase in land rights in agricultural labor-intensive districts is associated with a rise in land productivity.

Appendix

This section explains the variables used in the analyses and summary statistics at the household level. Table A1 defines all the variables used in this study. Table A2 presents the summary statistics of the household-level data.

Table A1: Variable definitions

A: District level	
Rice yield	Rice harvested in hundredweight divided by the area of net rice sown (in hectares) per district.
Labor productivity	Rice harvested (in hundredweight) divided by the number of farmers per district.
Share of privately owned land	This is the variable of interest in the baseline, which captures the effect of land rights on
Productivity	This is the share of agricultural land properly registered and certified to total agricultural land per district.
Pop. density	The number of inhabitants per square kilometer in a district.
Illiteracy	Percentage of illiterate inhabitants per district.
B: Corregimiento level	
Rice yield	Rice harvested in hundredweight divided by the area of net rice sown (in hectares) per corregimiento.
Labor productivity	Rice harvested (in hundredweight) divided by the number of farmers per corregimiento.
Share of privately owned land	This captures the effect of land rights on productivity. It is the share of agricultural land properly registered and certified to total agricultural land per district.
Pop. density	The number of inhabitants per square kilometer in a corregimiento.
Illiteracy	Percentage of illiterate inhabitants per corregimiento.
Sex ratio	The number of men per 100 women by corregimiento.
Rainfall	Mm of rain by corregimiento. Panama has 109 meteorological stations that measure the amount of rain. I used the data from the closest station if the corregimiento did not have one. In the case the corregimiento had more than one meteorological station, the average was used.
Share of irrigated land	The share of rice land irrigated per corregimiento.
Share of fertilized land	The share of land used for rice plantations that has used fertilizers per corregimiento.
Share of mechanized land	The share of rice land that has been mechanized per corregimiento.
Log median family income	The natural logarithm of the median income of families per corregimiento
Share of workers in agriculture	Share of farmers to total workers per corregimiento.
Share of farms with loans	The share of farms that received a loan per corregimiento.
Share of farms that used machines	The share of farms that invested in machinery per corregimiento.
C: Household level	
Applying for loans	Dummy variable. Whether the head of the household has applied for an agricultural loan in the past 12 months.
Obtaining loans	Dummy variable. Whether the head of the household has obtained an agricultural loan in the past 12 months.
Registered title deed	Dummy variable that takes the value of one if the household has a title deed completely registered and certified, and zero otherwise.
Possession rights	This takes the value of one if the owner has a title but it is not registered, and zero otherwise
Area	Area of land used for agricultural purposes in hectares.
Years of possession	The number of years that the household has used the land.
Log household consumption	Log of household consumption using 1997 US dollars.
Tractors	Dummy variable that takes the value of one if the household has a tractor to use on the land, and zero otherwise.
Trucks	Dummy variable that takes the value of one if the household has a truck used for agricultural purposes, and zero otherwise.
Agricultural sprayers	Dummy variable that takes the value of one if the household has used a sprayer on the land, and zero otherwise.
Sheds	Dummy variable that takes the value of one if the household has built a shed on its land, and zero otherwise.
Seeds	Dummy variable that takes the value of one if the household has bought high yield seeds or plants in the past year, and zero otherwise.
Natural fertilizers	Dummy variable that takes the value of one if the household has used natural fertilizers in the past year, and zero otherwise.
Other fertilizers	Dummy variable that takes the value of one if the household has used other fertilizers in the past year, and zero otherwise.
Pesticides	Dummy variable that takes the value of one if the household has used natural pesticides in the past year, and zero otherwise.

Table A2: Summary statistics at the household level

	Mean	Std. Dev.	Min.	Max
Applying for loans	0.053	0.225	0	1
Obtaining loans	0.049	0.216	0	1
Registered title deed	0.352	0.478	0	1
Possession rights	0.103	0.303	0	1
Area	20.3351	95.2341	.01	2500
Years of possession	21.75	15.40	0	92
Log household consumption	6.714	.961	3.669	10.455
Tractors	0.0131	0.114	0	1
Trucks	0.039	0.193	0	1
Agricultural sprayers	0.35	0.477	0	1
Sheds	0.085	0.279	0	1
Seeds	0.122	0.327	0	1
Natural fertilizers	0.096	0.295	0	1
Other fertilizers	0.226	0.418	0	1
Pesticides	0.295	0.456	0	1

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