Property Rights and Agricultural Performance: Effects of land formalization on Agricultural Performance

Author

Henry Andrés Gómez Ramírez

Submitted as a requirement to opt for the degree of

Master in Economics

Advisor

Julia Seither Afonso

Department of Economics

Master in Economics

Universidad del Rosario

Bogotá D.C. - Colombia

2024

Property Rights and Agricultural Performance: Effects of land formalization on Agricultural Performance*

Universidad del Rosario
Master Thesis in Economics

Henry Andrés Gómez Ramírez†

January 15, 2024

Abstract

This paper examine whether the implementation of the National Program for the Formalization of Rural Property in Colombia has had an impact on agricultural performance. The formalization program was a government initiative aimed at formalizing land ownership and improving the quality of life for farmers, through the promotion and coordination of actions to support efforts to formalize the right to property of rural property titles. I find that the implementation of the program in selected municipalities has not had significant effects on agricultural yeilds, although there are positive correlations in production and yield per hectare in certain specific crops. I identify the need to estimate the heterogeneous effects of program implementation with other types of policies such as access to credit, infrastructure, services, and others.

Keywords: Goverment Policy, Land Ownership and Tenure, Production

JEL Codes: I38, Q15, D24

*During nights and early mornings of uncertainty, you provided me with the necessary serenity to move forward (ILYGBeMed). To my master's advisors and professors, the knowledge gained from you will stay with me. Mauricio and Andrés, I am infinitely grateful for your feedback and the trust placed in a young individual whose sole capital was the desire to learn. To those who generously offered me comments and guided me in drafting this document during seminars and informal conversations, and to Julia, for accompanying me in the final stretch and providing me with the opportunity to take my first steps in teaching. Also, I appreciate the EFI-Colombia Scientific Alliance with grant code 185 and FP44842-220-2018.

†Department of Economics, Bogotá, DC, Colombia. E-mail: henryan.gomez@urosario.edu.co

1 Introduction

Land is a crucial asset in determining regional development, a significance more pronounced in the rural sector due to its nature and the necessity of using it as a productive resource. Ensuring full access and use is relevant (Deininger et al., 2009; Gáfaro et al., 2012), as the absence of a structure ensuring full access and use poses challenges where transaction costs and imperfect markets segment the market, restricting the use of mechanisms such as credit, rental markets, and exchange among producers from less to more efficient (Gáfaro et al., 2012; Deininger and Chamorro, 2004; Macours et al., 2010).

When studying property rights clarity, the conflictive and relative nature of these rights is often overlooked. Without considering the necessary mechanisms and complexities required to guarantee full property rights, risks such as speculative practices, dispossession, challenges in accessing financial markets, and evident informality issues are elevated (Jimena, 2014). In this context, the inability to protect land tenure, among other factors, is linked to the level of formalization in the territories. Tenure insecurity (or risks of expropriation) (Besley, 1995; Dercon. and Krishnan, 2009) is an additional obstacle to achieving economic efficiency in rural areas. Property titles allow the exclusion of other users and, therefore, impact the efficient allocation of resources (Ghatak and Roy, 2007; Bellemare, 2013), wealth distribution, population well-being, and market development (Gáfaro et al., 2012). Formality, like property titles, enhances efficiency in generating incentives for investment and production (Steven Lawry and Mtero, 2017), such as the allocation of better resources due to less need to allocate resources to protect property and people's participation in credit markets by using their new assets as collateral (Banerjee et al., 2002; Besley and Ghatak, 2010).

Although the literature shows that there are differential effects in income generation

related to historical factors that may be affecting the implementation of formalization processes (Benjaminsen et al., 2009; Higgins et al., 2018; Sjaastad and Cousins, 2009), especially among excluded groups such as women and ethnic groups whose interests are not included in the interests of the groups in power (Borras Jr and Franco, 2012; Meinzen-Dick and Mwangi, 2009).

The effects of land titling on various agricultural outcomes have been empirically studied due to the implementation of such policies in developing countries (Tseng et al., 2021). However, there is ambiguity in the results due to the unique dynamics of the territories where this phenomenon has been evaluated and the data limitations inherent in such studies (Rincón Barajas, 2023). Research has assessed effects on outcomes such as investment, productivity, indicators of well-being, and environmental aspects.

Regarding productivity, empirical studies often use yields/benefits per hectare as a measure to approximate this metric. However, there are risks of crop mixtures and market power that can influence the value of the produce due to access to inputs and, consequently, the production capacity (Binswanger et al., 1995). Concerning this indicator, studies show both positive effects in Bengal Banerjee et al. (2002) and Ethiopia Pender and Benin (2001), as well as negative effects (Ghatak and Roy, 2007; Bardhan and Mookherjee, 2007). The way in which these studies have assessed the results through matching strategies is documented in the literature (Rincón Barajas, 2023; Bardhan and Mookherjee, 2007). Some studies have not taken into account the dynamic effects of policy implementation. Recently, for Colombia, Rincón Barajas (2023) explores this phenomenon, delving into the estimation of these programs for the Colombian context in the implementation of land titling programs between the years 1990 and 2013 through a survey of beneficiaries. Additionally, the study controls for farm size and the existence of credit and technical assistance programs.

Likewise, it is known that investment determines the productivity of individuals Rincón Barajas (2023), and studies on the relationship between investment and land titles have shown that the allocation of titles ensures formality and should encourage investment (Feder, 1988) by providing access to savings and credit mechanisms. However, in recent years, it has been argued that, since the selection of households benefiting from these policies includes marginalized individuals (Atwood, 1990; Rincón Barajas, 2023), the effects of obtaining property titles are initially low among beneficiaries compared to non-beneficiaries. Learning processes are needed due to the need to adapt to high initial input costs (Lipton, 2011) and the adjustment of the producer who receives the title as a new manager (Deininger et al., 2009).

Regarding land informality, this is a prominent feature in developing countries, with Colombia, according to the Ministry of Agriculture, having close to 55% of total properties in rural areas, indicating a higher level of informality in land ownership. Additionally, around 40% of the land used in Colombia is agricultural, contributing approximately 20% of the country's employment. Considering this context, various governments in Colombia have implemented agrarian reforms to provide incentives for the development of the agricultural sector. Since the 1930s, policies have been introduced to establish rules for defining property rights in the rural sector and promote equitable access and land use. However, these reforms did not achieve the expected effects, primarily due to the existence of counter-reform processes that failed to impact the objectives set forth in these policies (Gómez Hernández, 2011).

During the Santos government, a program was implemented to guarantee property rights by delivering formal titles to informal land holdings. This initiative began in 2013 in munic-

ipalities defined by criteria related to high informality, low land theft, and low claims related to collective land titles. The program continued in 2014 and 2015. The existence of this program prompts the question of whether **the definition of property rights resulting from the application of the rural property formalization program has an effect on agricultural performance in Colombia**.

To address this question, two sets of data will be used. Firstly, productivity information (gross production and production in planted areas by crop type) and characteristics of the municipalities where the program was implemented in the first three years (2013 to 2015) will be employed. The effects will be estimated through a Two-Way Fixed Effects (TWFE) model, validated by a staggered Difference-in-Differences (DiD) approach. For this, data from the National Agricultural Survey (ENA), its agricultural evaluations, municipal panel variables from CEDE, information on informality from UPRA, and neighboring data will be utilized to define the correct counterfactuals. This exercise with these data will allow the identification of general effects of the program in the municipalities (panel data from 2007 to 2019). However, the possibility of identifying the use of community factors and characteristics (benefited producers from this program) is elusive due to the nature of the available data for this research.

In this regard, this paper contributes to the literature in three ways. Firstly, it allows us to understand the effects, not only on productivity (Rincón Barajas, 2023), but also on investment behavior (measured by a proxy of cultivated land) of a formalization program in Colombia, using quasi-experimental methods (TWFE and Staggered DiD). This enables us to approach (even with the limitations imposed by the use of aggregated data) estimating a causal effect and the dynamic behavior of such implementation in a context where this type of literature is just beginning to be explored in Colombia (Tseng et al., 2021; Rincón

Barajas, 2023). Secondly, it contributes to the literature to understand heterogeneous effects and the explanation of mechanisms that can explain where formalization programs are more effective given the characteristics of communities, access to goods, and services (Tseng et al., 2021), especially concerning the effects of the existence of programs in contexts of armed conflict, which is usually reviewed in qualitative literature. Thirdly, this paper contributes to expanding the understanding of how formalization programs behave in the results of the agricultural process (production, yields, cultivated and harvested areas) for different types of crops (transient, permanent, and annual).

2 Context and Methodology

2.1 Context

2.1.1 The Eternal Problem of Land and its Legislations

Throughout history, Colombia has been an agriculturally inclined country due to its wealth and geographic diversity. This diversity, spanning various thermal zones, enables the production of a significant variety of agricultural crops to meet domestic and international market demands. In the current context, Colombia is seen as a country with the potential to cover the increasing international demand for food by the mid-21st century, especially considering its approximately 39 million hectares of productive potential, of which only about 13.5% is currently being utilized (La Republica, 2022).

The historical inability to fully exploit the available capacity is attributed to the persistent agrarian problem, especially concerning the equitable distribution of land in Colombia (Centro Nacional de Memoria Histórica, 2022). This issue stems from the political nature of the conflict, challenging access conditions to certain territories, state centralization, and the

consequent difficulty in providing basic services. This history dates back to the colonial era when indigenous territories were incorporated into the domain of the Spanish crown (Centro Nacional de Memoria Histórica, 2016). A legal system was established shortly after, dividing the land into private territories (where the highest bidder became the owner), public lands (or national assets), and some indigenous territories (where the only right over the land was usufruct, not transaction) as an initial land market structure (Centro Nacional de Memoria Histórica, 2016). From the formation of the republic to the present day, virtually the only state land distribution policy has been the allocation of public lands, varying throughout history due to successive government modifications.

From the establishment of the republic until 1905, land allocation laws pursued various goals, such as compensating military and civilian participants in the wars of independence, attracting migrants to colonize lands and "improve the race," settling debts, and increasing the number of crops, among others (Centro Nacional de Memoria Histórica, 2016). Laws like 61 of 1874 and 48 of 1882 allowed individuals to acquire property rights simply by occupying "uncultivated" agricultural lands belonging to the nation, regardless of their size, as long as they were put to use. This policy, however, favored the accumulation of large landowners due to the limited technical capacity of the state at that time. These landowners marked territories occupied by other settlers, leading to prolonged land disputes in the first half of the 20th century (Legrand, Catherine, 1983; Londoño, Rocío, 2011; Centro Nacional de Memoria Histórica, 2016). Additionally, these policies created territorial bond strategies that allowed holders to expand their territories if they could extensively cultivate certain crops, contributing to the stratification of the emerging Colombian peasantry (Centro Nacional de Memoria Histórica, 2016).

Between 1900 and 1930, with the consolidation of conservative governments after the

Thousand Days' War, regulations were established to limit the allocation of public lands. This included reducing maximum limits from 5000 hectares to levels below 1000 hectares for the majority of settlers, as well as basing allocations on nationally significant crops. However, there were provisions for forgiving penalties for settlers who ceased producing crops of national interest before the Thousand Days' War (Centro Nacional de Memoria Histórica, 2016). In the 1930s, with the advent of liberal governments, efforts were made to resolve land definition conflicts resulting from regulations established in the first half of the 19th century. Laws 5 and 62 of 1930 and Law 25 of 1931 aimed to establish concession measures for public lands based on the specific needs of different regions, focusing on each region's priority objectives and controlling the number of hectares allocated in the territories of the Bananera Zone. An important development in this decade was the creation of Law 200 of 1936, which set limits on the time for using allocated public lands to a maximum of 10 years, required proof of ownership and a title presentation with a period of no less than 30 years, and established a special land jurisdiction to resolve disputes through "land judges" (Centro Nacional de Memoria Histórica, 2016). However, this law could not be applied and was repealed by Law 100 of 1944 (a conservative measure).

In the second half of the 20th century, prior to the 1991 constitution, certain laws and legal structures were established that continued to distribute public lands. Among other things, these laws set minimum land distribution levels for settlers, made the allocation process more cumbersome, extended allocations to ranchers, and excluded natural areas as new public lands. Although the objective was to prioritize allocations to poor settlers, the result was a reduction in the representation of small holders and an increase in allocation limits back to 5000 hectares (Centro Nacional de Memoria Histórica, 2016). With the establishment of the National Front, an attempt was made to define a new "Agrarian Reform" with Law 135 of 1968. With the idea of redistributing land concentration, the government began

buying land to deliver to small and medium-sized farmers through parceling, expecting them to use these lands. However, with the emergence of guerrillas, the increasing migration of rural populations to growing cities, administrative obstacles, irregularities and fraud committed by officials of the Caja Agraria and later INCORA (the entity that managed these resources), and counter-reform processes driven by large landowners, it became evident that the results of these efforts were not as expected. The GINI coefficient for land concentration showed almost no variation between 1961 and 1991, going from 0.832 to 0.802 (El Tiempo, 1997; Sánchez, Gonzalo, 1988; Centro Nacional de Memoria Histórica, 2016).

In the 1990s, amid the country's economic opening and a growing agricultural sector crisis due to this, the government of Cesar Gaviria enacted Law 160 of 1994. This law introduced the assisted land market as the main mechanism for peasant access to land, created two types of productive organizations, Zonas de Reserva Empresarial (ZDE) and Zonas de Reservas Campesinas (ZRC), and provided subsidies of up to 70% of the land value for subjects defined in Unidad Agrícola Familiar (UAF)[1] (Centro Nacional de Memoria Histórica, 2016). The law tasked the Board of Directors of INCORA with the methodological criteria for defining UAFs in homogeneous areas for populations affected by the conflict and the regularization of indigenous reserves. It also outlined the mechanisms for evaluation, review, and adjustments, as well as the rules to ensure land access. Moreover, it imposed responsibilities on beneficiaries, requiring them to repay the adjusted subsidy when alienating or leasing the land without INCORA's authorization within a specified time (12 years). Beneficiaries who violated these conditions would be characterized as acting in bad faith. The law also limited access to this benefit for holders with assets exceeding one thousand minimum wages, restricting access to wealthy individuals.

[1] A figure inherited from Law 135 of 1961 but regulated at this time

Although these reform definitions established interesting mechanisms, there is no concrete information from INCODER regarding the creation of ZREs and ZRCs or the evaluation of titling processes (Centro Nacional de Memoria Histórica, 2016). Although INCORA data shows that around 20,000 families benefited, after the liquidation of INCORA to create INCODER, notable information gaps exist regarding the lands that entered the National Agrarian Fund between 2001 and 2004. Additionally, around 36,733 hectares from extinction processes were contributed, apparently distributed among 2,889 families.

2.1.2 Program for Rural Property Formalization in Colombia

In 2010, with the start of President Santos' administration, the need arose to develop policies enabling individuals to access land, formalize properties, and provide incentives to enhance quality of life and income. In this context, Resolution 452 of 2010 was issued (Ministerio de Agricultura y Desarrollo Rural, 2010), creating and establishing the foundations to regulate the National Program for Rural Property Formalization. This program aimed to promote access to rural property and improve the quality of life for farmers. To achieve this goal, the program would coordinate actions to support the formalization of property rights for titles of rural properties, assisting interested parties in carrying out administrative, notarial, and registration procedures.

The program was implemented from 2013, being applied in priority municipalities each year due to resource constraints. The goal was to extend until 2021, assisting nearly fifty thousand families in property formalization by 2014 and around three hundred thousand cases by the end of the period.

The program's focus was on benefiting the vulnerable rural population due to conditions of poverty, marginalization, forced displacement, and female-headed households. Properties

obtained through violence, dispossession, forced abandonment, or used for illicit crops were excluded, as were those acquired through illegal activities or legal dispossession (Ministerio de Agricultura, 2013b). Additionally, the program aimed to:

1 - Develop a massive, integrated, and participatory Predial Sweeping Procedure in Mass Formalization Zones to support the regularization of private property and heritage fiscal assets.

2 - Train professionals in judicial and administrative processes using the new rural property formalization procedure.

3 - Consolidate a culture of Rural Property Formalization through national and local educational campaigns emphasizing the importance of property registration and the advantages of property ownership.

Similarly, the requirements for access are (Ministerio de Agricultura, 2013b):

1 - Be an occupant or informal possessor of a property located in one of the Mass Formalization Zones (ZFM) declared by the Ministry of Agriculture.

2 - Submit a formalization request for possession, occupation, false tradition, or an unregistered title of a rural property to the Technical Formalization Group.

3 - The Ministry of Agriculture and Rural Development declares the Mass Formalization Zone. This Zone can be the entire municipality or a part of it, clearly delimited on maps and cadastral charts.

4 - The Technical Formalization Group conducts brigades in the hamlets or places frequented by the population of the Formalization Zone.

5 - During these events, requests for property regularization from individuals are collected, and documentary and on-field information about the tenure situation and applicants are gathered.

6 - Once the collected information is assessed and compared with existing data in institutional databases, a definitive technical-legal concept is developed for each received request, with a specific recommendation indicating the most viable route to resolve the case. This includes:

7 - Judicial route: to address cases of ownership, succession settlement, where no agreement exists, and cases of false tradition.

   a. Notarial route: for liquidation of successions with prior agreement, deeds to formalize agreements, etc.

   b. Conciliation route: alternative conflict resolution mechanisms.

   c. Land Restitution Registry: when the requested property is in the "Registry of forcibly dispossessed and abandoned lands" defined in Law 1448 of 2011, or there are indications of a possible dispossession case not yet included in this registry, it will be reported to the Special Administrative Unit for the Management of Lands Restitution. This does not imply suspending the formalization process at this stage.

Regarding coverage, the ministry, through the Coordinating Unit, is responsible for defining Mass Formalization Zones (see Table 1) and prioritized intervention areas based on the following criteria (Ministerio de Agricultura, 2013b):

1 - Municipalities with a high concentration of informality (diagnosis made by the Program's Coordinating Unit based on registration and cadastral figures).

2 - Risk of dispossession or high incidence of population resistant to dispossession (information from the Restitution Unit).

3 - Involvement of territorial entities. Municipalities and departments that, within their Development Plans and Annual Investment Plans, anticipate incentives for formalization (special rates or relief from fines caused by non-timely payment of such taxes, applicable to Program properties).

4 - Involvement of local, national, or international cooperators.

5 - Compliance with environmental adjudicability requirements.

In a similar manner, the program aimed, after defining potential Mass Formalization Zones (ZFM), to conduct a socialization process in different municipalities with local administrative entities (municipalities and councils) to identify municipalities where the reception to the program was greater, select them, and then carry out a community awareness process about the program's arrival. The program would bring technical capabilities, set up a support office at the municipal headquarters, conduct a diagnostic process of previous conditions (geographical and legal), provide assistance in organizing documents, and submit requests to the judges for those properties whose process could be advanced within an average period of 18 months from the program's arrival in the municipality or until all community-submitted requests were completed. Although the program professionals withdrew from the location after the process was completed, the methodology documentation indicates that another objective of the program was to build capacities. Therefore, the program aimed to establish an office and train suitable personnel in the municipality so that future processes could be carried out successfully (Ministerio de Agricultura, 2013a).

2.2 Definition of Controls and treatments

To select the controls, two technically valid options are synchronized. As mentioned earlier, in both options, the municipalities that received the program (the treated individuals) are defined for the years 2013, 2014, and 2015 through specific resolutions from the Ministry of Agriculture, all published in the mid-year of implementation, and defining the municipalities where the program will be implemented (see Table 1) for each year. The selection process, in principle, does not appear to be random on the part of the ministry. The program guidelines state that the process follows these steps[2]: There is a list of municipalities with an index of informality of rural lands defined by UPRA for the year 2013. The ministry carries out a process to define possible zones for mass formalization to socialize in these municipalities (at the municipal headquarters) and open a registration process, selecting the zones for mass formalization in those municipalities where local entities were willing to receive the agents participating in the program (and are later selected in the resolutions). In this regard, in year n, it is not possible to know the eligible municipalities for that year from the information on potential areas to intervene. However, it is known that the main criterion for defining them, among other options, is the set of municipalities to intervene comes from the index of informality of lands[3].

[2]See page 16 of https://www.minagricultura.gov.co/Regulations/Resolutions/Annex%201%20-%20Guide%20formalization.pdf

[3]See page 15 of https://www.upra.gov.co/documents/10184/23342/Regularizacin+y%20+Access+to+Lands.pdf/6d87913f-40bd-4c7c-b446-67b9d8a8cb0a

Table 1: Municipalities selected by resolutions as beneficiaries of the Rural Property Formalization Program

Year	Resolution	Municipalities selected
2013	346 of 2013	**Boyacá**: Ramiriquí* – Moniquirá* – Villa de Leyva* – Sáchica* **Cundinamarca**: San Juan de Rio Seco* **Magdalena**: Ciénaga* **Caldas**: Manizales* **Risaralda**: Pereira* **Cauca**: Popayán* – Morales* – Mercaderes* – Timbio* – Santander de Quilichao* – Buenos Aires* – Caldono* – Piendamó* - Miranda* - Padilla* **Huila**: Pitalito* – San Agustín* **Nariño**: La Unión* **Valle del** Cauca: Jamundí*
2014	327 of 2014	**Antioquia**: Andes* **Boyacá**: Ventaquemada* **Caldas**: Neira* **Cauca**: Rosas* **Nariño**: San Bernardo* – San Pedro de Cartago* **Tolima**: Chaparral* **Sucre**: Ovejas*
2015	098 of 2015	**Antioquia**: Apartadó* – Arboletes* – Caldas* – Carepa – Ciudad Bolívar* – Chigorodó* – Cocorná* – Granada* – Mutatá* – Necoclí* – Remedios* – San Carlos* – San Francisco* – San Luis* – San Rafael* – Segovia* – Támesis* – Yarumal* **Boyacá**: Cómbita* – Chivata* – Oicatá* – Samacá* – Zetaquirá* – Motavita* **Caldas**: Pensilvania – Samaná* **Cesar**: Bosconia* – El paso* – La paz* – San Diego* **Cundinamarca**: Chocontá* – Villapinzón* **Chocó**: Quibdó* **Guajira**: Fonseca* – La jagua del Pilar* – San juan del Cesar* – Urumita* **Huila**: Isnos* – Oporapa* – Saladoblanco* **Magdalena**: Santa Marta* – Zona Bananera* **Meta**: Acacias* – Granada – San Juan de Arama* **Norte de Santander**: Gramalote* – Silos* **Risaralda**: Belén de Umbría* – Santa Rosa de Cabal* – Santuario* **Santander**: California* – Charta* – Matanza* – Suratá* – Tona* – Vetas* **Sucre**: Caimito* – San Marcos* **Tolima**: Ortega*

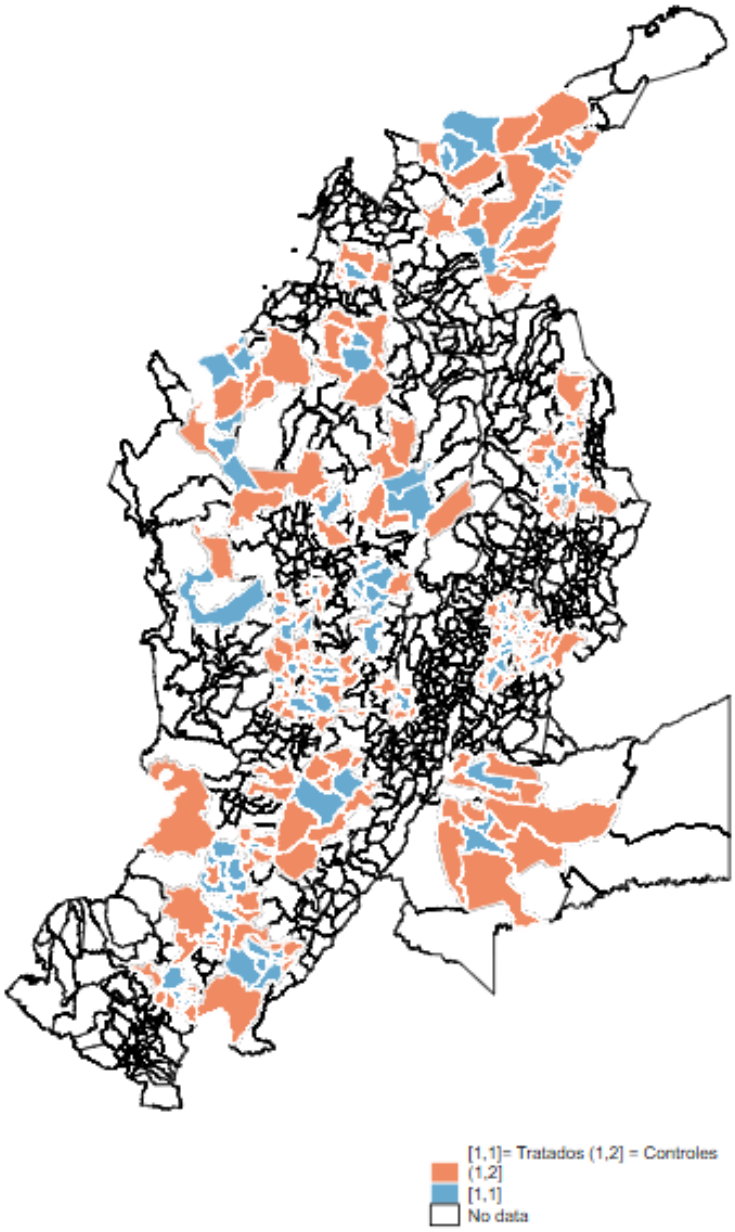
Note: Own development with data from MADR resolutions. This table presents the set of municipalities designated to undergo the rural property formalization program through mass formalization zones, as per various resolutions outlined by the Ministry of Agriculture. These municipalities will be treated as the treated group at different time points when the treatment was implemented. Due to the lack of information for Granadas Meta, this municipality is not considered in defining the control set with the information available in the CEDE.

Informality is the primary criterion for defining potential controls and treatments in this study. Using information available from the UPRA, we first identify the average informality value of land in municipalities receiving the treatment for the year 2013. Subsequently, we identify the standard deviation of this measure to establish a kind of bandwidth of informality that eligible municipalities in the control group may exhibit. If this approach were followed, the distribution of treated municipalities would result in a sample of approximately 400 municipalities that would form part of the control groups.

To refine the selection and choose municipalities with similar characteristics to the control group municipalities, a combination of formality selection and a close neighbor criterion is employed. For this purpose, the treated municipalities are selected, and, through spatial software, potential control municipalities are defined as those located at a distance greater than 1 km from the treated municipality. Subsequently, control municipalities for each treated municipality are chosen based on similar levels of land informality. The algorithm for selecting control municipalities takes into account: 1) The informality value of each treated municipality, 2) a bandwidth allowed for selecting control municipalities for each treatment equal to the value of land informality plus or minus one standard deviation from the complete sample, 3) identification of municipalities sharing a border of more than one kilometer with each treated municipality, selected at the discretion assuming that this border size allows municipalities to have spaces where they can exchange knowledge, work, and inputs, and 4) selection of border municipalities whose informality value is within the bandwidth of each treated municipality (see appendix 5).

Following this criterion, there are 87 treated municipalities and 187 control municipalities, resulting in a total of 274 municipalities in the complete sample. The distribution of the selected municipalities can be observed in Figure 1:

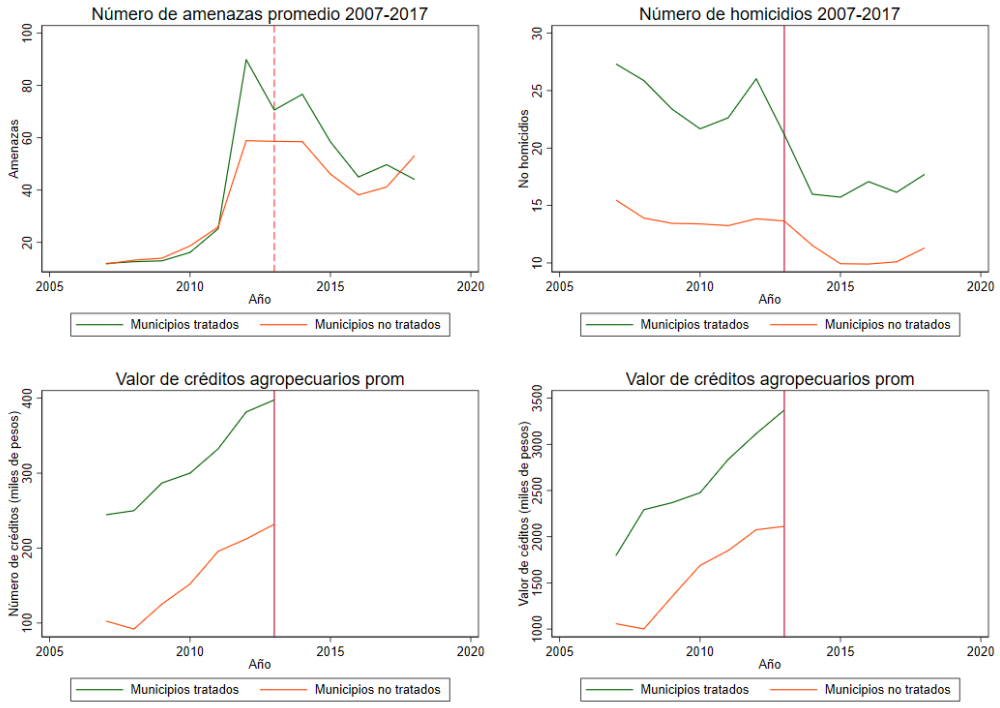
Figure 1: Municipalities selected for the analysis sample (Selection of controls and treatments)



Note: Own development with data from CEDE and UPRA. The figure depicts the distribution of treated and control municipalities at the national level. Municipalities shaded in blue represent the sample municipalities selected as treated (based on resolutions from the Ministry of Agriculture). Those shaded in orange are the controls selected through manual matching, which will be validated for differing characteristics before the first program application through an analysis of observable variables (Galiani and Schargrodsky, 2010)

The rationale for combining the two alternatives is to select municipalities that are most similar to the treatment municipalities in the variables of interest and other potential covariates that may be related to the variable of interest. For both measures, we conducted identification exercises and performed graphical trend tests before the program implementation for both the treatment and control municipalities. By doing this in a preliminary manner, it appears evident that integrating these alternatives will allow us to select a set of controls and treatments, even considering the limitations of available data (see 2)[4].

Figure 2: Trend in observables under the selection criterion (informality+Neighbor)



Note: Own development with data from CEDE and UPRA. The figure illustrates the trends in conflict and agricultural credit usage variables over time for the selected municipalities in the treatment and control groups. Visually, the figure suggests that, before the initial implementation of the titling program, the trends in these variables move in the same direction for both groups.

[4]Refer to the annexes for evidence of parallel trends and anticipation in the definition of geography and informality (6)

2.3 Empirical Strategy

2.3.1 TWFE

To answer the question about whether the entry into force of the rural property formalization program had effects on agricultural yeilds in the Colombian case, the important assumption that needs to be validated in this case is the existence of parallel trends (because with the correct specification of the counterfactual, we ensure overlap), for this first exercise i made a graph of the event study, given that the implementation process of the program took place in a staggered manner, the effect of the treatment would not be so clear, for this first approximation we are going to start from a TWFE specification as follows:

$$Y_{i,t} = \alpha_i + \propto_t + \beta PFPF_{i,t} + \varepsilon_{i,t} \tag{1}$$

Where $Y_{i,t}$ represents our agricultural outcomes by municipality and time, α_i are municipality fixed effects and $\propto_t$ time fixed effects that do not change, β is the value of the estimator (Effect) that has the implementation of the rural property formalization program in a municipality, the base year is 2013 (when this program is implemented for the first time) in order to see the correlation of the difference in yeilds for the municipalities where the program was implemented compared to those that did not receive the program.

2.3.2 Stagered DID

It would be expected that, as seen in the event study, the effect of the treatment estimator does not yield significant effects of the formalization program and agricultural productivity, therefore, a Goodman-Bacon decomposition regression (Callaway and Sant'Anna, 2021) will then be implemented. where we have three cohorts of municipalities treated by the program. In the year 2013 the group E1 (Early treated 1) treated in the year 2014 E2 (Early treated 2) and in the year 2015 L (Late treated) and those selected municipalities that did not receive

the program (U until the year 2019), the identification assumption here is the existence of parallel trends between the groups, therefore, this exercise is carried out in order to show the effect of the comparisons of different groups and determine if the effect of the initially treated (E1) and the treated late (L) present similar or heterogeneous results before and after treatment on the outcome (Yeilds). Given 3 cohorts, the comparison results will be the following for the treatment effect:

$$\hat{\delta}_{i,j} = \left(\bar{y}_i^{\text{post}(i)} - \bar{y}_i^{pre(i)}\right) - \left(\bar{y}_j^{post(i)} - \bar{y}_j^{pre(j)}\right) \tag{2}$$

[5]

In case of finding variation differences with respect to time or in units, the assumption of parallel trends would be violated. Given this possibility in the data, the estimation will be made using the method proposed by Callaway and Sant'Ana (Callaway and Sant'Anna, 2021), which is particularly adjusted to the case of this research since we face a staggered adoption of the program and heterogeneous effects of the treatment between cohorts (showing that the Goodman-Bacon decomposition method (Callaway and Sant'Anna, 2021) yields this difference between early and late cohorts). For this case, it is important to test the assumption of anticipation, in this research it will be tested by showing that the differences in changes in the productivity of the different groups treated before the first year of implementation of the program were not different from those of the untreated municipalities.

In this case, the ATT effect resulting from the formalization program should take the following form:

$$ATT_{\text{unc}}^{nev}(g,t) = E\left[Y_t - Y_{g-1} \mid G_g = 1\right] - E\left[Y_t - Y_{g-1} \mid C = 1\right] \tag{3}$$

[5] i and j represent a combination of treatment states of the municipalities (Untreated U) (Treated early E1) (Treated late E2)

In specification terms this takes the form of:

$$Y_{i,t} = \alpha_i + \alpha_t + \sum_{k=-K}^{-3} \gamma_k^{lead} D_{i,t}^k + \sum_{k=0}^{L} \gamma_k^{lags} D_{i,t}^k + \varepsilon_{i,t} \tag{4}$$

Where $Y_{i,t}$ represents our productivity outcome, α_i and α_t the fixed effects of municipality and time, the third expression from the right represents the interaction of productivity indicators treatment groups and later, $D_{i,t}^k$ is an indicator of a municipality that is k periods away from the initial treatment at time t. γ_k^{lags} represents how the treatment effect evolves with prolonged treatment (after starting the formalization program). Then the effects of the ATT in simple and group terms will be added to show the effect that the formalization program has on agricultural productivity.

2.3.3 Other Estimation Methods

Although the TWFE and Staggered DID methods are the ways in which this paper seeks to observe the effects of the implementation of the Colombian titling policy, and given the risks of using two-way fixed effects regressions due to comparing treatments at different points in time (Callaway and Sant'Anna, 2021) and the problems that arise from differential effects of the policy on the treated group due to potential anticipation effects (Galiani and Schargrodsky, 2010), and that two-way estimations include early treated, not yet treated, and never treated units in the comparison, we will examine the estimations of Goodman-Bacon (2018) which, in addition to providing the TWFE estimate, also provide weights in the estimations for different types of treated units.

In addition to knowing that the process of the titling policy in the Colombian case is not immediate (initiating the formalization process and receiving formalization titles), which introduces a random process that does not guarantee titling, we will also be able to observe in the estimations of Goodman-Bacon (2018) the weights that each of the different groups

can have in the estimation, showing that the weight of the comparisons between treated and never treated units is greater than the weight of comparisons between early treated, not yet treated, and never treated units.

2.3.4 Heterogenities

To estimate the heterogeneous effects of implementing the titling policy, we acknowledge that the inclusion of covariates of different measures in equation 1 will affect the estimation value, both in the formalization program estimator and within the covariates themselves, through the following relationship:

$$\beta PFPF_{i,t} = \gamma PFPF_{i,t} \pm \delta PFPF.X_{i,t} + \epsilon_{i,t} \tag{5}$$

Assuming that this error has a mean of zero and a standard deviation of 1, equation 1 takes the form:

$$Y_{i,t} = \alpha_i + \propto_t + \gamma PFPF_{i,t} \pm \delta PFPF.X_{i,t} \pm X_{i,t} + \varepsilon_{i,t} \tag{6}$$

On the side of the covariates, the equation takes the form:

$$Y_{i,t} = \alpha_i + \propto_t + \gamma PFPF_{i,t} \pm (\delta \pm \phi)(PFPF.X_{i,t}) \pm X_{i,t} + \varepsilon_{i,t} \tag{7}$$

Where γ will represent the estimator of the property formalization program, resulting from extracting the heterogeneous effects of different types of covariates within the treatment. The heterogeneous effects will arise from this extraction as well as from the effect that emerges from the estimation of the same covariates ($\delta \pm \phi$). This value can be positive or negative, depending on what is observed in the literature.

3 Data Description

3.1 Data used

I have two types of potential outcomes for this study. One wants to see the level of productivity measured in the entire municipality and by type of crop c (permanent, transitory, annual), seeking to establish a series of measures of agricultural productivity as a result of the ratio of the amount of total production (tons) and the planted area (hectares) in a municipality i in a year t. This information comes from the Municipal Agricultural Evaluations database provided by the Ministry of Agriculture. And a proxy for investment measured in the planted area available by municipality, crop, type of crop, and amounts of crops and harvests for the period 2006-2019.

$$\text{Yeilds by type of crop } => \text{ Yields }_{i,c,t} = \frac{\text{Production (Ton)}_{i,c,t}}{\text{sown area (Ha)}_{i,c,t}} \tag{8}$$

$$\text{Aggregate production } => \text{ Yields }_{i,t} = \frac{\text{Production (Ton)}_{i,t}}{\text{sown area (Ha)}_{i,t}} \tag{9}$$

The second measure that can be used as an outcome will be invest in municipality i in year t. For this measure, this will also be calculated for sown area the type of crop and in the aggregate.

$$\text{Invest (sown area) by type of crop } => \frac{\sum \text{ sown area (Ha)}_{i,t}}{\text{Numbers of crops}} \tag{10}$$

Likewise, there is also data to address this work, general information is collected, infrastructure, public spending, conflict, credit, among others, by municipality and year, it has information from the different municipal panels granted by the Center for Economic Development Studies (CEDE)) from the University of the Andes.

Even with this data, due to the lack of complete information in all municipalities, there is an unbalanced panel database, as not all municipalities have information on or engage in processes where they cultivate different types of crops, and there is no information for all years, as well as observable characteristics such as the violence situation, rural population, access to credit, among others. This database and the selection characteristics treated by the program do not conflict in the application of the Stagered DiD strategy.

3.2 Means and mean differences

Under the definition of controls for informality and border, the tables 2 report the average value of different and differences of their variable means related to the production process and other variables of the municipalities that are defined as treated and as controls respectively for the period 2006-2013, period before the implementation of the land titling formalization program in these locations.

The information shows that, for the period 2006-2013, the treated municipalities have higher average values of production variables (except for the variables of annual crops) than the control municipalities, most of these variables seem to have statistically significant average differences, however, this observation does not say much about whether the treated municipalities already face effects resulting from the introduction of the program, since it does not take into account trends resulting from the estimation of means.

Table 2: means and differences of production variables for treated and control municipalities 2006-2019

	Mpios Tratados mean/sd	Mpios Controles mean/sd	Diferencia b/t
A_SembradaANUAL	330.88	340.30	-9.43
	(802.69)	(1214.20)	(-0.14)
A_CosechadaANUAL	287.41	298.41	-11.00
	(738.28)	(1146.90)	(-0.18)
A_ProduccionANUAL	3294.03	3399.96	-105.93
	(8830.18)	(13524.90)	(-0.14)
Rendimiento_añoANUAL	11.15	10.83	0.32
	(5.33)	(5.24)	(1.01)
A_SembradaPERMANENTE	4573.15	3700.38	872.77**
	(4762.11)	(5244.72)	(3.15)
A_CosechadaPERMANENTE	3834.93	3090.75	744.18**
	(4172.77)	(4499.22)	(3.11)
A_ProduccionPERMANENTE	52024.36	53941.10	-1916.74
	(139386.56)	(217777.22)	(-0.18)
Rendimiento_añoPERMANENTE	8.83	8.33	0.51
	(6.98)	(5.51)	(1.55)
A_SembradaTRANSITORIO	1511.67	1501.27	10.40
	(2317.30)	(2597.42)	(0.08)
A_CosechadaTRANSITORIO	1394.29	1406.96	-12.67
	(2223.70)	(2540.54)	(-0.10)
A_ProduccionTRANSITORIO	9737.70	7865.21	1872.49*
	(22872.35)	(15276.37)	(2.09)
Rendimiento_añoTRANSITORIO	8.79	9.65	-0.86
	(10.89)	(13.97)	(-1.32)
A_Sembrada_Tot	5446.41	4698.92	747.50*
	(5519.29)	(6100.41)	(2.57)
A_Cosechada_Tot	4697.99	4083.46	614.53*
	(4895.09)	(5424.47)	(2.38)
Producción_Tot	54334.15	53792.76	541.39
	(130062.99)	(198245.01)	(0.06)
Rendimiento_Tot	23.23	23.13	0.10
	(15.03)	(17.32)	(0.12)
N	607	1304	1911

Note: This table displays differences in productions variables, which vary across individuals and time, with significance levels indicated at 99% (3 stars), 95% (2 stars), and 90% (1 star).

Otherwise, it can be observed that differences in information regarding violence, access to goods and services, and credit for the rural population are not statistically different between control and treatment municipalities for most observable covariates, especially variables related to credit for the rural population, access to credit for small and medium-sized producers, and women. Similarly, in the data, it is observed that, in the treated municipalities, the rural population and average agricultural GDP are higher than in the control municipalities by 6687 million, respectively. However, these latter municipalities have a rural index 3 pp higher than the treatment municipalities, and although this fact may show differences, the gap between the treatment and control groups is not very large (see appendix 9, 10, 11)

And although these tests do not demonstrate that the grouping is tight, recent studies have employed similar strategies to approach these results (Galiani and Schargrodsky, 2010). Additionally, in the results section, the outcomes of anticipation tests and parallel trends are presented to demonstrate that there are no prior behaviors in the aggregated information of the treated municipalities versus those selected as control.

4 Results

4.1 2WFE

The specification of 1 is carried out on the results of 4.1 for the yield per hectare and production (ton) outcomes. The 2WFE specification shows that, for yields per hectare, the implementation of the program in the municipalities has a positive correlation, these effects are significant for the different crop distinctions but not when we measure the yield for all crops, likewise, this correlation is shown negative for annual crops. For the outcome of yield, the identification shows that the municipalities for transitory crops that received the for-

malization program have the greatest effect, with 1.26 tons per hectare more yields in the treated municipalities.

La especificación de la ecuación 1 se realiza sobre los resultados de la tabla 4.1 para los rendimientos por hectárea y los resultados de área sembrada (toneladas). La especificación de 2WFE muestra que, para los rendimientos por hectárea, la implementación del programa en los municipios no tiene efectos estadísticamente significativas en la producción general y para cultivos de ciclo corto y de largo plazo, los efectos son significativos para la distinsión de cultivos Anuales (que dan un solo cultivo al año y deben cultivarse nuevamente luego de la cosecha). Asimismo, esta correlación se muestra negativa para los cultivos anuales para el resultado de rendimiento, la identificación este efecto reduce un 6 p.p. sobre los rendimientos en cultivos de anuales respecto el grupo de control en promedio, y aunque no es significativo el efecto, para la producción promedio total el signo de la productividad es negativo, lo cuál puede deberse a la posible naturaleza no lineal del proceso de productividad.(Rincón Barajas, 2023; Lipton, 2011; Kinsey and Binswanger, 1993; Deininger, 1999)

Table 3: Dependent Variable: Ln Yields per hectare (Tons/ha cultivated)

	(1) Total	(2) Anual	(3) Permanente	(4) Transitorio
post	-0.04	-0.06**	0.02	0.02
	(0.03)	(0.03)	(0.02)	(0.05)
Constant	3.00***	2.28***	2.00***	1.79***
	(0.01)	(0.01)	(0.01)	(0.01)
mean_in_control	2.99	2.27	2.00	1.81
r2	0.67	0.70	0.78	0.65
N	3,829.00	2,518.00	3,395.00	3,734.00

Standard errors in parentheses

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

Note: This regress by OLS variable that represent land titling intervention related to productivity outcome, which vary across individuals and time (fixed effect), with significance levels indicated at 99% (3 stars), 95% (2 stars), and 90% (1 star).

Regarding investment, measured in an aggregated manner in relation to the value of agricultural area in different types of crops planted by producers, taking into account Equation 1, there is some ambiguity concerning the investment value in municipalities where the program is applied compared to control municipalities. Although the sign is positive and significant in total production, increasing by 5 percentage points compared to the control group, it is not significant in the crop cycle specifications (see 4.1).

Table 4: Dependent Variable: Ln sown areas (Ha)

	(1) Total	(2) Anual	(3) Permanente	(4) Transitorio
post	0.05*	-0.06	0.04	-0.06
	(0.03)	(0.05)	(0.02)	(0.05)
Constant	7.92***	4.38***	7.40***	6.23***
	(0.01)	(0.01)	(0.01)	(0.01)
mean_in_control	7.89	4.24	7.34	6.20
r2	0.89	0.88	0.96	0.87
N	3,829.00	2,521.00	3,397.00	3,734.00

Standard errors in parentheses

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

Note: This regress by OLS variable that represent land titling intervention related to invest outcome (Ln), which vary across individuals and time (fixed effect), with significance levels indicated at 99% (3 stars), 95% (2 stars), and 90% (1 star).

This relationship holds and becomes significant for the harvested area outcome for total production (see A and A). This specification shows that, on average, after receiving the formalization program, the production is not positive, but in annual crops, the production decreased by 15 p.p compared to the control group, while the overall harvested area of program beneficiaries increased by 5 p.p.

This specification gives an idea of how the relationship between the variable of interest and the treatment variable manifests itself, however it may not control for possible late

treatment effects by treatment cohort, in the following sections the estimation for Bacon decomposition will be made and Callaway and Sant'Anna.

4.2 Bacon Descomposition

The application of the Bacon decomposition for the panel of 5 represent the estimation and weights for 2WFE for the different comparisons of the treated municipalities for yields and production.

Table 5: Bacon Descomposition Yeilds

Bacon Descomposition Total Yeild

Diff-in-diff estimate: -0.04

DD Comparison	Weight Avg	DD Est
Earlier T vs. Later C	0.03	-0.30
Later T vs. Earlier C	0.02	-0.12
T vs. Never treated	0.95	-0.03
T vs. Already treated		

T = Treatment; C = Comparison

Bacon Descomposition Total Yeild - annual crops

Diff-in-diff estimate: -0.52

DD Comparison	Weight Avg	DD Est
Earlier T vs. Later C	0.02	0.33
Later T vs. Earlier C	0.01	0.52
T vs. Never treated	0.97	-0.55
T vs. Already treated	0.00	0.00

T = Treatment; C = Comparison

Bacon Descomposition Total Yeild - permanent crops

Diff-in-diff estimate: 0.37

DD Comparison	Weight Avg	DD Est
Earlier T vs. Later C	0.02	-0.68
Later T vs. Earlier C	0.01	-1.09
T vs. Never treated	0.97	0.41
T vs. Already treated	0.00	0.00

T = Treatment; C = Comparison

Bacon Descomposition Total Yeild transient crops

Diff-in-diff estimate: 1.26

DD Comparison	Weight Avg	DD Est
Earlier T vs. Later C	0.02	-3.42
Later T vs. Earlier C	0.01	-1.49
T vs. Never treated	0.97	1.38
T vs. Already treated		

T = Treatment; C = Comparison

Note: The table displays the Goodman-Bacon (2018) methodology estimates for yields per hectare for each type of crop, along with the weights of the estimates among treatment groups

In both panels, the relationships of the estimate seem to hold (the value of the estimates does not change much), in addition to showing a fairly significant weight (above 97 percent in all different outcomes) to determine the value of the estimate. In fact, this behavior among the distribution of treated categories validates that the application of DiD TWFE is possible since the potential dynamic effects between early and late treatments and early and late controls are small enough to not significantly impact the policy application estimates.

In the next section, the verification of compliance with parallel trends and the estimation of the effect by the Callaway and Sant'Anna methodology will be shown.

4.3 Callaway and Sant'Anna

In the definition of Callaway and Sant'Anna, the ATT is calculated for the different outcomes, the table 6 calculates the assumptions of parallel trends and anticipation for the event study. For the definition of controls and treatments that were defined, the behaviors of the tests seem to indicate that there are parallel trends before the time in which the treatment is implemented.

Table 6: Pretrends and Anticipation test

Pretrends and Anticipation test				
	(1)	(2)	(3)	(4)
VARIABLES	Ho = Accept			
	Produc	Rend	A sem	A cos
Pretrends p value	0.007	0.009	0.000	0.075
Anticipation p value	0.000	0.000	0.000	0.000

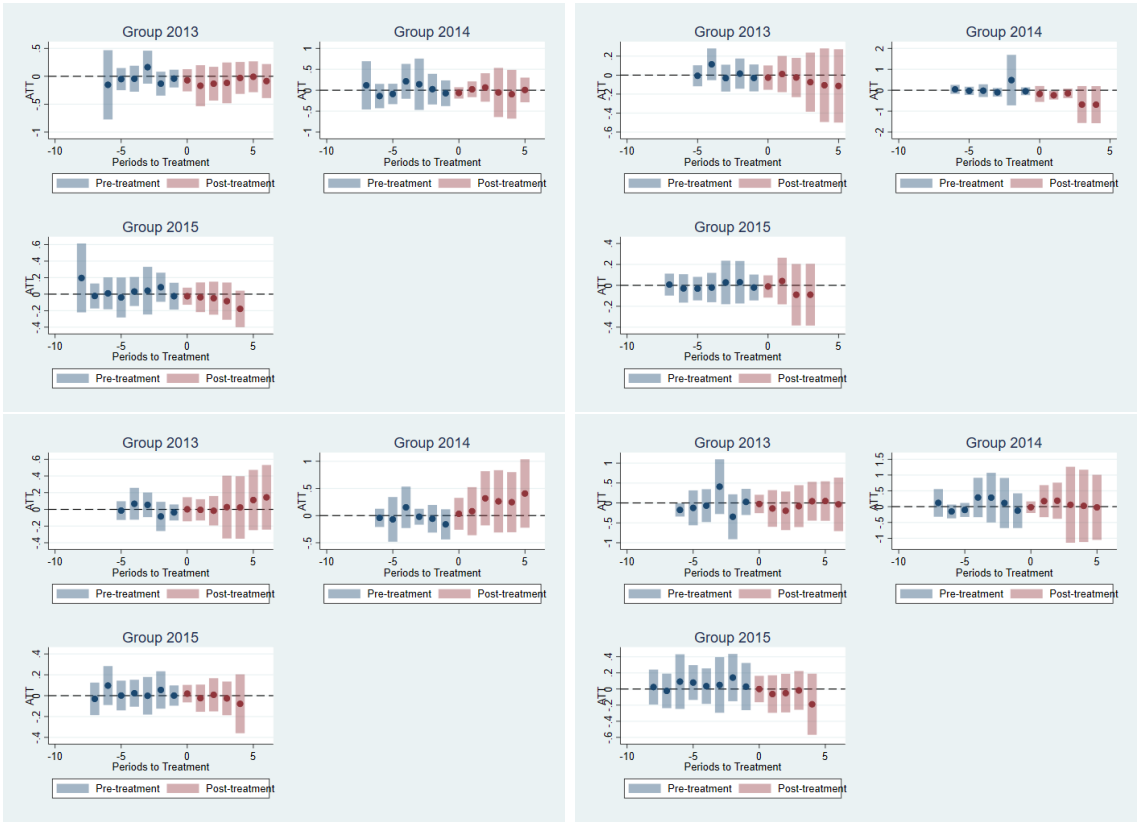
Note: The null hypotheses assume accepting parallel trends equal to zero and anticipation. P-values close to zero accept the existence of parallel trends.

Likewise, the estimated effects of implementing the program are shown in the table **??**, however, these effects appear to be non-significant and negative for total crop yields.

These "null effects" are visible in the specifications of the event study graphs that can be observed in Panel 3, where, although no effects different from zero can be observed, there is a trend in the average aggregated yields, showing a "U" shape behavior. Yields tend to decrease at the beginning of the intervention, followed by positive trends after the

intervention, particularly in the third year, especially for the estimation of permanent crops (Rincón Barajas, 2023), and a consistently negative trend for annual crops, especially for the treated municipality groups in the first two years of implementation (G 2013 and G 2014).

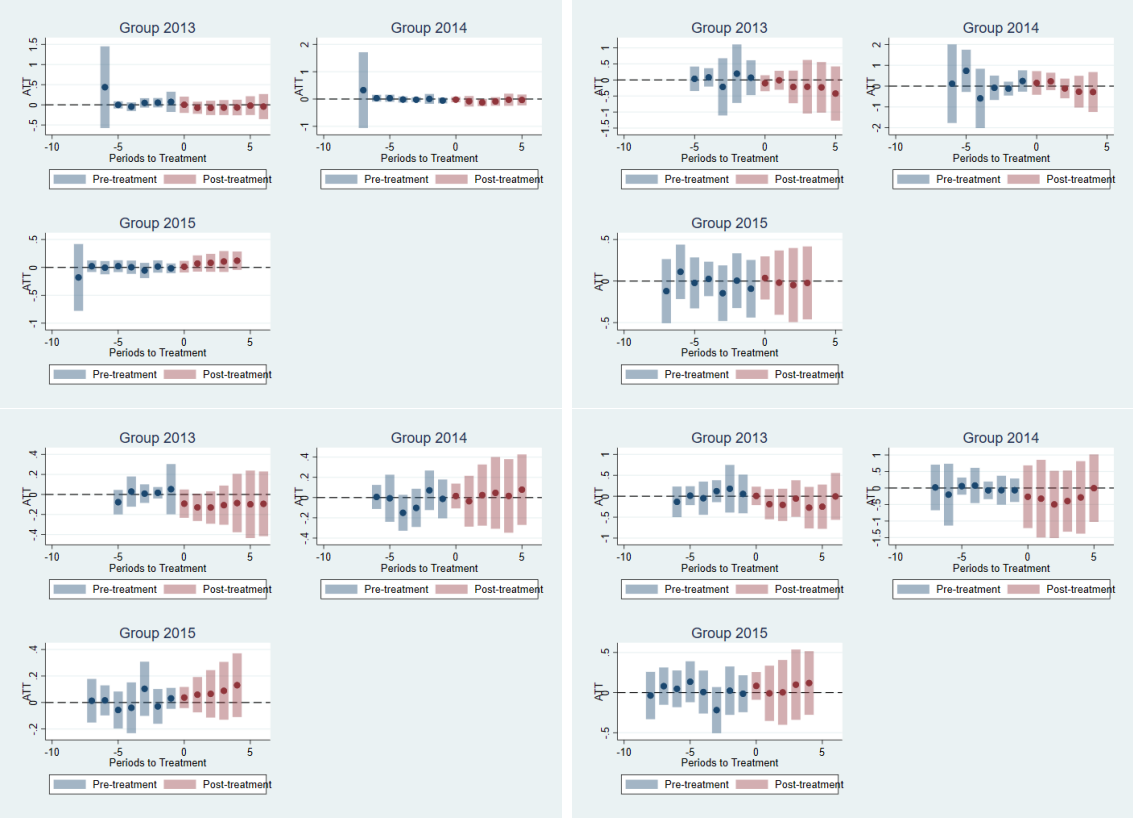
Figure 3: Event Study outcomes: Yeilds



Note: Event Studies by intervention groups (2013-2014-2015) in the following order: top-left (Ln of total yield), top-right (Ln of annual crop yield), bottom-left (Ln of permanent crop yield), bottom-right (Ln of transient crop yield).

Regarding the cultivated area (investment proxy), the observed trend in behavior is that, despite not seeing significant effects on the investment variable, the pattern tends to follow the "U" shape as described by (Galiani and Schargrodsky, 2010), especially for crops that maintain a longer productivity window due to the production cycle. For permanent crops, the trends show positive tendencies as the second year passes, while the trend behavior for annual crops shows negative tendencies (4), as indicated by the TWFE estimates.

Figure 4: Event Study outcome: sown area



Note: Event Studies by intervention groups (2013-2014-2015) in the following order: top-left (Ln of total sown area), top-right (Ln of annual crop sown area), bottom-left (Ln of permanent crop yielsown aread), bottom-right (Ln of transient crop sown area).

4.4 Policy controls, heterogenities

What the information shows is that, by itself, the implementation of the formalization program has no effect on the change in productivity measures, it remains as a future activity to develop the estimates with controls and interaction of variables of access to credit for municipalities who received the formalization program.

What the information shows is that, by itself, the implementation of the formalization program has no effect on the change in productivity measures. It remains as a future activity to develop estimates with controls and the interaction of variables related to access to credit for municipalities that received the formalization program.

The results in 7 show a set of exercises conducted to observe the behavior of production variables with controls for agricultural credit (number of credits) in general and for vulnerable populations. An increase of one credit for agricultural producers and victims of displacement results in a 0.3 percentage point increase compared to controls in production outcomes. There is also a 9 percentage point increase in the average yields of the municipality when the number of credits to small producers and young people increases.

Table 7: TWFE - Total outcomes

	(1) (Yeilds)	(2) (Yeilds)	(3) (Prod)	(4) (Prod)	(5) (A_Semb)	(6) (A_Semb)	(7) (A_Cosh)	(8) (A_Cosh)
PFR implemented	-0.038	-0.030	0.037	0.018	0.050*	0.067	0.052*	0.097*
	(0.03)	(0.07)	(0.04)	(0.07)	(0.03)	(0.05)	(0.03)	(0.06)
credits to small producers		-0.000		-0.000		0.000		0.000
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers post PFR		-0.000		-0.000**		-0.000		-0.000
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers(women) post PFR		-0.004		0.001		-0.001		-0.002
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers(women) post PFR		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
credits to producers(displ and small)		0.000		-0.001		-0.001		-0.002
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers(displ and small) post PFR		0.000		0.003*		0.001		0.001
		(0.00)		(0.00)		(0.00)		(0.00)
credits to producers(displ and small)		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
credits to small producers(displ and small) post PFR		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
credits to producers(displ and med)		0.003		-0.057		-0.011		0.000
		(0.03)		(0.04)		(0.02)		(0.02)
credits to small producers(displ and med) post PFR		-0.010		0.033		-0.016		-0.029
		(0.05)		(0.08)		(0.03)		(0.04)
credits to producers(young)		-0.010		-0.007		-0.001		-0.002
		(0.01)		(0.02)		(0.01)		(0.01)
credits to small producers(young) post PFR		0.096**		0.000		-0.009		-0.011
		(0.04)		(0.05)		(0.02)		(0.02)
credits to producers(victim and small)		0.001		0.001		-0.001		-0.001
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers(victim and small) post PFR		-0.000		-0.002**		-0.000		-0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Constant	3.004***	3.071***	9.540***	9.873***	7.922***	8.437***	7.774***	8.245***
	(0.01)	(0.04)	(0.01)	(0.04)	(0.01)	(0.03)	(0.01)	(0.03)
mean_in_control	2.990	2.990	9.498	9.498	7.888	7.888	7.742	7.742
r2	0.670	0.648	0.883	0.906	0.893	0.888	0.888	0.881
N	3829.000	1370.000	3829.000	1370.000	3829.000	1370.000	3829.000	1370.000

Standard errors in parentheses

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

Although the results of yields for all crops per municipality after the implementation of the PFR do not allow for the identification of effects different from zero, it is important to understand that the magnitude of being in a municipality with a degree of conflict eliminates the positive effects in the magnitude of the product of the implementation of the formalization policy. This relationship is observed in Table 8, where the results are negative; for example, municipalities that have received treatments (column 1) and have had conflicts over land, such as incidents of extortion, reduce the average value of yields per hectare at the municipal level by 13.2 p.p. and 0.1 p.p., respectively. This suggests persistent effects and counter-reforms that hinder the application and use of lands even with formalization processes (Gómez Hernández, 2011).

Interestingly, the presence of illicit crops has positive effects in the TWFE estimates for outcome and land use variables, increasing production, sown area, and harvested area by around 13 p.p. when it comes to municipalities that have benefited from formalization processes.

Table 8: TWFE - Conflict outcomes

	(1) (Yeilds)	(2) (Yeilds)	(3) (Prod)	(4) (Prod)	(5) (A_Semb)	(6) (A_Semb)	(7) (A_Cosh)	(8) (A_Cosh)
PFR implemented	-0.038	-0.047	0.037	-0.055	0.050*	-0.037	0.052*	-0.045
	(0.03)	(0.04)	(0.04)	(0.05)	(0.03)	(0.03)	(0.03)	(0.04)
Presence of coca crops		0.008		0.098		0.050		0.031
		(0.05)		(0.06)		(0.04)		(0.04)
Presence of coca crops		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
Presence of coca crops post PFR		-0.013		0.132*		0.117**		0.141***
		(0.05)		(0.07)		(0.05)		(0.05)
Presence of land conflicts		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
Presence of land conflicts post PFR		-0.132**		-0.008		0.047		0.070
		(0.07)		(0.09)		(0.07)		(0.07)
Extortion incidents		-0.001**		-0.002**		-0.003***		-0.003***
		(0.00)		(0.00)		(0.00)		(0.00)
Extortion incidents post PFR		-0.002		0.002		0.004**		0.004**
		(0.00)		(0.00)		(0.00)		(0.00)
Threat incidents		-0.000**		0.000		0.000		0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Threat incidents post PFR		0.000		0.001		0.000		0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Displacement expulsion		-0.000		0.000		-0.000		0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Displacement expulsion post PFR		0.000***		0.000*		0.000		0.000
		(0.00)		(0.00)		(0.00)		(0.00)
reception of displaced		0.000*		0.000		0.000*		0.000
		(0.00)		(0.00)		(0.00)		(0.00)
reception of displaced post PFR		-0.000**		-0.000*		-0.000		-0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Constant	3.004***	3.025***	9.540***	9.671***	7.922***	8.214***	7.774***	8.059***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
mean_in_control	2.990	2.990	9.498	9.498	7.888	7.888	7.742	7.742
r2	0.670	0.688	0.883	0.905	0.893	0.900	0.888	0.894
N	3829.000	2846.000	3829.000	2846.000	3829.000	2846.000	3829.000	2846.000

Standard errors in parentheses

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

In relation to understanding the behavior of production and yields in municipalities where the policy is applied and there is a presence of coca crops and investment through access to credit, the results show that an increase in the amount of credits granted in these municipalities has positive effects on production and agricultural yield variables. These effects are significant for annual and permanent crops (see Appendix 16). While the results seem

to show positive effects for transient crops in yields when there is access to credit in municipalities where medium-sized producers and victims of displacement receive higher levels of credit, positive effects when young people receive credit but negative effects (cite transient and credit) in municipalities that receive the formalization program and an increase in the number of credits.

Regarding conflict, the results by type of crop show that, in areas where there are annual crops, the outcome of extortion incidents increases production variables, such as harvested area, when places tend to have illicit crops (coca) (see Appendix 17), as well as in permanent and transient crops.

5 Conclusions

The results of this research process, while acknowledging that the estimation results do not show effects of implementing policies to formalize property titles, can be compared with other efforts to estimate causal effects in Colombia (Rincón Barajas, 2023). The findings suggest that the trends resulting from the allocation of titling policy processes exhibit non-linear patterns (Rincón Barajas, 2023), emphasizing the need to explore the effects of policies on different populations (such as youth, displaced individuals, and small-scale producers). Although it is not guaranteed that other populations cannot benefit, receiving access to financing could yield positive results in the medium and short term due to the joint benefits of the policy.

Moreover, the results indicate differentiated effects concerning conflict. Policies should take into account variations in the production capacity profiles of different crop cycles. It becomes crucial to consider integrating policies beyond credit access in regions where the cultivation and planting trends of long-term crops suggest that in conflict-prone areas, the

policy's effects are not significant. This situation may compel individuals to make decisions to mix their crop set with illicit crops.

It is important to highlight that this analysis has inherent limitations related to using aggregated information, inability to control for events like migrations, productivity dynamics, and timing of title application and receipt. The assumption in this research considers the time when the resolution is applied to the municipality and starts counting from there. As mentioned by Rincón Barajas (2023), this risk affects the process of full identification. This raises the debate to explore the titling process of this policy, seeking to exploit the available but sensitive data provided by the DNP.

References

Atwood, David A. (1990) "Land registration in Africa: The impact on agricultural production," *World Development*, 18 (5), 659–671, https://EconPapers.repec.org/RePEc:eee:wdevel:v:18:y:1990:i:5:p:659-671.

Banerjee, Abhijit V., Paul J. Gertler, and Maitreesh Ghatak (2002) "Empowerment and Efficiency: Tenancy Reform in West Bengal," *Journal of Political Economy*, 110 (2), 239–280, 10.1086/338744.

Bardhan, Pranab and Dilip Mookherjee (2007) "Land Reform And Farm Productivity In West Bengal," Boston University - Department of Economics - The Institute for Economic Development Working Papers Series dp-163, Boston University - Department of Economics, https://ideas.repec.org/p/bos/iedwpr/dp-163.html.

Bellemare, Marc (2013) "The Productivity Impacts of Formal and Informal Land Rights: Evidence from Madagascar," *Land Economics*, 89 (2), https://EconPapers.repec.org/RePEc:uwp:landec:v:89:y:2013:ii:1:p:272-290.

Benjaminsen, Tor, Stein Holden, Christian Lund, and Espen Sjaastad (2009) "Formalisation of Land Rights: Some Empirical Evidence from Mali, Niger and South Africa," *Land Use Policy*, 26, 28–35, 10.1016/j.landusepol.2008.07.003.

Besley, Timothy (1995) "Property Rights and Investment Incentives: Theory and Evidence from Ghana," *Journal of Political Economy*, 103 (5), 903–937, 10.1086/262008.

Besley, Timothy and Maitreesh Ghatak (2010) "Property Rights and Economic Development," 5, Chap. Chapter 68, 4525–4595: Elsevier, https://EconPapers.repec.org/RePEc:eee:devchp:v:5:y:2010:i:c:p:4525-4595.

Binswanger, Hans P., Klaus Deininger, and Gershon Feder (1995) "Power, distortions, revolt and reform in agricultural land relations," in Chenery, Hollis and T.N. Srinivasan eds. *Handbook of Development Economics*, 3 of Handbook of Development Economics, Chap. 42, 2659–2772: Elsevier, https://ideas.repec.org/h/eee/devchp/4-42.html.

Borras Jr, Saturnino M. and Jennifer C. Franco (2012) "Global Land Grabbing and Trajectories of Agrarian Change: A Preliminary Analysis," *Journal of Agrarian Change*, 12 (1), 34–59, https://doi.org/10.1111/j.1471-0366.2011.00339.x.

Callaway, Brantly and Pedro H.C. Sant'Anna (2021) "Difference-in-Differences with multiple time periods," *Journal of Econometrics*, 225 (2), 200–230, https://doi.org/10.1016/j.jeconom.2020.12.001, Themed Issue: Treatment Effect 1.

Centro Nacional de Memoria Histórica (2016) "Tierras y conflictos rurales Historia, políticas agrarias y protagonistas," https://centrodememoriahistorica.gov.co/wp-content/uploads/2020/01/tierras-y-conflictos-rurales.pdf.

——— (2022) "¿De quien es la tierra en Colombia?," https://www.centrodememoriahistorica.gov.co/micrositios/balances-jep/tierras.html.

Deininger, K., S. Jin, and H. K. Nagarajan (2009) "Land Reforms, Poverty Reduction, and Economic Growth: Evidence from India," *Journal of Development Studies*, 45 (4), 496–521, 10.1080/00220380902725670.

Deininger, Klaus (1999) "Making negotiated land reform work : initial experience from Brazil, Colombia, and South Africa," Policy Research Working Paper Series 2040, The World Bank, https://ideas.repec.org/p/wbk/wbrwps/2040.html.

Deininger, Klaus and Juan Sebastian Chamorro (2004) "Investment and equity effects of land regularisation: the case of Nicaragua," *Agricultural Economics*, 30 (2), 101–116, https://doi.org/10.1111/j.1574-0862.2004.tb00180.x.

Dercon., Stefan and Pramila Krishnan (2009) "Land Rights Revisited," https://mitpress.mit.edu/9780262014069/institutional-microeconomics-of-development/.

El Tiempo (1997) "Reforma Agraria, 35 años perdidos," https://www.eltiempo.com/archivo/documento/MAM-539519.

Feder, G. (1988) "Land policies and farm productivity in Thailand.," *Johns Hopkins University Press, Baltimore, Md*, https://documents1.worldbank.org/curated/en/245931468765012425/pdf/multi-page.pdf.

Galiani, Sebastian and Ernesto Schargrodsky (2010) "Property rights for the poor: Effects of land titling," *Journal of Public Economics*, 94 (9), 700–729, https://doi.org/10.1016/j.jpubeco.2010.06.002.

Ghatak, Maitreesh and Sanchari Roy (2007) "Land reform and agricultural productivity in India: a review of the evidence," *Oxford Review of Economic Policy*, 23 (2), 251–269, https://EconPapers.repec.org/RePEc:oup:oxford:v:23:y:2007:i:2:p:251-269.

Goodman-Bacon, Andrew (2018) "Difference-in-Differences with Variation in Treatment Timing," Working Paper 25018, National Bureau of Economic Research, 10.3386/w25018.

Gáfaro, Margarita, Ana María Ibáñez, and David Zarruk (2012) "Equidad y eficiencia rural en Colombia: una discusión de políticas para el acceso a la tierra," Documentos CEDE 10318, Universidad de los Andes, Facultad de Economía, CEDE, https://ideas.repec.org/p/col/000089/010318.html.

Gómez Hernández, Bersarión (2011) "La tenencia de la tierra y la reforma agraria en Colombia," https://hdl.handle.net/10901/13755.

Higgins, Daniel, Tim Balint, Harold Liversage, and Paul Winters (2018) "Investigating the impacts of increased rural land tenure security: A systematic review of the evidence," *Journal of Rural Studies*, 61, 34–62, 10.1016/j.jrurstud.2018.05.001.

Jimena, Rojas M. Maria (2014) "Programa de Formalización de la Propiedad Rural ¿Un ejemplo del nuevo derecho y desarrollo en Colombia?", https://repositorio.uniandes.edu.co/server/api/core/bitstreams/6266ce3c-accf-403b-b407-6fb34a9357db/content.

Kinsey, Bill H. and Hans P. Binswanger (1993) "Characteristics and performance of settlement programs : a review," Policy Research Working Paper Series 1207, The World Bank, https://ideas.repec.org/p/wbk/wbrwps/1207.html.

La Republica (2022) "Solo se está aprovechando 13,5% de las 39,2 millones de hectáreas con potencial," https://www.larepublica.co/economia/del-34-del-area-potencial-para-cultivar-en-colombia-se-aprovecha-cerca-del-13-5-3391297.

Legrand, Catherine (1983) *Campesinos y asalariados en la Zona Bananera de Santa Marta (1900-1935)*: Anuario Colombiano de Historia Social y de la Cultura, Número 11, páginas 235-250, Bogotá, Facultad de Ciencias Humanas, Universidad Nacional de Colombia.

Lipton, M. (2011) "Land reform in developing countries: property rights and property wrongs.," *Routledge, London.*

Londoño, Rocío (2011) *Juan de la Cruz Varela: sociedad y política en la región de Sumapaz, (1902-1984)*: Bogotá, Facultad de Ciencias Humanas, Universidad Nacional de Colombia.

Macours, Karen, Alain de Janvry, and Elisabeth Sadoulet (2010) "Insecurity of property rights and social matching in the tenancy market," *European Economic Review*, 54 (7), 880–899, https://doi.org/10.1016/j.euroecorev.2010.02.002.

Meinzen-Dick, Ruth S. and Esther Wairimu Mwangi (2009) "Cutting the web of interests: Pitfalls of formalizing property rights," *Land Use Policy*, 26, 36–43, https://api.semanticscholar.org/CorpusID:154385961.

Ministerio de Agricultura (2013a) "Guía Metodológica para Formalización Masiva de la Propiedad Rural por Barrido Predial," https://www.minagricultura.gov.co/Normatividad/Resoluciones/Anexo%201%20-%20Guia%20formalizacin.pdf.

——— (2013b) "Programa de Formalización de la Propiedad Rural," https://www.minagricultura.gov.co/tramites-servicios/desarrollo-rural/Paginas/v1/Programa-de-Formalizacion-de-la-Propiedad-Rural.aspx.

Ministerio de Agricultura y Desarrollo Rural (2010) "Resolución 0452. Por el cual se crea el Programa de Formalización de la Propiedad Rural y su unidad Coordinadora.," https://www.minagricultura.gov.co/Normatividad/Resoluciones/Resolucin%20No%20000452%20de%202010.pdf.

Pender, John L. and Samuel Benin (2001) "Impacts Of Land Resdistribution On Land Management And Productivity In The Ethiopian Highlands,"Technical report.

Rincón Barajas, Jorge A. (2023) "Productivity dynamics and state support after a land titling program: Evidence from Colombia," *Land Use Policy*, 131, 106690, https://doi.org/10.1016/j.landusepol.2023.106690.

Sjaastad, Espen and Ben Cousins (2009) "Formalisation of Land Rights in the South: An Overview," *Land Use Policy*, 26, 1–9, 10.1016/j.landusepol.2008.05.004.

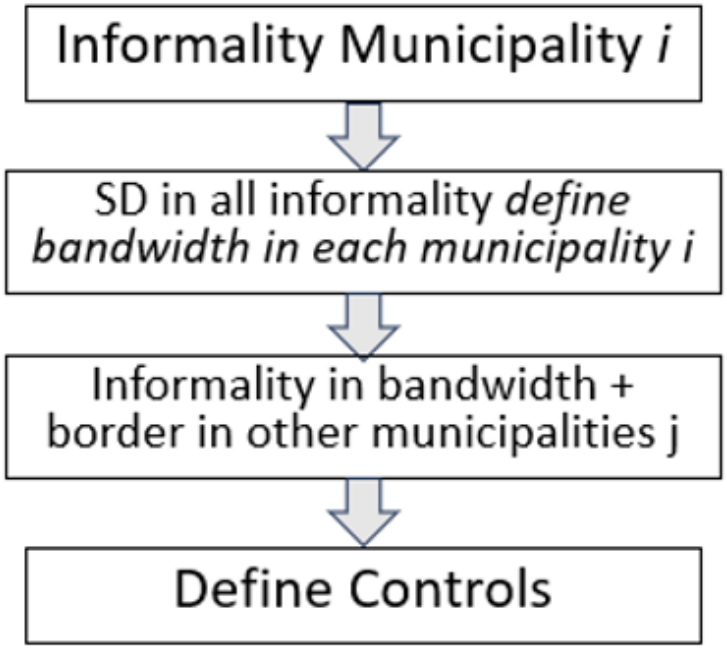
Steven Lawry, Ruth Hall Aaron Leopold Donna Hornby, Cyrus Samii and Farai Mtero (2017) "The impact of land property rights interventions on investment and agricultural productivity in developing countries: a systematic review," *Journal of Development Effectiveness*, 9 (1), 61–81, 10.1080/19439342.2016.1160947.

Sánchez, Gonzalo (1988) *Rehabilitación y violencia bajo el Frente Nacional*: Instituto de Estudios Políticos y Relaciones Internacionales, IEPRI, Universidad Nacional de Colombia, 21-46.

Tseng, Tzu-Wei Joy, Brian Robinson, Marc Bellemare et al. (2021) "Influence of land tenure interventions on human well-being and environmental outcomes," *Nature Sustainability*, 4, 10.1038/s41893-020-00648-5.

A Appendix

Figure 5: Counterfactual Selection Process Diagram



Note: The diagram illustrates the flow of the algorithm implemented to select the municipalities that will be part of the control group used to assess the performance of the policy.

Table 9: means and differences of other variables for treated and credit control municipalities pretratment 2006-2013

	Mpios Tratados mean/sd	Mpios Controles mean/sd	Diferencia b/t
nuf_grande_productor	1.38	1.98	-0.61
	(4.16)	(6.97)	(-1.72)
nuf_jovenes_rurales	0.00	0.00	0.00
	(0.00)	(0.00)	(.)
nuf_grupo_todos_productor	0.27	0.30	-0.04
	(0.87)	(1.08)	(-0.74)
nuf_mediano_productor	40.79	30.15	10.64***
	(54.20)	(34.56)	(5.18)
nuf_mujer_rural	0.22	0.09	0.14*
	(1.57)	(0.73)	(2.57)
nuf_peq_productor	275.04	197.10	77.94***
	(366.45)	(221.72)	(5.75)
nuf_victimas_conflicto_pp	0.00	0.00	0.00
	(0.00)	(0.00)	(.)
vrf_agrem	349.63	611.99	-262.36
	(1456.16)	(2420.29)	(-0.97)
vrf_grande_productor	1474.93	1573.38	-98.45
	(6788.30)	(5983.82)	(-0.28)
vrf_grupo_todos_productor	196.71	165.14	31.57
	(1532.23)	(737.00)	(0.59)
vrf_jovenes_rurales	0.00	0.00	0.00
	(0.00)	(0.00)	(.)
vrf_mediano_productor	1806.76	1560.98	245.78
	(2190.87)	(2739.42)	(1.94)
vrf_microempresario_mediano	0.00	0.00	0.00
	(0.00)	(0.00)	(.)
vrf_microempresario_peq	0.00	0.00	0.00
	(0.00)	(0.00)	(.)
vrf_mujer_rural	0.74	0.30	0.44*
	(5.57)	(2.71)	(2.25)
vrf_peq_productor	1325.68	989.20	336.48***
	(1871.23)	(1139.76)	(4.84)
vrf_victimas_conflicto_pp	0.00	0.00	0.00
	(0.00)	(0.00)	(.)
N	607	1304	1911

Note: This table displays differences in credit variables, which vary across individuals and time, with significance levels indicated at 99% (3 stars), 95% (2 stars), and 90% (1 star).

Table 10: means and differences of other variables for treated and conflict control municipalities pretratment 2006-2013

	Mpios Tratados mean/sd	Mpios Controles mean/sd	Diferencia b/t
retro_pobl_rur	14736.35	11329.29	3407.06***
	(12921.76)	(12544.21)	(5.47)
indrural	0.55	0.59	-0.03**
	(0.25)	(0.23)	(-2.90)
pib_agricola	37994.70	31307.59	6687.11**
	(37287.21)	(38237.16)	(2.71)
ocupespan_1510_1561	0.35	0.36	-0.01
	(0.48)	(0.48)	(-0.55)
d_refuerzo	0.09	0.11	-0.01
	(0.29)	(0.31)	(-0.96)
conflictos_1918_1931	0.13	0.14	-0.01
	(0.33)	(0.35)	(-0.76)
conflicto	0.05	0.06	-0.02
	(0.21)	(0.25)	(-1.58)
tpobc_FARC	0.18	0.15	0.03
	(0.88)	(0.64)	(0.81)
tpobc_ELN	0.02	0.02	0.00
	(0.15)	(0.13)	(0.30)
tpobc_DESC	2.18	1.64	0.54
	(8.01)	(8.29)	(1.13)
tpobc_AUC	0.03	0.01	0.02*
	(0.27)	(0.12)	(2.07)
asalt_pob	0.00	0.00	0.00
	(0.04)	(0.03)	(0.55)
incur_pob	0.00	0.00	0.00
	(0.04)	(0.03)	(0.55)
terrorismot	0.75	0.67	0.07
	(1.80)	(2.69)	(0.61)
secues_ext	0.32	0.15	0.17***
	(1.20)	(0.54)	(4.34)
secues_simp	0.23	0.18	0.05
	(0.94)	(1.27)	(0.82)
secuestros	0.55	0.33	0.22**
	(1.83)	(1.49)	(2.78)
hostigamientos	0.07	0.12	-0.04
	(0.37)	(0.82)	(-1.08)
hostig_MD	0.06	0.05	0.01
	(0.53)	(0.34)	(0.72)
H_coca	80.46	253.36	-172.89***
	(112.18)	(491.46)	(-3.60)
lotes_coca	76.32	261.93	-185.61***
	(104.66)	(458.38)	(-4.18)
errad_manual	106.27	155.20	-48.93
	(176.10)	(462.63)	(-1.10)
coca	0.18	0.14	0.04*
	(0.38)	(0.34)	(2.41)
o_amenazas	23.21	18.75	4.46
	(53.24)	(66.44)	(1.31)
o_perd_mue	10.43	15.53	-5.10
	(42.83)	(70.72)	(-1.29)
d_perd_mue	4.58	4.96	-0.38
	(21.55)	(35.03)	(-0.19)
e_acto_terror	12.85	10.94	1.92
	(60.13)	(44.49)	(0.54)
e_amenaza	23.53	19.01	4.52
	(53.64)	(67.13)	(1.31)
e_desplaza	436.58	430.43	6.16
	(931.51)	(1432.08)	(0.10)
e_perd_mue	10.55	15.96	-5.41
	(43.45)	(73.31)	(-1.33)
desplazados_expulsion	481.35	467.73	13.62
	(961.79)	(1474.76)	(0.19)
desplazados_recepcion	618.78	367.64	251.14**
	(2101.89)	(1158.28)	(3.18)
N	607	1304	1911

Note: This table displays differences in conflict variables, which vary across individuals and time, with significance levels indicated at 99% (3 stars), 95% (2 stars), and 90% (1 star).

Table 11: means and differences of other variables for treated and services controls municipalities pretratment 2006-2013

	Mpios Tratados mean/sd	Mpios Controles mean/sd	Diferencia b/t
cober_subsidiado	0.91	0.91	-0.00
	(0.13)	(0.12)	(-0.25)
contributivo	18044.32	12679.82	5364.49
	(50553.57)	(44964.48)	(1.77)
nacimientos	750.37	576.27	174.09*
	(1344.91)	(1394.01)	(2.57)
naci_bajopeso	59.87	46.24	13.63*
	(111.55)	(117.33)	(2.40)
defunciones	216.86	157.81	59.05**
	(441.29)	(354.31)	(3.13)
defun_menores	11.26	8.32	2.94**
	(22.16)	(21.60)	(2.75)
defun_ninez	2.35	1.91	0.45*
	(3.85)	(4.34)	(2.16)
truracued	38.40	31.43	6.97**
	(40.51)	(37.43)	(3.02)
truraseo	13.67	15.93	-2.26
	(28.82)	(29.98)	(-1.27)
truralcan	12.96	13.94	-0.98
	(28.20)	(27.73)	(-0.59)
catastro	14153.72	14315.15	-161.43
	(24596.40)	(36976.77)	(-0.06)
retro_pobl_rur			3407.06***
			(5.47)
N	607	1304	1911

Note: This table displays differences in services variables, which vary across individuals and time, with significance levels indicated at 99% (3 stars), 95% (2 stars), and 90% (1 star).

Table 12: Variable dependiente: Ln Producción (Toneladas)

	(1) Total	(2) Anual	(3) Permanente	(4) Transitorio
post	0.04	-0.15**	0.03	0.01
	(0.04)	(0.07)	(0.04)	(0.06)
Constant	9.54***	6.53***	8.82***	7.70***
	(0.01)	(0.02)	(0.01)	(0.01)
mean_in_control	9.50	6.40	8.77	7.69
r2	0.88	0.85	0.95	0.84
N	3,829.00	2,518.00	3,395.00	3,734.00

Standard errors in parentheses

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

Table 13: Variable dependiente: Ln Área Cosechadas (ha cosechadas)

	(1) Total	(2) Anual	(3) Permanente	(4) Transitorio
post	0.05*	-0.08	0.03	-0.06
	(0.03)	(0.06)	(0.03)	(0.05)
Constant	7.77***	4.24***	7.18***	6.14***
	(0.01)	(0.02)	(0.01)	(0.01)
mean_in_control	7.74	4.11	7.12	6.11
r2	0.89	0.86	0.96	0.86
N	3,829.00	2,517.00	3,394.00	3,734.00

Standard errors in parentheses

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

Table 14: heterogeneous effects on outputs - annual crops and credit

	(1) (Yeilds)	(2) (Yeilds)	(3) (Prod)	(4) (Prod)	(5) (A_Semb)	(6) (A_Semb)	(7) (A_Cosh)	(8) (A_Cosh)
PFR implemented	-0.062**	-0.001	-0.148**	-0.042	-0.058	0.025	-0.075	-0.025
	(0.03)	(0.05)	(0.07)	(0.13)	(0.05)	(0.11)	(0.06)	(0.12)
credits to small producers		-0.000		0.000**		0.000**		0.000**
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers post PFR		-0.000***		-0.000*		-0.000		-0.000
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers(women) post PFR		0.000		-0.013		-0.014		-0.013
		(0.00)		(0.01)		(0.01)		(0.01)
credits to small producers(women) post PFR		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
credits to producers(displ and small)		0.013		0.146***		0.131**		0.132***
		(0.02)		(0.05)		(0.05)		(0.05)
credits to small producers(displ and small) post PFR		0.001		-0.158**		-0.150**		-0.157***
		(0.03)		(0.06)		(0.06)		(0.06)
credits to producers(displ and small)		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
credits to small producers(displ and small) post PFR		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
credits to producers(displ and med)		-0.020		0.189		0.171		0.203
		(0.04)		(0.16)		(0.16)		(0.16)
credits to small producers(displ and med) post PFR		-0.163		-0.619**		-0.356		-0.452*
		(0.10)		(0.29)		(0.24)		(0.24)
credits to producers(young)		0.015		0.053		0.035		0.036
		(0.01)		(0.04)		(0.03)		(0.04)
credits to small producers(young) post PFR		-0.045		-0.149		-0.020		-0.118
		(0.08)		(0.31)		(0.32)		(0.33)
credits to producers(victim and small)		0.000		-0.002		-0.002		-0.003
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers(victim and small) post PFR		-0.000		0.003		0.001		0.003
		(0.00)		(0.00)		(0.00)		(0.00)
Constant	2.276***	2.328***	6.533***	6.635***	4.377***	4.451***	4.236***	4.290***
	(0.01)	(0.03)	(0.02)	(0.07)	(0.01)	(0.07)	(0.02)	(0.07)
mean_in_control	2.266	2.266	6.396	6.396	4.242	4.242	4.109	4.109
r2	0.702	0.716	0.846	0.835	0.882	0.876	0.863	0.860
N	2518.000	954.000	2518.000	954.000	2521.000	956.000	2517.000	954.000

Standard errors in parentheses

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

Note: This regress by OLS variable that represent land titling intervention related to productivity outcome (Ln), which vary across individuals and time (fixed effect), with significance levels indicated at 99% (3 stars), 95% (2 stars), and 90% (1 star). and controls in credit variables in Annual crops

Table 15: heterogeneous effects on outputs - permanent crops and credit

	(1) (Yeilds)	(2) (Yeilds)	(3) (Prod)	(4) (Prod)	(5) (A_Semb)	(6) (A_Semb)	(7) (A_Cosh)	(8) (A_Cosh)
PFR implemented	0.015	-0.114**	0.035	0.043	0.040	0.057	0.030	0.128**
	(0.02)	(0.05)	(0.04)	(0.07)	(0.02)	(0.05)	(0.03)	(0.06)
credits to small producers		0.000		0.000		0.000		0.000***
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers post PFR		0.000*		-0.000***		-0.000		-0.000*
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers(women) post PFR		-0.002		0.002		-0.002**		-0.003***
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers(women) post PFR		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
credits to producers(displ and small)		0.003**		-0.001		-0.002**		-0.003***
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers(displ and small) post PFR		-0.001		0.004*		0.001		0.002*
		(0.00)		(0.00)		(0.00)		(0.00)
credits to producers(displ and small)		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
credits to small producers(displ and small) post PFR		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
credits to producers(displ and med)		-0.041		-0.012		0.045**		0.064**
		(0.03)		(0.04)		(0.02)		(0.03)
credits to small producers(displ and med) post PFR		0.090		0.054		-0.010		-0.029
		(0.07)		(0.08)		(0.04)		(0.06)
credits to producers(young)		-0.024**		-0.034*		-0.020***		-0.026***
		(0.01)		(0.02)		(0.01)		(0.01)
credits to small producers(young) post PFR		0.059*		0.009		-0.004		-0.014
		(0.03)		(0.05)		(0.02)		(0.02)
credits to producers(victim and small)		-0.000		0.001		-0.000		-0.000
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers(victim and small) post PFR		0.000		-0.001		-0.000		-0.001
		(0.00)		(0.00)		(0.00)		(0.00)
Constant	1.998***	1.997***	8.820***	9.534***	7.397***	8.218***	7.180***	7.940***
	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	(0.02)	(0.01)	(0.02)
mean_in_control	2.002	2.002	8.769	8.769	7.340	7.340	7.120	7.120
r2	0.784	0.813	0.947	0.944	0.965	0.950	0.961	0.945
N	3395.000	1260.000	3395.000	1260.000	3397.000	1260.000	3394.000	1260.000

Standard errors in parentheses

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

Note: This regress by OLS variable that represent land titling intervention related to productivity outcome (Ln), which vary across individuals and time (fixed effect), with significance levels indicated at 99% (3 stars), 95% (2 stars), and 90% (1 star). and controls in credit variables in Permanent crops

Table 16: heterogeneous effects on outputs - transient crops and credit

	(1) (Yeilds)	(2) (Yeilds)	(3) (Prod)	(4) (Prod)	(5) (A_Semb)	(6) (A_Semb)	(7) (A_Cosh)	(8) (A_Cosh)
PFR implemented	0.023	0.007	0.014	-0.246*	-0.063	-0.340***	-0.062	-0.326***
	(0.05)	(0.12)	(0.06)	(0.14)	(0.05)	(0.12)	(0.05)	(0.12)
credits to small producers		-0.000		-0.000*		-0.000		-0.000
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers post PFR		0.000		0.000**		0.000***		0.000***
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers(women) post PFR		-0.007		0.000		0.005		0.005
		(0.00)		(0.01)		(0.00)		(0.00)
credits to small producers(women) post PFR		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
credits to producers(displ and small)		-0.001		-0.002		-0.004		-0.004
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers(displ and small) post PFR		0.001		-0.001		0.002		0.002
		(0.00)		(0.00)		(0.00)		(0.00)
credits to producers(displ and small)		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
credits to small producers(displ and small) post PFR		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
credits to producers(displ and med)		0.073*		0.102		0.057		0.052
		(0.04)		(0.06)		(0.06)		(0.06)
credits to small producers(displ and med) post PFR		-0.004		0.014		0.020		0.007
		(0.08)		(0.10)		(0.09)		(0.09)
credits to producers(young)		-0.022		0.054*		0.062***		0.062***
		(0.02)		(0.03)		(0.02)		(0.02)
credits to small producers(young) post PFR		0.065		-0.190**		-0.239**		-0.241**
		(0.06)		(0.08)		(0.10)		(0.10)
credits to producers(victim and small)		0.002		-0.003**		-0.003**		-0.003**
		(0.00)		(0.00)		(0.00)		(0.00)
credits to small producers(victim and small) post PFR		-0.002		-0.001		-0.001		-0.001
		(0.00)		(0.00)		(0.00)		(0.00)
Constant	1.794***	1.816***	7.695***	7.737***	6.231***	6.339***	6.143***	6.292***
	(0.01)	(0.06)	(0.01)	(0.07)	(0.01)	(0.06)	(0.01)	(0.06)
mean_in_control	1.805	1.805	7.687	7.687	6.202	6.202	6.115	6.115
r2	0.650	0.582	0.841	0.800	0.868	0.848	0.862	0.845
N	3734.000	1334.000	3734.000	1334.000	3734.000	1334.000	3734.000	1334.000

Standard errors in parentheses

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

Note: This regress by OLS variable that represent land titling intervention related to productivity outcome (Ln), which vary across individuals and time (fixed effect), with significance levels indicated at 99% (3 stars), 95% (2 stars), and 90% (1 star). and controls in credit variables in transient crops

Table 17: heterogeneous effects on outputs - annual crops and conflict

	(1) (Yeilds)	(2) (Yeilds)	(3) (Prod)	(4) (Prod)	(5) (A_Semb)	(6) (A_Semb)	(7) (A_Cosh)	(8) (A_Cosh)
PFR implemented	-0.062**	-0.102***	-0.148**	-0.179*	-0.058	-0.041	-0.075	-0.078
	(0.03)	(0.03)	(0.07)	(0.09)	(0.05)	(0.07)	(0.06)	(0.08)
Presence of coca crops		-0.019		-0.075		-0.052		-0.055
		(0.04)		(0.09)		(0.07)		(0.08)
Presence of coca crops		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
Presence of coca crops post PFR		-0.073		0.171		0.139		0.237*
		(0.08)		(0.16)		(0.12)		(0.13)
Presence of land conflicts		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
Presence of land conflicts post PFR		0.061		-0.188		-0.098		-0.154
		(0.07)		(0.25)		(0.20)		(0.23)
Extortion incidents		-0.000		0.008***		0.007***		0.008***
		(0.00)		(0.00)		(0.00)		(0.00)
Extortion incidents post PFR		-0.001		-0.013***		-0.010**		-0.012***
		(0.00)		(0.00)		(0.00)		(0.00)
Threat incidents		-0.000		-0.000		-0.000		-0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Threat incidents post PFR		-0.000		-0.000		-0.000		-0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Displacement expulsion		0.000		0.000		0.000		0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Displacement expulsion post PFR		0.000		0.000		-0.000		-0.000
		(0.00)		(0.00)		(0.00)		(0.00)
reception of displaced		-0.000		0.000		0.000		0.000
		(0.00)		(0.00)		(0.00)		(0.00)
reception of displaced post PFR		0.000		0.000		0.000		0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Constant	2.276***	2.291***	6.533***	6.686***	4.377***	4.540***	4.236***	4.377***
	(0.01)	(0.01)	(0.02)	(0.03)	(0.01)	(0.02)	(0.02)	(0.03)
mean_in_control	2.266	2.266	6.396	6.396	4.242	4.242	4.109	4.109
r2	0.702	0.727	0.846	0.847	0.882	0.880	0.863	0.862
N	2518.000	2060.000	2518.000	2060.000	2521.000	2062.000	2517.000	2059.000

Standard errors in parentheses

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

Note: This regress by OLS variable that represent land titling intervention related to productivity outcome (Ln), which vary across individuals and time (fixed effect), with significance levels indicated at 99% (3 stars), 95% (2 stars), and 90% (1 star). and controls in conflict variables in Annual crops

Table 18: heterogeneous effects on outputs - permanent crops and conflict

	(1) (Yeilds)	(2) (Yeilds)	(3) (Prod)	(4) (Prod)	(5) (A_Semb)	(6) (A_Semb)	(7) (A_Cosh)	(8) (A_Cosh)
PFR implemented	0.015	0.056*	0.035	-0.019	0.040	-0.009	0.030	-0.024
	(0.02)	(0.03)	(0.04)	(0.04)	(0.02)	(0.03)	(0.03)	(0.03)
Presence of coca crops		-0.002		-0.033		0.048*		0.011
		(0.03)		(0.04)		(0.03)		(0.03)
Presence of coca crops		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
Presence of coca crops post PFR		-0.120**		-0.038		-0.003		0.055
		(0.05)		(0.07)		(0.04)		(0.04)
Presence of land conflicts		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
Presence of land conflicts post PFR		-0.288***		0.040		0.066		0.124*
		(0.06)		(0.09)		(0.05)		(0.07)
Extortion incidents		-0.002***		-0.001		0.001		0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Extortion incidents post PFR		-0.001		-0.001		-0.003***		-0.002**
		(0.00)		(0.00)		(0.00)		(0.00)
Threat incidents		0.000		-0.000		-0.000**		-0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Threat incidents post PFR		0.000**		0.001		0.000***		0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Displacement expulsion		0.000*		0.000		-0.000		0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Displacement expulsion post PFR		0.000*		0.000*		0.000***		0.000**
		(0.00)		(0.00)		(0.00)		(0.00)
reception of displaced		-0.000		-0.000		-0.000		-0.000
		(0.00)		(0.00)		(0.00)		(0.00)
reception of displaced post PFR		-0.000		-0.000		-0.000*		0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Constant	1.998***	1.986***	8.820***	9.271***	7.397***	7.873***	7.180***	7.662***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
mean_in_control	2.002	2.002	8.769	8.769	7.340	7.340	7.120	7.120
r2	0.784	0.814	0.947	0.954	0.965	0.963	0.961	0.958
N	3395.000	2611.000	3395.000	2611.000	3397.000	2612.000	3394.000	2611.000

Standard errors in parentheses

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

Note: This regress by OLS variable that represent land titling intervention related to productivity outcome (Ln), which vary across individuals and time (fixed effect), with significance levels indicated at 99% (3 stars), 95% (2 stars), and 90% (1 star). and controls in conflict variables in Permanent crops

Table 19: heterogeneous effects on outputs - transient crops and conflict

	(1) (Yeilds)	(2) (Yeilds)	(3) (Prod)	(4) (Prod)	(5) (A_Semb)	(6) (A_Semb)	(7) (A_Cosh)	(8) (A_Cosh)
PFR implemented	0.023	0.045	0.014	-0.062	-0.063	-0.218***	-0.062	-0.220***
	(0.05)	(0.07)	(0.06)	(0.08)	(0.05)	(0.07)	(0.05)	(0.07)
Presence of coca crops		-0.033		0.110		0.248***		0.258***
		(0.07)		(0.10)		(0.08)		(0.08)
Presence of coca crops		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
Presence of coca crops post PFR		-0.076		0.155		0.039		0.031
		(0.11)		(0.18)		(0.13)		(0.13)
Presence of land conflicts		0.000		0.000		0.000		0.000
		(.)		(.)		(.)		(.)
Presence of land conflicts post PFR		-0.285**		0.080		0.226		0.238
		(0.11)		(0.17)		(0.15)		(0.15)
Extortion incidents		-0.000		0.000		0.000		0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Extortion incidents post PFR		-0.003		-0.002		0.004		0.004
		(0.00)		(0.00)		(0.00)		(0.00)
Threat incidents		-0.001***		-0.000**		0.000*		0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Threat incidents post PFR		0.000		-0.000		-0.000		-0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Displacement expulsion		-0.000		-0.000		-0.000**		-0.000**
		(0.00)		(0.00)		(0.00)		(0.00)
Displacement expulsion post PFR		0.000		0.000		0.000**		0.000**
		(0.00)		(0.00)		(0.00)		(0.00)
reception of displaced		0.000*		0.000***		0.000**		0.000**
		(0.00)		(0.00)		(0.00)		(0.00)
reception of displaced post PFR		-0.000		-0.000		-0.000		-0.000
		(0.00)		(0.00)		(0.00)		(0.00)
Constant	1.794***	1.710***	7.695***	7.518***	6.231***	6.242***	6.143***	6.144***
	(0.01)	(0.02)	(0.01)	(0.03)	(0.01)	(0.02)	(0.01)	(0.02)
mean_in_control	1.805	1.805	7.687	7.687	6.202	6.202	6.115	6.115
r2	0.650	0.627	0.841	0.815	0.868	0.867	0.862	0.860
N	3734.000	2768.000	3734.000	2768.000	3734.000	2768.000	3734.000	2768.000

Standard errors in parentheses

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

Note: This regress by OLS variable that represent land titling intervention related to productivity outcome (Ln), which vary across individuals and time (fixed effect), with significance levels indicated at 99% (3 stars), 95% (2 stars), and 90% (1 star). and controls in conflict variables in transient crops