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# The role of land property rights in the war on illicit crops: Evidence from Colombia

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ABSTRACT

This paper examines the effect of the formalization of land property rights in the war against illicit crops, using the case of Colombia. We argue that as a consequence of the increase in state presence and visibility, municipalities with a higher level of formalization of their land property rights witnessed a greater reduction in the area allocated to illicit crops. We hypothesize that this is due to the possibility of obtaining more benefits in the newly installed institutional environment when land is formalized, and the increased cost of growing illicit crops on formal relative to informal land. We find that a one-standard-deviation increase in the formality index for smallholders is related to a reduction in the share of municipal area allocated to coca crops of 0.101 percentage points. That is, the formalization of one additional hectare of land with respect to small landholders in an average municipality in the year 2000 is associated with a decrease of approximately 1.4 hectares of land allocated to coca within that particular municipality, ceteris paribus. These results remain robust to a number of sensitivity analyses. Our findings contribute to empirical evidence on the positive effects of formal land property rights and effective policies in the war on drugs.



## 1. Introduction

The distribution and definition of land property rights play a crucial role in the transition from an agricultural to an industrial economy (Barraclough, 1970; Easterly, 2007). In most western economies, a more formalized scheme of land property rights has been associated with higher levels of investment, income growth, accumulation of human and physical capital and poverty reduction, among other social and economic outcomes (Banerjee, Gertler, & Ghatak, 2002; Besley & Burgess, 2000; Dercon & Krishnan, 2010; Deininger & Nagarajan, 2009). By contrast, high levels of informality might represent an important hindrance to the development process (Acemoglu & Robinson, 2006; Barraclough, 1970; Dercon & Krishnan, 2010). Many scholars have suggested that a lack of formal land rights could hinder law enforcement by government bodies, increase social tensions, facilitate illegal recruitment, forced displacement and land appropriation, and boost illegal activities in conflict areas (André & Platteau, 1998; Grossman & Kim, 1995; Ibanez & Carlsson, 2010). Despite the empirical evidence on the social and economic outcomes associated with either formal or informal land property rights systems, relatively little attention has been placed on the relationship between the strength of land property rights and illicit activities.

In Colombia, on average, approximately 22 percent of all private rural land has no formal title, of which 89 percent are small plots of less than 20 hectares – ha. These territories are characterized primarily by weak law enforcement, an abundance of natural resources, and a high prevalence of poverty, which creates a perfect breeding ground for illegal activities such as coca cropping (Dávalos et al., 2011). During the 1990s, Colombia became the largest coca producer in the world (Angrist & Kugler, 2008). In response, the Colombian and US governments launched the program *Plan Colombia*, which was intended to strengthen the military power, social cohesion and justice. As a result, Colombia became a major recipient of US military assistance (Dube & Naidu, 2015). Nonetheless, despite the billions of dollars spent, the coca production economy seemed hardly damaged. Instead, because of the adaptive behavior of the coca growers, in 2009 nearly the same amount of cocaine was being produced on only half of the land that was being used for the cultivation of coca crops before the beginning of *Plan Colombia* (GAO, United States Goverment

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Accountability Office, 2008; Mejía, 2010b). This context demonstrates the need to thoroughly understand which strategies were more effective in reducing coca production, and under which circumstances.

In this paper, we analyze the role of the level of formality of land property rights in the "War on Drugs" in Colombia. We argue that the low presence of the state in most of the Colombian regions before 2000 boosted the spread of coca crops throughout the territory. Once the rule of law increased, attempts to reduce coca crops were more effective in those municipalities with more formalized land property rights. Two main mechanisms might explain this relationship. First, improved institutional conditions due to the increased state presence (e.g., *Plan Colombia*), could have been more attractive to peasants with legal titles because they were able to benefit more from alternative programs (both within *Plan Colombia* and outside the scope of this counter-drug policy), for example by using land as collateral to obtain credit, or by substituting illegal crops for low-risk cash crops, among others. We call this the substitution mechanism. Second, there is an increase in the cost of cultivating coca due to more severe sanctions. On the one hand, formal ownership implies criminal responsibility for landholders that grow coca on their land plot. On the other hand, land titles inherently increase land value, *ceteris paribus*. Hence, as the government expropriates landowners with coca crops from their land, the cost associated with expropriation rises. This operates as a standard deterrence mechanism as proposed by Becker (1968). In sum, we argue that improved land rights create microeconomic incentives to change risk-taking behavior once law enforcement increases.

Our identification strategy exploits the plausibly exogenous variation in the level of formalization of land property rights at the municipal level provided by the "Program for Land Titling and Modernization of the Registry of Deed and Cadastre." This program was a joint effort by the Colombian Government and the Inter-American Development Bank (IDB). This initiative was intended to increase the coverage of cadastral information and the level of formalization of land property rights across the Colombian territory. The program was implemented between 1995 and 2000 in about one-fifth of the Colombian municipalities, leading to a plausible exogenous source of temporal variation in the level of formalization in these municipalities for the following reasons. First, it started a supply-driven formalization process for landowners whose titles were not formally registered. Second, this process was centralized and implied a minimum level of involvement by the landowner. Third, the duration of the process until the resolution of the formalization process was driven by factors that are arguably exogenous to unobserved characteristics that can be correlated with the presence of coca crops in a municipality. Importantly, since these municipalities were all subject to the same program, for our sample the quality of the land tenure information is reliable. Also, we expect measurement errors not to be correlated with unobservables either.

There are several threats to our identification strategy. First, increased levels of formalization could lead coca growers to migrate to other municipalities where the formalization process is slower to grow coca there, which would confound our effect. Second, there may be omitted time variant productivity conditions at the municipal level that might also explain the change in coca crops. Third, the level of formalization of the land property rights is correlated with the development process itself, and so our results could be capturing a broader social phenomena that is also time variant at the municipal level. Fourth, the government may have deliberately targeted those municipalities that experienced an improvement in land formalization through their other counter-drug policies. In such a case, those policies would be confounding our results. We provide empirical evidence to rule out these threats, as well as additional sensitivity analyses using alternative independent variables.

Additionally, we provide empirical evidence on a transmission mechanism that could explain the relation: improved institutional conditions allow peasants to benefit more from alternative legal activities (i.e. substitution). We test this mechanism in two different ways. First, by using information on coffee cropping, the most important cash crop in Colombia, we test whether the change in the level of formality of land property rights is positively correlated with coffee growing. Such a correlation would suggest peasants might be benefiting from this alternative crop. Second, we test whether alternative development programs that were universally implemented in coca growing municipalities persisted more in places with improved land rights. Such a situation would strengthen the argument that peasants could be benefiting more from legal alternatives.

We use a data set of Colombian municipalities from 2000 to 2009. As a proxy for the level of formalization of land property rights, we build an index based on the share of small plots ($\leqslant 20$ ha) without legal deeds. We create the index using plot-level census data from the Colombian Geographical Institute Agustín Codazzi–IGAC, *Spanish acronym*–. We focus primarily on these smaller plots, as the vast majority of coca is found to be produced on such land[1] (Mejía & Rico, 2010). Often, the strength or safety of property rights is measured through an index based on the risk of expropriation (Acemoglu, Johnson, & Robinson, 2001; Knack & Keefer, 1995). Although having a formal title or deed does not guarantee that a person is protected from becoming a victim of expropriation when law enforcement is weak, we argue that titling allows for the possibility of resorting to formal mechanisms to regain lost land through judicial institutions. In addition, we use information on coca crops provided by the United Nations Office on Drugs and Crime–UNODC–and the Colombian Government.

We estimate a fixed effects model for the sample of municipalities where the "Program for Land Titling and Modernization of the Registry of Deed and Cadastre" took place and either have natural conditions for cropping coca (i.e., an altitude of 500 to 2000 meters above the sea level) or ever had coca crops during the period from 2000 to 2009. In addition to controlling for time-invariant municipal characteristics, this specification allows us to introduce different linear and non-linear time trends that could bias our estimates. Because of the highly endogenous relationship between the "War on Drugs" and coca production, we cannot directly include controls for law enforcement. Although this issue is partially addressed by the inclusion of municipal-level fixed effects, we also include the interaction between the time trend and the presence of military bases of the government. One characteristic of the US military aid in Colombia is that it is disbursed to specific military units that operate from different military bases. Thus, one may expect that those municipalities with military bases were more exposed to the increase in law enforcement (Dube & Naidu, 2015).

Our findings suggest that stronger property rights structures have a negative effect on the share of land allocated to coca crops. We find that a one-standard-deviation increase in the formality index for small landowners is associated with a decrease in the share of municipal area allocated to coca crops of 0.101 percentage points, on average. To put these numbers into perspective, they imply that the formalization of one additional hectare of land with respect to small landholders in an average municipality in the year 2000 is associated with a decrease of approximately 1.4 hectares of land allocated to coca within that particular municipality, *ceteris paribus*. This is a local effect for the sample

[1] According to Mejía and Rico (2010), the average size of a coca field in 2002 was 2.2 ha, in 2008 around 0.6 ha. This implies that around 166,000 rural household were involved in coca crop cultivation in 2008.

of municipalities included in the "Program for Land Titling and Modernization of the Registry of Deed and Cadastre" that also have natural conditions to grow coca. Moreover, we do not find spillover effects on neighboring municipalities. Other sensitivity analyses using different samples and measures of land formality offer confirmatory results. Regarding the transmission mechanism, we find that a one-standard-deviation increase in the formality index for small land plot owners is associated with the appearance of 77 new coffee fields, on average. We also find that a one-standard-deviation increase in the formality index is associated with an increase of about 40 percentage points regarding the likelihood of having alternative development programs in the municipality.

To the best of our knowledge, this is the first study to provide empirical evidence on the relationship between different levels of formalization of land property rights and illicit activities such as coca growing. Hence, our study contributes to the economic literature in two distinctive ways. First, we contribute to the debate on the importance of institutions concerning micro- and macroeconomic and social performance. Second, our results provide technical support in favor of policies focusing on the strength of institutions as an effective alternative to counter illicit behavior such as coca production. For the specific case of Colombia and other drug producing countries, land rights formalization presents an effective alternative to other policies such as aerial eradication, which have been proven not only ineffective but also counterproductive. Indeed, Mejía, Restrepo, and Rozo (2017) find that spraying one additional hectare with glyphosate is associated with a decrease of up to 0.030 hectares of land cultivated with coca crops. Even though both studies differ with respect to the sample of municipalities and territories under study–which might limit a direct comparison, the effect is more than an order of magnitude larger.

The structure of the paper is as follows. Section 2 discusses the economic framework of land property rights and illicit activities. In Section 3 we provide a brief overview of the institutional context in Colombia. Section 4 introduces the data and our identification strategy. The results are discussed in Section 5. Section 6 concludes.

## 2. Land property rights and illegal behavior: an economic framework

Land property rights form a key component of an institutional setting, establishing the rules for the use of and access to land (Dercon & Krishnan, 2010; North, 1990). A well-defined land property rights scheme should guarantee a private, exclusive, transferable, alienable, and enforceable right to appropriate any rent or benefit from the land (Demsetz, 1967; Feder & Feeny, 1991). It therefore implies a social and political scheme to enforce these rights. In most Western societies, formal titles or deeds constitute a physical representation of a property rights system (i.e., *de jure*), whereby the state enforces the complete enjoyment of land rights. In contrast, in many developing countries, land property rights still fall within the realm of informal customary law, which is often based on ethical or religious principles. Within such a system, rather than the physical representation of land titles, people or communities hold symbolic and intangible rights to land (i.e., *de facto*) (Besley, 1995; Dercon & Krishnan, 2010). In general, these systems are considered less efficient than their formal counterparts, due to their less strict characteristics, in combination with weak law enforcement and limited transferability (Besley & Persson, 2009; Deininger, Ali, & Yamano, 2008; Demsetz, 1967; Feder & Onchan, 1987; Hafer, 2006).

A number of positive economic and social outcomes are commonly associated with formal and well-defined land property rights systems in rural and urban areas. First, several scholars report positive effects on rural investment. Two mechanisms are considered here. On the one hand, as a direct consequence of a reduction in the risk of expropriation (i.e., decreased uncertainty), the expected returns might increase. Consequently, peasants and external investors are more inclined to invest in the short, medium and long terms, resulting in higher productivity and therefore rural welfare (Besley, 1995; Deininger et al., 2008). On the other hand, because formal titles to land can be easily used as collateral, credit markets are more accessible for land owners, increasing potential investment (Deininger et al., 2008; Feder & Onchan, 1987). Although these arguments are susceptible to endogeneity (i.e., more investment could incentivize a demand for improved land rights), the results seem to be robust after controlling for this potential bias (Besley, 1995). Second, formal land property rights prompt efficiency in the land market. The marketability gains could lead to an important increase in land transactions (Conning & Robinson, 2007). This new dynamic modifies not only the equilibrium prices in the land market but also matching efficiency in the land rental markets, resulting in a significant increase in productivity (Deininger & Chamorro, 2004; Macours, Janvry, & Sadoulet, 2010). Third, in addition to the mechanisms highlighted above, a growing body of evidence reveals positive effects on income growth and the accumulation of human and physical capital (Besley & Burgess, 2000; Deininger & Nagarajan, 2009), poverty reduction (Galiani & Schargrodsky, 2010), labor supply (Field, 2007), political empowerment (Goldstein & Udry, 2008), reduction in social confrontations (Albertus & Kaplan, 2013) and an increase in the bargaining power of the less wealthy in a region (Banerjee et al., 2002).

Nevertheless, formal land property rights schemes are not necessarily the best option in every context. Multiple studies report counter-evidence against the positive effects noted above (Brasselle, Gaspart, & Platteau, 2002; Pande & Udry, 2006). Brasselle et al. (2002) find in Burkina Faso that traditional, more customary, communal and informal institutions create a good small-scale investment climate just as well as their codified and secure counterparts do. Deininger and Jin (2006) find similar ambiguous evidence related to productivity and investment using data from Ethiopia, arguing that the increased percentage of formal land property rights through the number of planted trees had discouraged productivity and enhanced investments such as terracing. Jacoby and Minten (2007) find for Madagascar that the economic benefits from extending land titling would be minor and would not exceed its implementation cost. Nonetheless, as these authors note, these findings are due primarily to effectiveness of the customary tenure and their informal enforcement mechanisms (e.g., religious punishment), which are found to be as effective as their formal counterparts only when well established (Besley, Burchardi, & Ghatak, 2012; Brasselle et al., 2002; Goldstein & Udry, 2008; Jacoby & Minten, 2007).

An important implication of the strength of land property rights is the reduction in the risk of expropriation, which could affect portfolio choice. The absence of titles or effective mechanisms to enforce them deprives poor families of a valuable insurance and saving tool that could provide protection during bad times and retirement (see Galiani & Schargrodsky, 2010 in an urban context). Hence, squatters usually opt for other insurance alternatives, preferring a short time horizon and risky portfolio (Besley, 1995). This might create opportunities for illicit behavior to emerge, especially in rural areas with weak law enforcement and the natural conditions to develop profitable and illegal crops. Nevertheless, little is known about the potential implications of the strength of land property rights for illicit behavior.

## 3. Land property rights and coca crops in Colombia: an institutional background

In Colombia, the land property rights system can be characterized as dual.[2] On the one hand, a large portion of land plots with formalized titles were the result of land distribution during the colonial period, as well as the various polices for the assignation of public land during the last two centuries (Ibáñez & Muñoz-Mora, 2010).[3] The remaining land stayed primarily informal due to the unplanned expansion of the agricultural frontier. This dual and unequal scheme has become not only an important hurdle to the development of the region and country but also one of the main sources of social conflict (LeGrand, 1988). The Colombian government has made several attempts to resolve this duality in the property rights scheme.[4] Nevertheless, after multiple attempts to implement land reforms, the old structure remained firmly in place Binswanger, Deininger, and Feder, 1995; Machado, 2009. Two explanations are primarily responsible for this failure: (i) poor design and low state capacity and (ii) the power of large landowners, who blocked and transformed the reforms to their benefit (Ibáñez & Muñoz-Mora, 2010). Recently, Law 160, issued in 1994, was designed to spur rural development through the promotion of land markets, which conferred the responsibility for clarifying property rights on the peasant. Supply-oriented formalization programs, in which the state promoted titling, making it easier for landowners to obtain titles, and in which the state verified and reconfirmed existing titles, have been rare, with the latest one between 1995 and 2002. This program, called "Program for Land Titling and Modernization of the Registry of Deed and Cadastre", led by the IDB and the Colombian government, gave over 250,000 households a formal title.[5]

The 1980s witnessed the rise of coca cartels, in a country torn by political conflict with unresolved historical land issues. Although Colombian drug dealers were initially drug intermediaries rather than producers,[6] during 1990s, coca crops rapidly spread across all Colombian territories (Mejía & Rico, 2010).[7] Several facts explain this expansion. First, due to the effective policies to counter drug production in Peru and Bolivia, Colombian drug dealers were left with no other option than to find new locations for their coca growing and producing activities (Angrist & Kugler, 2008). Second, as demand for cocaine grew, which increased potential profits of this illicit industry, illegal groups began participating actively in the production of coca crops. The strategy of these groups was to use most of the territories under their control for coca production, where small-scale coca growers were obliged to sell their output to these groups exclusively in return for protection and technical support.[8]

The expansion of coca crop fields occurred primarily on the agricultural frontier, where the lack of law enforcement, the weak definition of land property rights, the abundant natural resources and the high prevalence of poverty generated a perfect environment to establish the coca production industry, which is based principally on small coca growers (i.e., small land plots)[9] (Angrist & Kugler, 2008; Dávalos et al., 2011; Mejía & Rico, 2010). While only a small portion of total profits remains with the small coca growers, this profit is relatively larger than that from any other alternative crop (Mejía & Rico, 2010). Over time, Colombia has witnessed many policies to reduce coca production, with *Plan Colombia* being the most comprehensive.[10] This program had three pillars: strengthen military power, increase social cohesion and development, and strengthen justice.[11] The seizure of raw materials for coca production, manual and aerial eradication of coca fields, land expropriation, destruction of laboratories, interdiction of drug shipments and promotion of alternative development programs were frequent tactics under this policy (GAO, United States Goverment Accountability Office, 2008; Mejía, 2010b). *Plan Colombia* was complemented by an intense counter-insurgency policy, launched by President Alvaro Uribe (2002–2010). Despite a meaningful increase in law enforcement in all national territories[12] and halting the expansion of coca fields, the production side was hardly affected. In fact, nearly the same amount of cocaine is being produced on half the land that was being used for the cultivation of coca crops before the implementation of *Plan Colombia* (Mejía, 2010b).

These mixed results might be explained by a number of reasons. First, because drug producers' capacity to counteract anti-drug policies is much larger than the capacity of drug traffickers, policies were less effective on the production side (Mejía et al., 2017; Mejía & Restrepo, 2008). Small coca growers appeared to be able to learn and adapt rapidly, thereby evading the rule of law and reallocating their crops (Mejía & Rico, 2010; Mejía & Restrepo, 2008). Second, it seems to suggest that small coca growers follow a persistent risk-taking behavior pattern, whereby coca cultivation becomes inelastic to increases in perceived risk. Ibanez and Carlsson (2010) note that this behavior cannot be explained solely by monetary reasons. Non-monetary variables, such as experience with coca cultivation, legitimacy of authorities, and religion, could also be important factors in this decision-making procedure on the part of coca growers. Hence, an increase in law enforcement is efficient if and only if the policies generate microeconomic incentives that alter the risk-taking behavior of coca growers, thereby restoring the link between small coca growers and the state. In such a context, the strength of land property rights might have had an

[2] Ample of literature can be found on land issues in Colombia. Ibañez and Munoz-Mora (2010) provide a general overview of the different land institutions and policies from the colonial period until the late twentieth century.

[3] After independence, most of the colonial institutions remained in place, with the land titles that originated during Spanish rule being enforced by the new sovereign state (Machado, 2009). This set the initial conditions for land property rights in Colombia, with large formalized land plots based on former semi-feudal structures (Ibáñez & Muñoz-Mora, 2010; LeGrand, 1988).

[4] For a detailed description of those policies, see Machado (2009) and Ibáñez and Muñoz-Mora (2010).

[5] This program was designed to consolidate and strengthen an open, transparent, and efficient land market that would facilitate access to the financial system for urban and rural property owners. Registered titles would be awarded to approximately 100,000 parcels of land in 200 rural municipalities and 150,000 parcels of urban property in 50 municipalities (Colombian Goverment – IDB, 1997).

[6] The cocaine production process usually consists of four stages: (i) growing and cropping the coca leaves; (ii) the extraction of coca paste; (iii) the transformation thereof into cocaine base; and (iv) the conversion of cocaine base into cocaine hydrochloride, a process that, due to its complexity, usually takes place in local laboratories. The final stage is trafficking or commercialization (Mejía & Rico, 2010).

[7] Mejía (2010a) note: "In 1990, Peru had the largest number of hectares under coca cultivation (about 62 percent of the total), and Colombia the lowest (14 percent). By 1999, these shares had completely reversed, with Peru having 21 percent of the total, Bolivia, 12 percent, and Colombia 67 percent."

[8] Furthermore, rebels minimize economic risks and cost by providing technical assistance, a minimum price and collection of yield at the farm gate. (Anecdotal evidence from an interview with a demobilized high-rank member of FARC, July 2010) (Moreno-Sanchez, Kraybill, & Thompson, 2003).

[9] As Dávalos et al. (2011, p. 1225) note: "The expansion of coca itself is an indication that these municipalities constitute the agricultural frontier, where settled land ends and new inroads begin. If so, these municipalities should have a greater proportion of their surface in forest because socio-political integration and economic development have produced massive forest loss in Colombian history."

[10] *Plan Colombia* originated between 1998 and 1999 as a bilateral cooperation program between the governments of Colombia and the United States to counter illegal drugs and organized crime. The program demanded combined average annual spending of US$ 1.7 billion (2011 US dollars) between 1999 and 2005 (GAO, United States Goverment Accountability Office, 2008).

[11] For a complete technical overview and evaluation of *Plan Colombia*, see Mejía (2010b) and Mejía and Restrepo (2008), or from an political perspective, see GAO, United States Goverment Accountability Office (2008).

[12] Before 2002, nearly 5 percent of Colombian municipalities (i.e., 50) did not have a police presence. During the government of President Uribe, the presence of the police and army increased in 18 percent of Colombian municipalities (Cortés, Vargas, Hincapie, & del Rosario Franco, 2012).

important role in the efficiency and effectiveness of the war on illegal crops in Colombia.

## 4. Empirical framework

### (a) *Data*

We use a ten-year longitudinal data set for all Colombian municipalities covering the period 2000–2009.[13] Based on remote sensing, the United Nations Office on Drugs and Crime–UNODC– and the Colombian government provide the net area allocated to coca crops in each Colombian municipality over time.[14]

As our main variable of interest, we use an original index for the level of formalization in land property rights for small plots ($\leqslant$ 20 ha),[15] based on the cadastral information provided by the Colombian Geographical Institute Agustín Codazzi – IGAC, *Spanish acronym*–.[16] Cadastral data is collected through plot censuses, which gather information on the owner, the physical characteristics of the land and, specifically, on the registration of any formal title or deed at the local registry offices;[17] this allows us to categorize every plot as *formal* or *informal*. Thereby, we define our land tenure formality index for smallholders $\leqslant$20 ha), $f_{i,t}$, as:

$$f_{i,t} = \frac{\text{Area (ha) of formal properties for small landholders } (\leqslant 20 \text{ ha})_{i,t}}{\text{Private cadastral area (ha) for small landholders } (\leqslant 20 \text{ ha})_{i,t}}$$

The cadastral municipality information can be in two different states: (i) If no data collection has been performed, people are obliged to declare their land themselves without any technical verification. This creates very vague information known as a *fiscal cadastral*; (ii) once the plot census has taken place, all information on the location, ownership, physical characteristics and size is verified by a technician. From this point onward, municipalities are considered to have a *cadastral formation*. Because it is impossible to perform a plot census every year, owners are obliged to report any land transactions, in a process called *cadastral conservation*. In order to keep the information up to date, Colombian regulation dictates that municipalities must conduct a new plot census within five years after being formed or updated. Whereas the first plot census or *cadastral formation* is a centralized decision made by the Colombian central government, the updating process is generally a combined decision of local and central authorities.[18] Given the structure of the cadastral information, several concerns might arise. First, as additional information after the official plot census is self-reported by the owner, this could generate measurement error due to miss-reporting. That is, our index could be underestimating the actual situation of land property rights due to unobserved owner characteristics that might disincentivize the registration of new titles or deeds. Second, given the high demands in terms of the organization costs required for the updating process, only well-motivated politicians will promote such policies. Furthermore, illegal actors or large owners could manipulate the local institutions to block the implementation of titling programs or the updating of the cadastral information to maintain the *status quo* (Fergusson, 2013). This might generate an important selection problem through which a systematic difference could arise between municipalities with different cadastral information quality, which could be correlated with the persistence of coca crops.

To address the measurement problem, we focus our analysis in a sample of municipalities that were subject to *cadastral formation* with the "Program for Land Titling and Modernization of the Registry of Deed and Cadastre".[19] This program had two main objectives (Colombian Goverment – IDB, 1997): (i) increase the coverage of the cadastral information in municipalities with *fiscal cadastre*; and (ii) improve the formalization of land property rights throughout the Colombian territory. The first objective of the program allows us to control for the measurement problem. In particular, since these municipalities were collectively selected to conduct their first plot census, our estimates will be based on a homogeneous sample with reliable land tenure data. The second objective will be important for our identification strategy and we will elaborate more on this in the next section. In addition to restricting our analysis to this sample of municipalities, we focus only on those that either have natural conditions to crop coca (i.e., an altitude 500 to 2000 meters above sea level) or ever had coca during the period 2000–2009.

As a result of the program, about one-fifth of all Colombian municipalities, primarily those located at the former agricultural frontier, experienced their first plot census. Graph 1 depicts the timing of the first plot census of all Colombian municipalities that either have natural conditions to crop coca or ever had such crops between 2000–2009. Our baseline sample is highlighted in the grey square. There are a number of municipalities that had their first plot census after 1990 and before the program started. Since we cannot guarantee that such *cadastral formation* processes are exogenous to unobserved characteristics of the municipalities, nor be certain that data quality is homogeneous for all of them, we exclude them from our analysis.[20]

Regarding the policies of *Plan Colombia*, we use information provided by UNODC and the Colombian government. For the interdiction policies we consider two variables: number of kilograms of coca leaves seized and number of laboratories destroyed.[21] Furthermore, we include the number of hectares eradicated both

[13] We exclude the municipalities in the department of Antioquia, as the information on property rights is managed by a descentralized agency and are not available for the same period of time. We will include as a robustness check.

[14] Because coca fields could change within the same year, UNODC and the Colombian government use a cut-off date at the end of each year to estimate the area under coca cultivation. Some potential measurement errors need to be taken into account. First, while satellite images are corrected for meteorological conditions, some bias such as mountain slopes and the false identification of abandoned fields as active ones could persist. Second, the method for data collection on the coca fields could rule out the detection of short term coca plantations. Some of these disadvantages are partially addressed with auxiliary information from the Colombian government and correction through verification overflights (UNODC, 2011).

[15] There is an open debate on the definition of the size of small plots in developing countries (among others, see Berry, 2010; Carter, 1984 & Eastwood et al., Eastwood, Lipton, & Newell, 2010). We opt for a conservative definition of small farms, using 20 ha as the threshold. Nonetheless, the results are qualitatively similar using other thresholds such as $\leqslant$10 ha and $\leqslant$5 ha.

[16] This institution is responsible for collecting and managing information for all municipalities in Colombia with the exception of Medellín, Bogotá, Cali and all municipalities in the department of Antioquia, which are decentralized. For further information on this process, see Ibáñez, Muñoz-Mora, and Gafaro (2012). Data from Medellín, Bogotá and Cali is mainly urban, hence is out of the scope of our analysis. Antioquia's data set is available only from 2006 onward. We use the data from IGAC only and thus we exclude those municipalities from the analysis. There should not be any correlation between unobserved characteristics of those municipalities in Antioquia and our variables of interest, hence such exclusion is not expected to bias our results. In any case, we re-estimate our equations including this information and do not find an important differences.

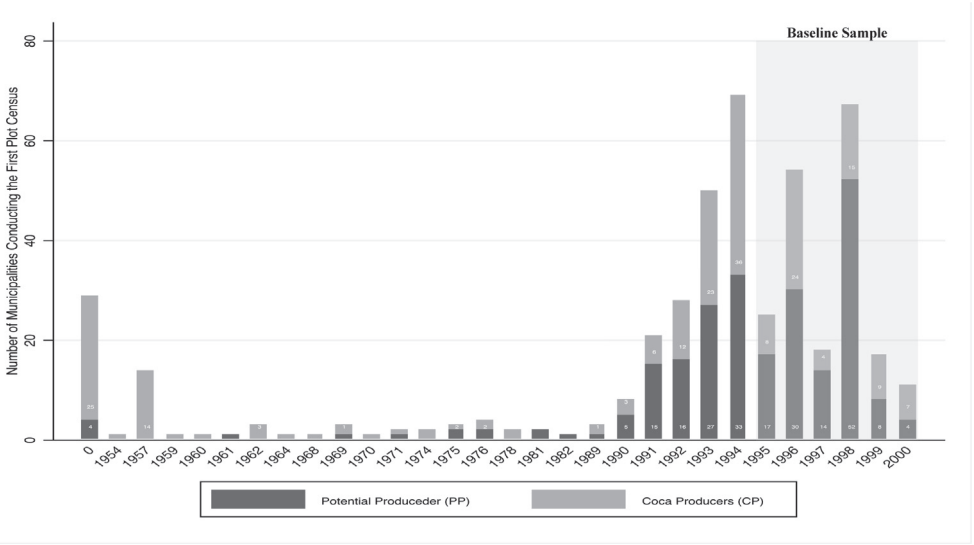
[17] Despite that, under Colombian law, a tenant without a title could claim some basic rights to the land, only registered titles are considered *formal*.

[18] For further details on the process and the different administrative duties of the local and central governments, see Resolutions 2555 of 1988 and 70 of 2011 of the Geographical Institute Agustín Codazzi.

[19] During this period, various policies and programs were launched to improve the coverage of the cadastral information and the formalization of land property rights. For instance, Law 388 of 1997 stated that the central government is obliged to perform a plot census for all *fiscal cadastral* land plots within one year.

[20] Municipalities with low-quality cadastral information generally have an important difference between geographical and cadastral areas, which means that not all plots were visited by the cadastral census. In the municipalities that were selected in our sample, both the mean and median of the cadastral areas is 97 percent of the physical area, which reconfirms the quality of the data.

[21] As we noted above, there are different stages in the coca production process; we aggregate all types of laboratories destroyed without distinction.




**Graph 1.** Timing of first plot census in Colombian municipalities. *Notes*: We include all municipalities that either have natural conditions to crop coca (i.e. altitude 500 to 2000 mts over sea) or ever had coca. We excluded Antioquia. Data source: IGAC, 2013, 2013.

by aerial spraying and manually.[22] Regarding the alternative development policies, we use the presence of Forest Warden Family programs[23] and Productive Projects programs.[24] Finally, we include additional geographic and socio-economic controls. These include the presence of military bases, indigenous or forest protected areas, distance to national capital, altitude and municipality area.

Our baseline sample considers all municipalities for which the cadastral information was formed between 1995 and 2000 (i.e. those subject of the program) and either have natural conditions to crop coca, or ever had coca during 2000–2009. Table 1 reports the descriptive statistics. Data is at the municipal-year level. Our sample includes information for 192 municipalities covering the ten-year period. Total hectares of coca crop fields per municipality are highly concentrated in small areas, as shown by the high standard deviation and the fiftieth and ninetieth quantiles. This is also reflected in the low share of municipal area devoted to coca crops. Smaller land plots are statistically significant less formalized than the medium-size land plots, on average. The statistics of the *Plan Colombia* variables reflect the policies as elaborated upon in the context section, with a focus on aerial spraying, anti-narcotic operations and manual eradication. The alternative development projects received only minor attention in the period of observation. The four remaining variables complement the data description, revealing large differences in land quality over the municipality land, but low shares of public and indigenous land, as well as natural reserves. We also report the statistics on the time-invariant covariates.

Graph 2 depicts the kernel distribution of our main variable of interest for two years: 2000 and 2009. We see that the formality index for small-holders is concentrated on the right-hand side, at approximately 0.95. Notwithstanding only minor changes between the points of observation (i.e., the Kolmogorov-Smirnov test could not reject the null hypothesis), we confirm the increasing tendency over time towards formality.

Graphs 3 and 4 depict the spatial distribution of the average share of municipality area allocated to coca crops and the number of years with coca crop presence over the period 2000–2009, respectively. All Colombian municipalities are included, but we highlight our baseline sample. In general, we find that, on average, in most of the coca-producing municipalities, less than 0.02 percent of land was allocated to coca production, with few cases in the upper tercile. When we consider the average number of years of growing coca, we find greater spatial heterogeneity. At first glance, we observe no spatial patterns between the coca producers included in our sample and those excluded.

Table 2 looks at the difference in the *"War on Drugs"* between coca-producing municipalities excluded and included in our baseline sample. We cannot reject the null hypothesis of equality in the share of municipal area allocated to coca crops. Yet, we do find a systematic difference in the number of years with the presence of coca crops, which shows less persistence in municipalities that are included in our sample. Because of the universal nature of all other policies of the *"War on Drugs"*, we do not find any systematic differences between the excluded municipalities and our baseline sample.

### (b) *Identification strategy*

The empirical strategy we pursue in this paper can be described as follows. Before *Plan Colombia* was launched, the low presence of the state in most of the Colombian territories fostered the spread of coca crops in all areas. However, once the rule of law was increased due to the implementation of *Plan Colombia*, reducing coca crops was more effective in those municipalities with a higher level of formal land property rights. Two main mechanisms might explain this relation. First, improved institutional conditions due to the increased state presence could be more beneficial and therefore

[22] This information is the sum of the hectares manually eradicated by national policy, army and the mobile groups of eradication – GME, *Spanish Acronym*.

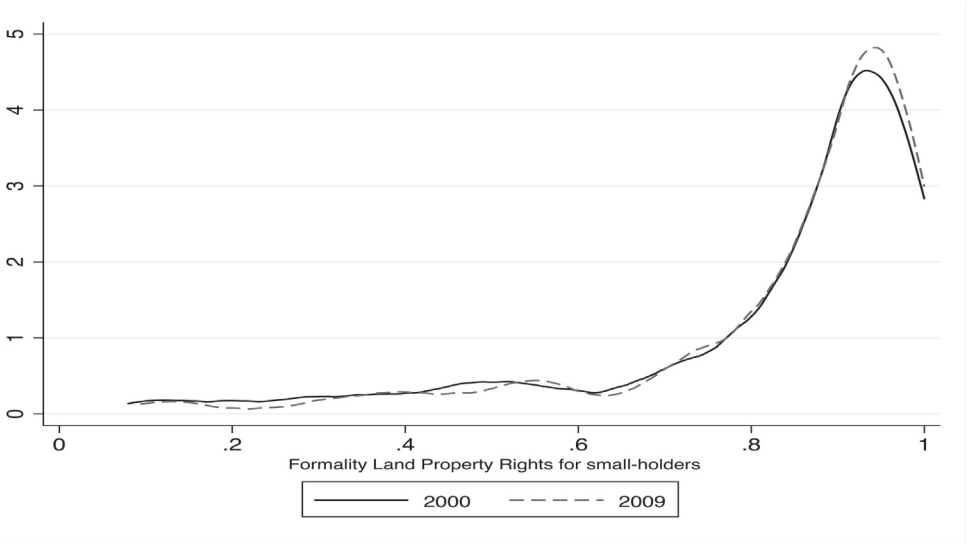
[23] This program was implemented in seven phases: (i) *Phases I-II*: three years of intervention during 2003–2006, with 36,222 households in 35 beneficiary municipalities; (ii) *Phase III*: three years of intervention during 2006–2009, with 17,406 households in 25 beneficiary municipalities; (iii) *Phase IV*: one and a half years of intervention during 2007–2009, with 33,546 households in 39 beneficiary municipalities; (iv) *Phase V*: one and a half years of invention during 2008–2010, with 19,743 households in 24 beneficiary municipalities; (v) *Phase VI*: two and a half years of intervention with 7,401 households in 5 beneficiary municipalities; and (vi) *Phase VII*: two and a half years of intervention with 7,759 households in 21 beneficiary municipalities (UNODC & Colombian Goverment, 2011). In our analysis, we include municipalities that benefited during phases I to IV.

[24] In 1996, the Colombian Government launched the National Program for Alternative Development – PLANTE, *Spanish acronym* – which sought to support productive projects in coca-affected municipalities. After 2003, all of these projects were embedded in the module of Alternative Development programs of Plan Colombia. Therefore, while officially Plan Colombia only began supporting projects in 2003, information on productive projects is available since 2000.

**Table 1**
Summary statistics.

| | Observations | Mean | Std. Deviation | Q50 | Q90 |
|---|---|---|---|---|---|
| Share of municipality area on coca fields (×100%) | 1920 | 0.064 | 0.366 | 0.000 | 0.103 |
| Formality land property rights for small-holders (⩽20 ha) | 1920 | 0.831 | 0.198 | 0.908 | 0.978 |
| Formality land property rights for medium-holders (>20 ha–⩽200 ha) | 1920 | 0.844 | 0.184 | 0.908 | 0.991 |
| Share of private cadastral area on small plots (⩽20 ha) | 1920 | 0.427 | 0.268 | 0.401 | 0.816 |
| Aerial Spraying (ha) | 1920 | 201.463 | 1043.879 | 0.000 | 0.000 |
| Manual coca erradication (ha) | 1920 | 134.924 | 723.497 | 0.000 | 85.000 |
| Number of laboratories destroyed | 1920 | 2.457 | 16.676 | 0.000 | 3.000 |
| Seizure of coca leaves (kg) | 1920 | 755.862 | 6114.339 | 0.000 | 350.000 |
| Municipal Development Index | 1920 | 45.481 | 15.164 | 43.443 | 66.800 |
| Government Military bases (yes = 1) | 1920 | 0.016 | 0.124 | 0.000 | 0.000 |
| Protected areas (forest) (yes = 1) | 1920 | 0.188 | 0.390 | 0.000 | 1.000 |
| Indigenous protected areas (yes = 1) | 1920 | 0.177 | 0.382 | 0.000 | 1.000 |
| Unsatisfied Basic Needs Index (1993) | 1920 | 48.291 | 16.789 | 44.200 | 72.600 |
| Distance to capital (km) | 1920 | 70.976 | 55.376 | 57.540 | 125.558 |
| Altitude (Height above mean sea level) (mts) | 1920 | 1242.432 | 605.624 | 1359.000 | 1875.000 |
| Municipality area (ha) | 1920 | 62261.146 | 1.65e + 05 | 23300.000 | 1.25e + 05 |

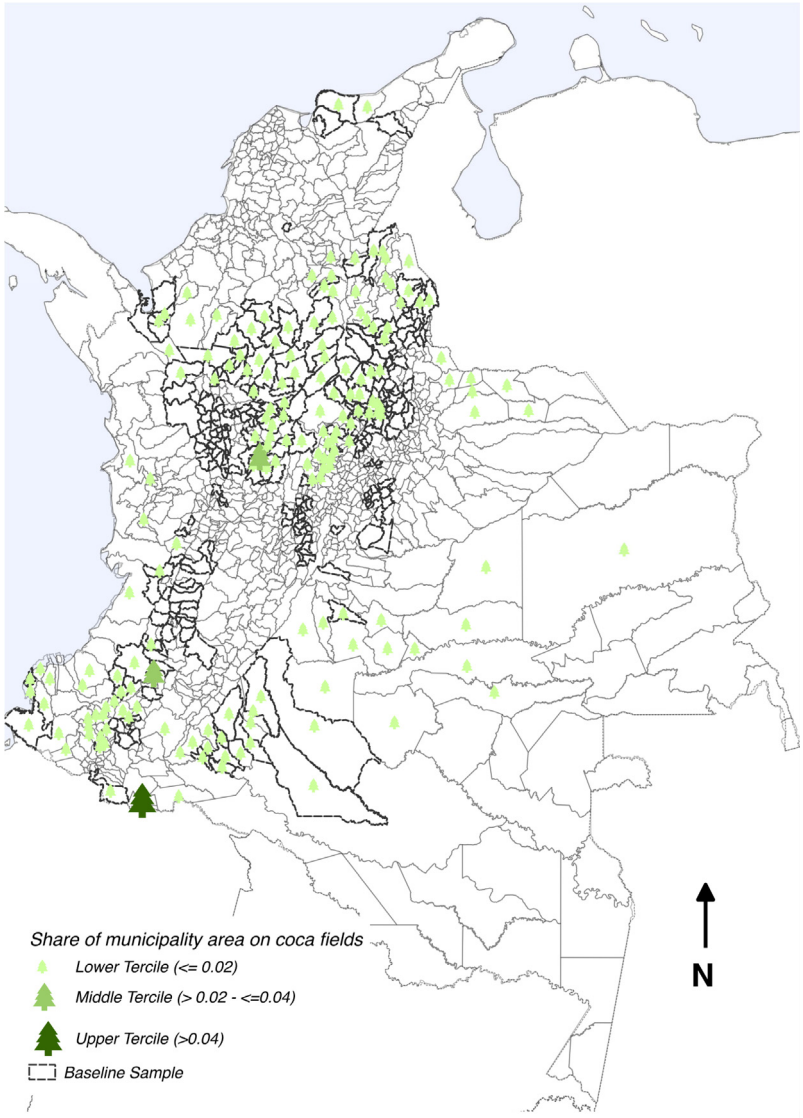
*Notes*: We include all the municipalities that were part of the "Program for land titling and modernization of the registry of deed and cadastre" and either have natural conditions to crop coca (i.e. altitude 500 to 2000 mts over sea) or ever had coca during 2000 to 2009. We excluded Antioquia. *Data source:* National Census (1993); UNODC, 2013; IGAC, 2013.




**Graph 2.** Kernel distribution for the Formality Land Property Rights for small-holders (⩽20 ha) in 2000 and 2009. *Notes*: We include all the municipalities that were part of the "Program for land titling and modernization of the registry of deed and cadastre" and either have natural conditions to crop coca (i.e. altitude 500 to 2000 mts over sea) or ever had coca during 2000 to 2009. Information from Antioquia's cadastral information is only available only from 2006 onward, we only include it as robustness check. Two-sample Kolmogorov-Smirnov test [p-value = 0.640]. Data source: IGAC, 2013; Antioquia's Regional Government, 2013.

more attractive to peasants with legal titles because their formal title allows them to use the land more in this setting, become more visible, and take better advantage of alternative programs. This not only holds for the programs offered through *Plan Colombia* but also in general through the positive externalities of having formal property rights (e.g., higher productivity, investment, social capital), allowing the peasant to choose low-risk and legal crop substitutes. We call this the substitution mechanism. Second, as highlighted, formalization implies a cost increase of cultivating coca because of the sanctions one could face when cultivating coca on formal land. On the one hand, a formal owner of a land plot growing coca crops is charged formally with a criminal offense when discovered. Furthermore, the government expropriates coca growers with a formal title when caught and, since formal deeds inherently increase land value, the cost of expropriation increases for the peasant. In sum, we argue that improved land rights create microeconomic incentives to change risk-taking behavior once law enforcement is increased.

We exploit the variation in the level of formalization for those municipalities subject to the "Program for Land Titling and Modernization of the Registry of Deed and Cadastre." As we noted earlier, the program had two main objectives: (i) increase the coverage of the cadastral information in municipalities with *fiscal cadastre*; and (ii) improve the formalization of land property rights throughout the Colombian territory. For identification purposes we benefit from the second objective. In particular, we take advantage of the following three characteristics (Colombian Goverment – IDB, 1997). First, it initiated a supply-driven formalization process for landowners whose titles were not formally registered. Under a traditional demand-driven formalization process, only self-motivated peasants would formalize their ownership claiming the deeds directly. This implies that changes in the level of formalization in a municipality can be explained by unobserved characteristics of the peasants that lead them to claim–or not–a title. However, the fact that the formalization processes that were initiated by the program were supply-side




**Graph 3.** Spatial distribution for the average share of municipality area on coca fields over 2000–2009. *Notes*: Mean = 0.05%; Std Dev = .296. The map includes all Colombian municipalities. The baseline sample refers municipalities that were part of the "Program for land titling and modernization of the registry of deed and cadastre" and either have natural conditions to crop coca (i.e. altitude 500 to 2000 mts over sea) or ever had coca during 2000 to 2009. Information from Antioquia's cadastral information is only available from 2006 onward, we only include it as robustness check. Data source: UNODC, 2013; IGAC, 2013; Antioquia's Regional Government, 2013.

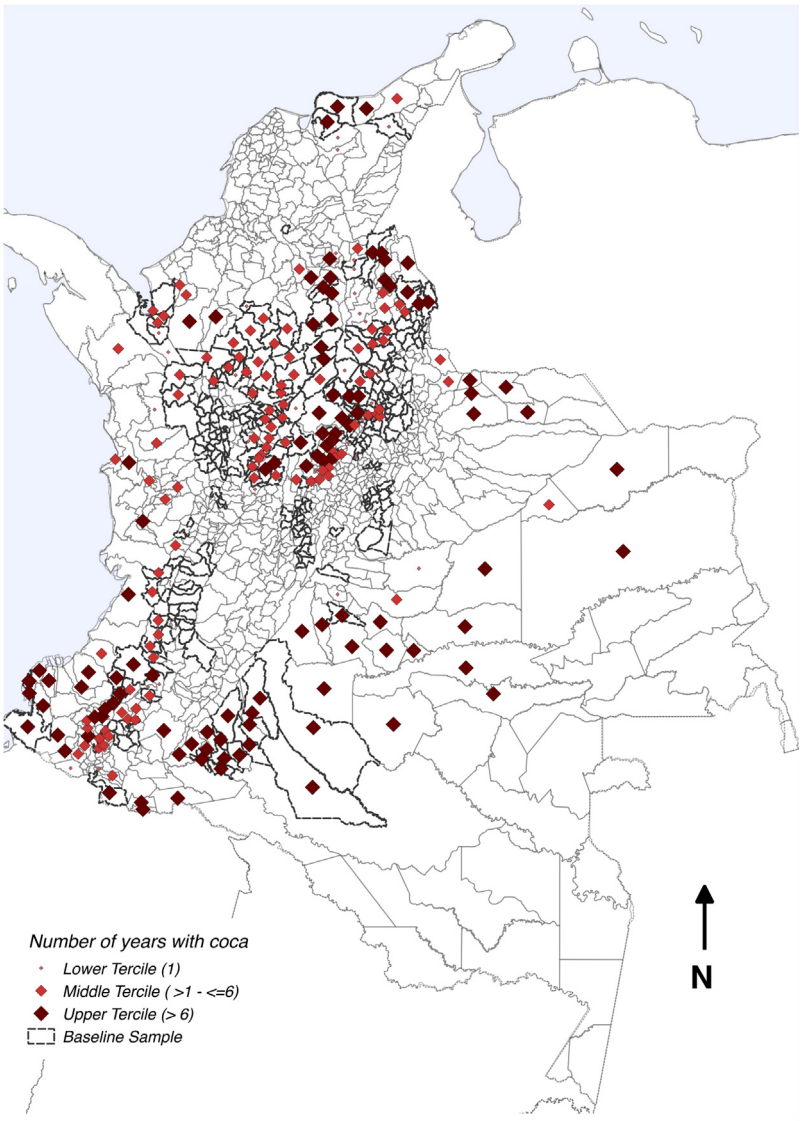
driven, implies that the decision of formalization will be orthogonal to individual characteristics.

Second, all formalization procedures within the program came from the central government without interference of local politicians, and implied a minimum level of involvement by the landowner. Because the common process to obtain a title for one's land implies heavy involvement and decisions by the squatters, some peasants could decide to remain informal to crop coca, or to delay the process. If this would be the case, municipalities with more suitable conditions for growing coca would show less variation in their formality index than would municipalities with less coca presence. The "Program for Land Titling and Modernization of the Registry of Deed and Cadastre" organized the formalization processes centrally, requiring little involvement of the landholder.[25] Such centralization efforts reinforce the exogeneity argument with respect to unobserved characteristics of the peasants that could be correlated with their willingness to crop coca.

Third, the duration of the formalization processes was mainly caused by factors that are arguably exogenous to unobserved characteristics that could also be correlated with the presence of coca crops. The duration of this procedure varies depending on the complexity of the clarification of the title. Whereas in some cases the clarification of the property rights lasted a few years as these titles were easily verifiable, in other it lasted several years as many institutions need to be involved in the process. For instance, in those cases in which the land plots were located within public idle land, or those land plots with measurement errors concerning the borders or the total area of the land, required the involvement of specific centralized agencies that have representatives at the department or sub-regional levels. Thus, we do not expect the requirements of the different agencies participating in the processes, or the productivity levels of those bureaucrats involved, to be endogenous to unobserved characteristics at the municipal level that might be time variant.

Yet, even if the "Program for Land Titling and Modernization of the Registry of Deed and Cadastre" provides a plausibly exogenous

[25] Indeed, the program was replaced at the beginning of the 2000s by the ICARO initiative, which received support by the World Bank and was more ambitious in scope. This initiative sought to massively cross validate cadastral and registry information to ease the formalization procedures.




**Graph 4.** Spatial distribution for the number of years with coca fields over 2000–2009. *Notes*: Mean = 1.592; Std Dev = 3.179. The map includes all Colombian municipalities. The baseline sample refers municipalities that were part of the "Program for land titling and modernization of the registry of deed and cadastre" and either have natural conditions to crop coca (i.e. altitude 500 to 2000 mts over sea) or ever had coca during 2000 to 2009. Information from Antioquia's cadastral information is only available from 2006 onward, we only include it as robustness check. Data source: UNODC, 2013; IGAC, 2013; Antioquia's Regional Government, 2013.

variation in land formality at the municipal level, one additional concern is related to the selected sample of municipalities that we include in our analysis (i.e. those subject to the program that also possess the natural conditions to crop coca). More specifically, a systematic difference might be present between our sample and other municipalities. To test this, we run a basic quasi-random assignment test to check for the presence of any systematic differences between our baseline sample and the excluded municipalities. In particular, we estimate the following equation:

$$c_i = \alpha_0 + \alpha_1 D_i + \nu_i \quad (1)$$

where $c_i$ represents the characteristics of a given village, $D_i$ is a dummy variable indicating whether the municipality had its first census plot between 1995 and 2000, and $\nu_i$ stands for the error term clustered at the department level. If this cadastral formation process is uncorrelated with municipality characteristics, then $\alpha_1$ would be small and statistically insignificant for all characteristics. We use information from the 1993 Colombian National Census and other socioeconomic information for the period 1993–2000 provided by the data set from Universidad de los Andes – Colombia. Table 3 shows the results for 19 different characteristics. We find that municipalities included in our sample were closer to the national capital (km), were more populated, had a lower incidence of poverty (1993) and less presence of protected areas. In contrast, we do not find differences in other characteristics related to violence or institutional strength, among other characteristics. To account for these systematic differences that may form a potential source of bias due to the absence of complete randomness, we will include these factors as controls in our specifications.

We study the effects of land formality on coca crops by estimating the following equation:

$$Coca\ crops_{i,t} = \alpha\ Formality\ land_{i,t} + c_i + \gamma_t + \mathbf{X}_{i,t}\beta + u_{i,t} \quad (2)$$

where the sub-index $i$ refers to the municipality and $t$ the time period (i.e., $t = 2000, \ldots, 2009$). The dependent variable, $Coca\ crops_{i,t}$, is the proportion of municipality area allocated to coca. Our main variable of interest is the index of formal land property rights for small plots ($\leqslant$20 ha), $Formality\ land_{i,t}$. Our hypothesis is that, on

**Table 2**
Difference on *War on Drugs* between coca producers municipalities excluded and coca producers municipalities included in the baseline sample.

| | Excluded | Our sample | Difference |
|---|---|---|---|
| Share of municipality area on coca fields (×100%) | 0.220<br>[0.888]<br>(1485) | 0.185<br>[0.374]<br>(670) | 0.036<br>[0.040] |
| Number of years with coca crops | 6.522<br>[2.185]<br>(1485) | 6.164<br>[0.029]<br>(670) | 0.358*<br>[0.164] |
| Aerial Spraying (ha) | 506.291<br>[-0.902]<br>(1485) | 571.799<br>[0.367]<br>(670) | −65.508<br>[72.660] |
| Manual coca erradication (ha) | 451.618<br>[2.088]<br>(1485) | 335.060<br>[0.037]<br>(670) | 116.558*<br>[55.824] |
| Number of laboratories destroyed | 6.710<br>[0.284]<br>(1485) | 6.391<br>[0.777]<br>(670) | 0.319<br>[1.126] |
| Seizure of coca leaves (kg) | 2178.212<br>[0.694]<br>(1485) | 1832.656<br>[0.487]<br>(670) | 345.557<br>[497.581] |

*Notes*: Standard errors in brackets, number of observation in parenthesis. * Significant at 10%, ** significant at 5%, and *** significant at 1%. Two-side mean test significance reported. We only include "*Coca Producers*" (i.e. at least one year with coca between 2000 and 2009). *Baseline* refers to municipalities that were part of the "Program for land titling and modernization of the registry of deed and cadastre". *Excluded* are those municipalities that were not part of the mentioned program. We excluded Antioquia. *Data source:* UNODC, 2013; IGAC, 2013.

**Table 3**
Quasi-random assignment test (i.e $c_i = \alpha_0 + \alpha_2 1(BaselineSample) + \upsilon_i$).

| | $\alpha 2$ | Std. errors | Observations |
|---|---|---|---|
| Distance to Bogota (km) | −40.067* | [18.787] | 558 |
| Altitude (Height above mean sea level) (mts) | 168.733 | [84.470] | 558 |
| Population (1993) | 11389.639*** | [2559.591] | 548 |
| Poverty (%) (1993) | −0.032* | [0.016] | 533 |
| Income Gini Index (1993) | 0.002 | [0.005] | 533 |
| School Attendance (1993) | −0.601 | [0.653] | 530 |
| Unsatisfied Basic Need -UBN- (1993) | −13.034*** | [2.496] | 558 |
| Rural population index (Rural/Urban) (1993) | −1.321* | [0.545] | 547 |
| Average Homicide Rate (by 100 person) (1990–2000) | 0.168 | [0.086] | 558 |
| Average Number of attacks to civilians (1990–2000) | 0.026 | [1.090] | 548 |
| Average Number of massacres (1990–2000) | 0.053 | [0.059] | 558 |
| Presence of Agrarian Bank (yes = 1) | 0.103 | [0.138] | 542 |
| Presence of High-School (yes = 1) | 2.889 | [1.583] | 542 |
| Average public income per-capita (average 1990–2000) | 0.004 | [0.004] | 548 |
| Presence of indigenous communities (yes = 1) | −0.121* | [0.053] | 558 |
| Presence of afrocolombian communities (yes = 1) | −0.055 | [0.052] | 558 |
| Presence of National Park (yes = 1) | −0.063 | [0.047] | 558 |
| Presence of Protected Forest Area (yes = 1) | −0.075** | [0.023] | 558 |
| Hectares allocated to coffee (1997) | 479.388*** | [126.545] | 558 |

*Notes*: Robust standard errors in brackets,clustered by department level. * Significant at 10%, ** significant at 5%, and *** significant at 1%. All regressions included constant. $\alpha_2$ refers the point estimate for each evaluated outcome $(c_i)$ (i.e $c_i = \alpha_0 + \alpha_2 1(BaselineSample) + \upsilon_i$, where $1(BaselineSample)$ is a dummy variable indicating whether the municipality was part of the "Program for land titling and modernization of the registry of deed and cadastre").*Data source:* National Census (1993) and CEDE (2015).

average, municipalities with major increases in the level of formality had a relatively lower share of municipality area allocated to coca crops (i.e., $\alpha < 0$).

We control for various potential unobservable characteristics. First, $c_i$ stands for fixed municipality conditions (e.g., natural conditions, roads, among others) that could be correlated with the presence of coca crops, making some municipalities more prone than others to grow illegal crops.[26] Second, we control for common shocks across years using year fixed effects, $gamma_t$. Third, we include a vector of control variables that vary across specifications, $\mathbf{X}_{i,t}$. This vector includes three sets of controls. First, *geographic controls* whereby we intend to control for unobservable temporal trends associated with geographic characteristics such as: distance to capital, average rainfall 1970–2000, and the presence of indigenous reserved areas and forests. Empirical evidence has suggested that the persistence of coca crops in recent years is correlated with the presence of particular natural conditions and the existence of protected areas (UNODC, 2011). Second, we include *coca-market and law enforcement controls*. Because of the high endogeneity between the "War on Drugs" and coca production, we cannot directly include controls for law enforcement. To control for this, we include coca region-year fixed effects to control for common events that affected all municipalities within a given region in a specific year[27] and the interaction of a time trend and the presence of government military bases. One characteristic of the US military aid in Colombia is that it is disbursed to specific military units that operate from different

[26] Therefore, highly formalized municipalities before 2000 (i.e., $Formality\ land_{i,j,t} = 1 \forall t$) and municipalities with a fixed level of formality (i.e., $Formality\ land_{i,j,t} = c \forall t$) will be naturally excluded from our identification strategy.

[27] UNODC (2011) identify seven regions in which production, techniques and input prices in the coca market are homogeneous. These zones are usually the geographic unit of policy implementation.

military bases. Thus, one may expect that those municipalities with presence of military bases were more exposed to the increase in law enforcement (Dube & Naidu, 2015). Third, we include *socio-economic controls* to control for other local development. In particular, we include the temporal interaction trend of the Unsatisfied Basic Needs Index (1993) and a Municipal Development Index. Finally, $u_{i,t}$ is clustered on two levels: municipality and department-year. This two-way clustering allows us to improve the inference because the standard errors are corrected for any bias associated with time-variant department-level characteristics (Cameron, Gelbach, & Miller, 2011).

We propose a set of robustness checks. We begin by introducing a new set of covariates in an effort to explore alternative explanations for our estimates. As the UNODC (2011) notes, one of the main challenges of the war on drugs in Colombia is the mobility of coca growers; hence, our results could be explained by the fact that coca growers move to other locations, leaving their original locations. Therefore, a reduction in coca crops in one municipality could be explained by an increase in coca crops in neighboring areas. While we already control for time-variant unobservable effects within coca regions, we include three variables in an effort to capture the spillover effects of such behavior. In particular, we include the change in the presence of coca crops between the current and the subsequent year considering three distances: 25 km, 50 km and 100 km.[28]

We also test the sensibility of our results using different samples and outcome measures. First, we repeat our baseline results using all municipalities that had their first plot census, first, before 1990 and, second, since 1990. Although these samples might be extremely biased by the quality of the land information, the microeconomic incentives provided by the improved land property rights should persist. Second, we drop the coca-producing departments that were not coca producers during the 1990s (Angrist & Kugler, 2008). It may be the case that the reduction in coca crops is associated with less-suitable conditions for planting coca crops and not with improved land property rights. If it were the case, our results should disappear when we constrain our sample to regions traditionally regarded as coca-producing regions. Third, as the strength of property rights system is strongly related to the development process itself, our results could be capturing a broader social phenomenon. Therefore, we re-estimate our specification without those municipalities that had an important improvement during the period 2000–2009. We use information provided by the Colombian National Planning Department, which categorizes Colombian municipalities into six different levels according to their development states (1 more development – 6 less development). Thus, we exclude those municipalities that improved their status between 2000 and 2009. Fourth, it may be the case that the government specifically targeted those municipalities with improved levels of formalization of their land property rights with their other counter-drug policies. To study whether this was the case, we repeat our estimations replacing the outcome variable, the presence of coca crops, by three alternatives: number of destroyed coca laboratories, seizure of coca leaves and the number of hectares eradicated either manually or by aerial spraying.

Finally, we run a placebo test by changing our variable of interest. Coca is produced primarily on small plots, but to test this statement, we re-estimate our baseline specification using two alternative definitions of the level of formalization of land property rights in terms of size. Following the same logic as with small landholders, we calculate the formality of land property rights index for medium landholders (>20 ha-⩽200 ha) and large landholders (⩾20 ha). Because the two mechanisms presented in this paper through which the strength of property rights may reduce coca crops apply primarily to small landholders, we expect to see no effect on the coca crop presence for medium and large landholders.

(c) *Testing the substitution mechanism*

We argue that improved land property rights of small landholders provide microeconomic incentives to change risk-taking behavior once law enforcement is increased. We hypothesize two mechanisms are responsible for this: greater benefits from substitutive legal activities and higher costs associated to cropping coca once the plot is formalized. We empirically test the mechanisms using two alternative outcome variables. First, using information from the National Coffee Information System (SICA, *Spanish Acronym*) provided by the National Federation of Coffee Growers in Colombia, we use a proxy for the number of new coffee fields per year in each municipality. Coffee is the most important cash crop in Colombia, and the plants grow in similar natural conditions as coca (altitude, climate, soil, etc.), making them perfect substitutes. If peasants with formalized land rights have more incentives to grow legal substitutes, we expect that improved land property rights for smallholders will be related to an increase in new coffee fields.

Second, we test whether the alternative development projects are more persistent in municipalities with improved land rights. These development projects offered a variety of other agricultural legal alternatives to peasants. Hence, we expect that the persistence of alternative development programs will be correlated to higher levels of formalization of the land property rights.

## 5. Empirical results

Our findings show a significant negative relationship between the level of formalization of land property rights and the number of hectares allocated to coca crops per municipality. These results are robust to the introduction of additional controls, the use of different samples and the performance of a placebo test. The empirical evidence indicates that this effect is presumably due to the substitution mechanism.

(a) *Baseline results*

Table 4 presents our baseline results using a panel of Colombian municipalities over the period from 2000 to 2009. We present four different specifications including the different controls in $\mathbf{X}_{i,t}$. The point estimate of the formality index of property rights for small landowners is negative and significant in all specifications. Furthermore, the magnitude of the coefficient remains relatively stable as we include more controls, which suggests a robust relationship between informality in land tenure and the presence of coca crops. In general, we find that a one-standard-deviation increase in the formality index for smallholders (i.e., 0.198 percentage points) is related to a reduction in the share of municipal area allocated to coca crops of 0.101 percentage points. To put these numbers into perspective, they imply that the formalization of one additional hectare of land with respect to small landholders in an average municipality in the year 2000 is associated with a decrease of approximately 1.4 hectares of land allocated to coca within that particular municipality, *ceteris paribus* .[29] This is a local

[28] Distances are computed using the main urban center of each municipality. We choose to use this instead of the centroid of the municipality polygon because it provides a better representation of real distance. We estimate the Euclidean distance.

[29] In 2000, on average, a municipality that covers an area of 62,262 hectares, had around 10.4% of its total area allocated to coca crops and 82% of the total area for land small holders with formal title.

**Table 4**
Baseline results.

| | (I) | (II) | (III) | (IV) |
|---|---|---|---|---|
| *Dependent variable: share of municipality area on coca fields (×100%)* | | | | |
| Formality land property rights for small-holders (⩽20 ha) | −0.141*** | −0.122** | −0.118** | −0.101*** |
| | [0.050] | [0.054] | [0.049] | [0.035] |
| Observations | 1920 | 1920 | 1920 | 1920 |
| Municipalities | 192 | 192 | 192 | 192 |
| Year Fixed Effect | Yes | Yes | Yes | Yes |
| Municipality Fixed Effect | Yes | Yes | Yes | Yes |
| Geographic Specific Trend | No | Yes | Yes | Yes |
| Coca-Market and Law Enforcement Controls | No | No | Yes | Yes |
| Socio-Economic Specific Trend | No | No | No | Yes |

*Notes*: * Significant at 10%, ** significant at 5%, and *** significant at 1%. Robust standard errors in brackets, clustered by municipality and by department-year. All regressions include constant. *Geographic Specific Trend* include: *(i)* Distance to Capita × time trend; *(ii)* Average rainfall 1970–2000 × time trend; *(iv)* Protected areas (forest) (yes = 1) × time trend; and, *(iv)* Indigenous protected areas (yes = 1) × time trend. *Coca-Market and Law Enforcement Controls* include: *(i)* Government Military bases (yes = 1) × time trend; and, *(ii)* Coca regions × time trend. *Socio-Economic Specific Trend* include: *(i)* Unsatisfied Basic Needs Index (1993) × time trend; and, *(ii)* Municipal Development Index. Sample is composed by all the municipalities that were part of the "Program for land titling and modernization of the registry of deed and cadastre" and either have natural conditions to crop coca (i.e. altitude 500 to 2000 mts over sea) or ever had coca during 2000 to 2009. We excluded Antioquia. *Data source:* UNODC, 2013; IGAC, 2013. Independent variables were standardized to have mean zero and standard deviation one.

**Table 5**
Baseline results including potential spillover effects.

| | (I) | (II) | (III) | (IV) |
|---|---|---|---|---|
| *Dependent variable: share of municipality area on coca fields (×100%)* | | | | |
| Formality land property rights for small-holders (⩽20 ha) | −0.141*** | −0.122** | −0.118** | −0.100*** |
| | [0.050] | [0.054] | [0.049] | [0.035] |
| Change on coca crops around 25 km | −0.005 | −0.006* | −0.005* | −0.007* |
| | [0.003] | [0.003] | [0.003] | [0.004] |
| Change on coca crops around 50 km | 0.001 | 0.001 | 0.001 | 0.001 |
| | [0.001] | [0.001] | [0.001] | [0.001] |
| Change on coca crops around 100 km | 0.000 | 0.000 | 0.000 | 0.000 |
| | [0.001] | [0.001] | [0.002] | [0.002] |
| Observations | 1920 | 1920 | 1920 | 1920 |
| Municipalities | 192 | 192 | 192 | 192 |
| Year Fixed Effect | Yes | Yes | Yes | Yes |
| Municipality Fixed Effect | Yes | Yes | Yes | Yes |
| Geographic Specific Trend | No | Yes | Yes | Yes |
| Coca-Market and Law Enforcement Controls | No | No | Yes | Yes |
| Socio-Economic Specific Trend | No | No | No | Yes |

*Notes*: * Significant at 10%, ** significant at 5%, and *** significant at 1%. Robust standard errors in brackets, clustered by municipality and by department-year. All regressions include constant. *Geographic Specific Trend* include: *(i)* Distance to Capita x time trend; *(ii)* Average rainfall 1970–2000 × time trend; *(iv)* Protected areas (forest) (yes = 1) × time trend; and, *(iv)* Indigenous protected areas (yes = 1) × time trend. *Coca-Market and Law Enforcement Controls* include: *(i)* Government Military bases (yes = 1) × time trend; and, *(ii)* Coca regions × time trend. *Socio-Economic Specific Trend* include: *(i)* Unsatisfied Basic Needs Index (1993) × time trend; and, *(ii)* Municipal Development Index. Sample is composed by all the municipalities that were part of the "Program for land titling and modernization of the registry of deed and cadastre" and either have natural conditions to crop coca (i.e. altitude 500 to 2000 mts over sea) or ever had coca during 2000 to 2009. We excluded Antioquia. *Data source:* UNODC, 2013; IGAC, 2013. Independent variables were standardized to have mean zero and standard deviation one.

effect for the sample of municipalities included in the "Program for Land Titling and Modernization of the Registry of Deed and Cadastre" that also have natural conditions to grow coca. That is, once the state became more present and visible after 2000, municipalities with larger improvements of their land property rights for small land plots had significantly less coca crops.

(b) *Sensitivity analyses*

In this section, we present a set of sensitivity analyses to confirm the robustness of our results. One one hand, we re-estimate our baseline results using additional controls, different samples, and alternative outcomes. On the other hand, we perform a placebo test to check whether our results are driven by general trends.

First, to account for alternative explanations for the reduction of coca crops, we consider additional covariates. In particular, we include three variables in an attempt to capture the spillover effect of the policies implemented through *Plan Colombia*. Table 5 presents the results. The point estimate of the formality index for smallholders remains similar in magnitude and statistically significant. Yet, we do not find any significant spillover effects at any distance. These results are relevant in light of different patterns of responses a peasant may have following the implementation of *Plan Colombia* policies. If it is the case that the response to these policies prevails over changes in the formality index in a municipality, we would have found a loss of significance in our coefficient of interest. The rationality of this threat is straightforward with, for instance, aerial spraying policies.

Second, we repeat the estimations using alternative samples. This allows us to check the sensitivity of our results regarding productivity conditions to grow coca, a broader development phenomena, and the quality of the data. These alternative samples include (i) as a benchmark, we retain our baseline results; (ii) municipalities that either had their first census plot or the last cadastral update after 1990; (iii) municipalities that either had their first census plot or the last cadastral update after 1980; (iv)

**Table 6**
Robustness check: different samples.

| | Baseline Sample (I) | Cadastral Census since 1990 (II) | Cadastral Census since 1970 (III) | Without non-traditional coca producers (IV) | Without developed municipalities (V) | With Antioquia (VI) |
|---|---|---|---|---|---|---|
| *Dependent variable: share of municipality area on coca fields (×100%)* | | | | | | |
| Formality land property rights for small-holders (⩽20 ha) | −0.101*** [0.033] | −2.185* [1.150] | −2.127* [1.137] | −0.231** [0.102] | −0.098*** [0.030] | −0.116*** [0.035] |
| Observations | 1920 | 3680 | 3740 | 440 | 1780 | 2228 |
| Municipalities | 192 | 368 | 374 | 44 | 178 | 269 |
| Year Fixed Effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Municipality Fixed Effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Geographic Specific Trend | Yes | Yes | Yes | Yes | Yes | Yes |
| Coca-Market and Law Enforcement Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Socio-Economic Specific Trend | Yes | Yes | Yes | Yes | Yes | Yes |

*Notes*: * Significant at 10%, ** significant at 5%, and *** significant at 1%. Robust standard errors in brackets, clustered by municipality and by department-year. **Baseline Sample (Column I)** refers to all the municipalities that were part of the "Program for land titling and modernization of the registry of deed and cadastre" and either have natural conditions to crop coca (i.e. altitude 500 to 2000 mts over sea) or ever had coca during 2000 to 2009. **Cadastral Census since 1990 (Column II)** includes municipalities that had either first census plot or updating process after 1990. **Cadastral Census since 1970 (Column III)** includes municipalities that had either first census plot or updating process after 1970. **Without non-traditional coca producers (Column IV)** includes the baseline sample without departments with coca production during nineties. **Without developed municipalities (Column V)** includes the baseline sample without those municipalities that improved their development status between 2000–2009 based on the National Planning Department (DNP, Spanish Acronym). **With Antioquia (Column VI)** We include the municipalities from Antioquia from 2006 onwards. *Geographic Specific Trend* include: *(i)* Distance to Capita × time trend; *(ii)* Average rainfall 1970–2000 × time trend; *(iv)* Protected areas (forest) (yes = 1) × time trend; and, *(iv)* Indigenous protected areas (yes = 1) × time trend. *Coca-Market and Law Enforcement Controls* include: *(i)* Government Military bases (yes = 1) × time trend; and, *(ii)* Coca regions × time trend. *Socio-Economic Specific Trend* include: *(i)* Unsatisfied Basic Needs Index (1993) × time trend; and, *(ii)* Municipal Development Index. Sample is composed by all the municipalities that were part of the "Program for land titling and modernization of the registry of deed and cadastre" and either have natural conditions to crop coca (i.e. altitude 500 to 2000 mts over sea) or ever had coca during 2000 to 2009. *Data source:* UNODC, 2013; IGAC, 2013; Antioquia's Regional Government, 2013. Independent variables were standardized to have mean zero and standard deviation one.

**Table 7**
Robustness check: falsification test.

| *Dependent variable: share of municipality area on coca fields (×100%)* | | | | |
|---|---|---|---|---|
| *Panel A: Medium landholders (>20 ha–⩽200 ha)* | | | | |
| | (I) | (II) | (III) | (IV) |
| Formality land property rights for median-holders (⩾20 ha–⩽200 ha) | 0.118 [0.204] | 0.137 [0.206] | 0.156 [0.217] | 0.153 [0.208] |
| Observations | 1920 | 1920 | 1920 | 1920 |
| Municipalities | 192 | 192 | 192 | 192 |
| *Panel B: Large landholders (⩾20 ha)* | | | | |
| | (I) | (II) | (III) | (IV) |
| Formality land property rights for large-holders (⩾20 ha) | −0.022 [0.017] | −0.013 [0.020] | −0.015 [0.020] | −0.015 [0.022] |
| Observations | 1541 | 1541 | 1541 | 1541 |
| Municipalities | 192 | 192 | 192 | 192 |
| Year Fixed Effect | Yes | Yes | Yes | Yes |
| Municipality Fixed Effect | Yes | Yes | Yes | Yes |
| Geographic Specific Trend | No | Yes | Yes | Yes |
| Coca-Market Specific Trend | No | No | Yes | Yes |
| Socio-Economic Specific Trend | No | No | No | Yes |

*Notes*: * Significant at 10%, ** significant at 5%, and *** significant at 1%. Robust standard errors in brackets, clustered by municipality and by department-year. All regressions include constant. *Geographic Specific Trend* include: *(i)* Distance to Capita × time trend; *(ii)* Average rainfall 1970–2000 × time trend; *(iv)* Protected areas (forest) (yes = 1) × time trend; and, *(iv)* Indigenous protected areas (yes = 1) × time trend. *Coca-Market and Law Enforcement Controls* include: *(i)* Government Military bases (yes = 1) × time trend; and, *(ii)* Coca regions × time trend. *Socio-Economic Specific Trend* include: *(i)* Unsatisfied Basic Needs Index (1993) × time trend; and, *(ii)* Municipal Development Index. Sample is composed by all the municipalities that were part of the "Program for land titling and modernization of the registry of deed and cadastre" and either have natural conditions to crop coca (i.e. altitude 500 to 2000 mts over sea) or ever had coca during 2000 to 2009. We excluded Antioquia. *Data source:* UNODC, 2013; IGAC, 2013. Independent variables were standardized to have mean zero and standard deviation one.

a sample without non-traditional coca producing municipalities; (v) a sample without developed municipalities; and (vi) a sample including the cadastral information from Antioquia. Table 6 shows the results. Notwithstanding an important increase in the magnitude of the coefficient for some samples, possibly due to bias associated with data quality,[30] the point estimate of the formality index for small landowners remains negative and statistically significant, confirming the robustness of our results.

Third, to analyze further whether our findings correspond to a general effect of institutional improvement, we perform a placebo test. In this test we adapt the formalization index for land property rights to medium-sized landholders. Table 7 shows the results. As expected, we find no significant effect for the point estimate of the formality index in all regressions, which again confirms the robustness of our results. As discussed in Section 3, coca fields are mainly operated by smallholders, and we would not expect any significant

[30] The major changes in the point estimate are in samples that include municipalities with relatively old cadastre data, which are in columns (II) and (III).

change in the presence of coca crops in a municipality following an improvement in formalization for medium-sized landowners.

Fourth, to study if the government deliberately targeted other counter-drug policies at those municipalities that experienced an improvement in land formalization, we re-estimate our results using alternative outcomes. In particular, we study whether there is any correlation between changes in formality and enforcement efforts on destruction of laboratories, coca eradication and seizure. Table 8 presents the result. We find no correlation between the formality index for small-holders and both enforcement activities under conventional levels of statistical significance, which confirms the robustness of our results.

(c) *Mechanisms*

Tables 9 show the results of testing the substitution effect using coffee fields and the presence of alternative development programs as outcome variables, respectively. We re-estimate the same specifications as in our baseline results.

Regarding the presence of coffee fields, the point estimate on the formality index for property rights for small landholders is positive and significant in all specifications. A one-standard-deviation increase in the formality index for smallholders is associated with the appearance of up to 77 new coffee fields, on average. These results therefore favor our mechanism whereby small farmers might find substitutive crops whenever land is formalized. Likewise, on the persistence of alternative development programs we also find a positive and statistically significant relationship. These alternative development programs consisted mainly in the implementation of productive projects–with no formalization components, and were universally implemented in coca growing municipalities Mejía, 2010b. Hence, this positive correlation may be explained by two main factors. First, improved institutional conditions are more attractive to coca growers with legal titles, and therefore, those development programs were more persistent. Second, a decrease in coca crops creates the need for such programs. Despite being unable to disentangle these two explanations, either is in favor of the substitution mechanism.

**Table 8**
Mechanisms: "War on Drugs" and land property rights.

| | Dep. Var.: Number of laboratories destroyed (I) | Dep. Var.: Coca hectares eradicated (II) | Dep. Var.: Seizure of coca leaves (kg) (III) |
|---|---|---|---|
| Formality land property rights for small-holders (⩽20 ha) | −2.232 | −85.521 | 296.980 |
| | [3.133] | [379.574] | [857.179] |
| Observations | 1920 | 1920 | 1920 |
| Municipalities | 192 | 192 | 192 |
| Year Fixed Effect | Yes | Yes | Yes |
| Municipality Fixed Effect | Yes | Yes | Yes |
| Geographic Specific Trend | Yes | Yes | Yes |
| Coca-Market Specific Trend | Yes | Yes | Yes |
| Socio-Economic Specific Trend | Yes | Yes | Yes |

*Notes*: * Significant at 10%, ** significant at 5%, and *** significant at 1%. * Significant at 10%, ** significant at 5%, and *** significant at 1%. Robust standard errors in brackets, clustered by municipality and by department-year. All regressions include constant. At the Column I, **Alternative Development programs** takes one when there is presence of program of Forest Warden Families and/or alternative productive projects in a giving municipality. At the Column II, **Coca hectares eradicated** is the sum of hectares eradicated either manually or by aerial spraying. At the Column II, **Seizure of coca leaves (kg)** is the sum if all the Seizure of coca leaves in the giving municipality. *Geographic Specific Trend* include: *(i)* Distance to Capita x time trend; *(ii)* Average rainfall 1970–2000 × time trend; *(iv)* Protected areas (forest) (yes = 1) × time trend; and, *(iv)* Indigenous protected areas (yes = 1) × time trend. *Coca-Market and Law Enforcement Controls* include: *(i)* Government Military bases (yes = 1) × time trend; and, *(ii)* Coca regions × time trend. *Socio-Economic Specific Trend* include: *(i)* Unsatisfied Basic Needs Index (1993) × time trend; and, *(ii)* Municipal Development Index. Sample is composed by all the coffee producer municipalities that were part of the "Program for land titling and modernization of the registry of deed and cadastre" and either have natural conditions to crop coca (i.e. altitude 500 to 2000 mts over sea) or ever had coca during 2000 to 2009. We excluded Antioquia. *Data source:* UNODC, 2013; IGAC, 2013. Independent variables were standardized to have mean zero and standard deviation one.

**Table 9**
Substitution mechanisms.

| | Dep. Var.: Number of new coffee fields (I) | Dep. Var.: Presence of Alternative Development programs (II) |
|---|---|---|
| Formality land property rights for small-holders (⩽20 ha) | 76.920** | 0.405*** |
| | [37.009] | [0.106] |
| Observations | 1540 | 1920 |
| Municipalities | 154 | 192 |
| Year Fixed Effect | Yes | Yes |
| Municipality Fixed Effect | Yes | Yes |
| Geographic Specific Trend | Yes | Yes |
| Coca-Market Specific Trend | Yes | Yes |
| Socio-Economic Specific Trend | Yes | Yes |

*Notes*: * Significant at 10%, ** significant at 5%, and *** significant at 1%. Robust standard errors in brackets, clustered by municipality and by department-year. All regressions include constant. *Geographic Specific Trend* include: *(i)* Distance to Capita × time trend; *(ii)* Average rainfall 1970–2000 × time trend; *(iv)* Protected areas (forest) (yes = 1) × time trend; and, *(iv)* Indigenous protected areas (yes = 1) × time trend. *Coca-Market and Law Enforcement Controls* include: *(i)* Government Military bases (yes = 1) × time trend; and, *(ii)* Coca regions × time trend. *Socio-Economic Specific Trend* include: *(i)* Unsatisfied Basic Needs Index (1993) × time trend; and, *(ii)* Municipal Development Index. In column I, sample is composed by all the coffee producer municipalities that were part of the "Program for land titling and modernization of the registry of deed and cadastre" and either have natural conditions to crop coca (i.e. altitude 500 to 2000 mts over sea) or ever had coca during 2000 to 2009. We excluded Antioquia. *Data source:* UNODC, 2013; IGAC, 2013. Independent variables were standardized to have mean zero and standard deviation one.

## 6. Conclusions

This article provides empirical evidence on the influence of the level of formalization of land property rights on the presence of illegal crops in Colombia. Despite the empirical and theoretical evidence on the effects of well-defined land property rights, little is known about the importance of these crucial institutions in the context of illicit behavior. This is particularly relevant in a context of a large-scale war on drugs, as in Colombia, where the interaction between a persistent drug economy and a dual land property rights scheme has fostered the spread of illegal crops across the territory.

We use a panel data set of municipalities spanning from 2000 to 2009, containing detailed information on coca crops, land titling, and the implementation of *Plan Colombia* policies. We exploit the temporal variation in land formalization for a sample of municipalities that had their first cadastral census performed between 1995 and 2000. During this period, the Colombian government, along with the Interamerican Development Bank, launched a centralized initiative to increase the coverage and quality of the cadastral information. This program led to a change in land formalization that is arguably exogenous to unobserved municipal characteristics.

We argue that the attempts to reduce coca crops with the implementation of *Plan Colombia* were more effective in those municipalities with more formalized land property rights. Two mechanisms might explain this relationship. On the one hand, land formalization creates an institutional setting that allows peaseants to benefit more from legal alternatives (i.e. substitution effect). On the other hand, it increases the cost of growing coca due to more severe sanctions. Our results suggest that there is a negative and statistically significant relation between land formalization and the presence of coca crops. In particular, we find that a one-standard-deviation increase in the land formality index is associated with a reduction of 0.101 percentage points in the area allocated to coca. A number of sensitivity analyses provide confirmatory results. We also provide evidence on the substitution mechanism.

To put these numbers into perspective, they imply that the formalization of one additional hectare of land with respect to small landholders in an average municipality in the year 2000 is associated with a decrease of approximately 1.4 hectares of land allocated to coca within that particular municipality, *ceteris paribus*. The most comparable study to this paper on the eradication of coca crops is Mejía et al. (2017). They find that spraying one additional hectare of land with glyphosate is associated with a reduction of up to 0.030 hectares of land allocated to coca crops. Since aerial spraying of coca crops also has counterproductive effects (Camacho & Mejia, 2017), and manual eradication policies as well,[31] and land formalization is often associated with positive externalities regarding a number of development outcomes (Banerjee et al., 2002; Besley & Burgess, 2000; Dercon & Krishnan, 2010; Deininger & Nagarajan, 2009), we see our results as favoring a different approach to reduce coca crops in Colombia: land formalization.

Our mechanisms are embedded in the property rights framework and, consequently, institutions in general. In this sense, our results also contribute to the more general literature on improved land institutions, development and growth.

[31] Up to mid 2017, about 25% of all land mine victims in Colombia were manual eradicators, as reported by the Counter-Land Mines Program of the Colombian government.

## Conflict of interest

The autor declares that they have no relevant or material financial intereses that relate to the research described in this paper.

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