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**Conference Paper**

# When too much punishment decreases legality. The case of coca-reducing policies in Colombia

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# When too much punishment decreases legality. The case of coca-reducing policies in Colombia

Juanita Vasquez-Escallon*

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**Abstract**

States want their people to follow the law. They can either persuade them, sanction law-breakers, or both. But sanctions do not only alter people's perception of risks and costs; they also affect how people view their state and its legitimacy, unleashing a series of non-economic factors that determine compliance with the law. In fact, when a sanction is perceived as unjust it may be inefficient in reducing law violations and could crowd-out legality in other aspects of life. Law scholars warn against violating the principle of proportionality by exerting extreme punishment in comparison with the magnitude of the crime, as it may result in the loss of citizen cooperation with the law. I take one of Colombia's drug-reducing policies, aerial spraying of coca crops and study the effect of its disproportionate use on legal crops. My results point to a non-linear effect of punishment on legality: spraying shocks or extreme spraying in relation to the amount of illegal crops found reduce engagement in legal crops, where as proportional levels of spraying induce legality. I use four different sources of data to test this relationship: macro data on all coca growing municipalities in Colombia, and micro data of three very different sets of farmers, namely coca growers surveyed by the UNODC, farmers that are beneficiaries of Colombia's biggest alternative development Program (Forest Warden Families) and coffee growers in municipalities that have had coca. I find the same results in all four samples and conclude that when the state overdoes its coercive actions, these can backfire and crowd out legality.

*Keywords:* Public Policy, Colombia, illegal behavior, agriculture

*JEL Classification:* D78, O13, K42, Q12, O54

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# 1 Introduction

Achieving citizen compliance with the law is a primary goal for any state. However, a simple recipe of increasing costs (risk of being caught and size of punishment) can even back fire in ways that hinder legality-based development. A balance must be struck between, on the one hand, signaling that certain behaviors are detrimental to society and should therefore be punished –the expressive function of the law (Kahan 1997; Bohnet and Cooter, 2003; Cooter, 1988)– and on the other, keeping punishment within reasonable limits as a basic consideration of fairness: the principle of proportionality (Balmer, 2008; von Hirsch, 1992). I empirically test this balance using a coca crop-reducing policy (aerial spraying) implemented in Colombia for over a decade and test whether disproportional doses of punishment crowd out one of the main legal alternative to coca crops, legal crops.

My main hypothesis is that severe punishment may be perceived as a violation of the principle of proportionality, changing the way people perceive the state's fairness, which could in turn lead to lower levels of general law compliance, captured by a reduction in investments in legal crops. I study the channels that may lead to such a reduction: First, legal crops could simply be destroyed when the herbicide is off-target; second, a high spraying disproportionality could mean that many hectares that are not planted with coca are sprayed discouraging farmers from planting legal crops in the future; third, the environment could deteriorate and become unsuitable for agricultural activities; fourth, people are displaced because of the spraying, reducing the rural labor needed for working with legal crops; and fifth, legitimacy in the state is diminished and so are any efforts for cooperation and adherence to a culture of legality by communities that experienced disproportionate spraying. I find that many channels can be simultaneously at play and find support for the crop damage/ environmental channel, as well as for the displacement and legitimacy channels.

I test these hypotheses with the use of four different data sources. The first one is a panel macro dataset covering all coca growing regions of Colombia for the past 5 years and three micro data sources, the first one being a United Nations Office for Drugs and Crime (UNODC) survey carried out with coca growers in the Putumayo-Caqueta region, one of Colombia's traditional coca growing regions. The second dataset comes from a sample of beneficiaries surveyed in 2012 for the evaluation of the Forest Warden Families (FWF) Program, Colombia's current biggest alternative development program and the third is a coffee growers' panel census collected by the National Coffee Federation. These three samples represent very different types of farmers; the first group has been heavily involved in coca growing and highly exposed to spraying and manual eradication while the second group has also been involved in coca growing or has been at high risk of getting involved with coca but has received support from the state to voluntarily change coca for a legal crop. The third group has focused on coffee and has been exposed to coca and coca crop spraying to a much lesser degree than the first two. I find that high levels of spraying disproportionality *reduce* legal crops but proportional spraying *induces* legal crops, and these results persist in the micro-datasets despite huge differences between the three groups. Additional evidence points to the fact that this reduction is not due to legal crops being damaged by spraying, but to a conscious decision of not planting legal crops after a spraying shock has occurred.

This is a novel study in two ways. It is to the best of my knowledge the first study to

empirically test how a policy aimed at reducing an illegal behavior (illegal crops) generates positive and negative externalities on a closely related legal behavior (legal crops) depending on the proportionality of the punishment.[1] Additionally, even though there are studies that capture the efficiency (or inefficiency) of coca spraying in reducing coca crops (see studies mentioned in Section 3), no study looks at the externalities that this policy has on legal crops, which are the closest legal alternative available to coca for farmers. Thus, this paper contributes to better understanding how the law and economic decisions are connected, and how public policies might have both positive and negative externalities depending on their implementation.

This paper is divided into 7 sections. The next one mentions the general theoretical background around the balance between crime and punishment followed by a short description of the Colombian context regarding coca and the coca spraying policy. Section 4 describes the data sets used and defines disproportionate spraying and spraying shocks, while section 5 sets out the methodology for the analysis. Section 6 presents descriptive statistics and empirical results, and explores possible channels involved in the reduction of legal crops as a result of intensified spraying. Finally, section 7 concludes.

## 2 Crime and punishment theoretical background

The question of how severely a crime should be punished has been largely debated by legal scholars and political scientists. The law has a deterring function by increasing the costs of committing a crime, and an expressive function (Kahan 1997; Bohnet and Cooter, 2003; Cooter, 1998), that serves to educate the public by showing what is morally undesirable (Feldman, 2011). But, for the law to be effective in reducing criminal activity there needs to be perceived as fair and appropriate for their institutions (Kuperan and Sutinen, 1998) and just (Jackson et al., 2012; Tyler, 2006; Tyler and Fagan, 2008; Thoumi, 2009; Dahrendorf, 1980).

Severe punishment erodes law abiders' disposition to obey and changes their moral assessment of cooperation, as extreme punishment is sometimes seen as a tool to punish certain social classes or minorities disproportionally (Kahan, 1997). This is in line with Jackson et al. (2012) who mention that "the experience of procedural unfairness –including disrespectful treatment and unfair decision making– erodes feelings of shared group membership and with the authority concerned" (p.1053). Sheffrin and Triest (1991) also find that perceived inequities in the system lead to lower compliance. Frey and Jegen (2001) mention that when people feel that the authorities representing the law treat them respectfully and fairly, they comply more (see Tyler 1989, 1997 and 2006 for an extensive empirical evidence on fairness and compliance).

A basic consideration of fairness is the principle of proportionality (Balmer, 2008; von Hirsch, 1992). Balmer (2008) points out that this principle dates back to the Code of Hammurabi and the old testament, where "an eye for an eye" sets the argument that the

[1] Thoumi (2009) mentions that authoritarian regimes that exclude certain groups can end up incentivizing crime, but he does not look at how legal counterparts are crowded out and does not develop any empirical analysis.

magnitude of the punishment should be similar to that of the crime. Von Hirsch (1992) gives proportionality a crucial role in the sanctioning theory, as it gives people a notion of justice and fairness. According to this author, fairness would be accomplished by avoiding both extremes of severity and leniency. The link between fairness and trust in the state has also been researched; post-communist states have shown evidence that the single most important determinant of trust in institutions was in fact how fair they were perceived by the citizens (Kluegel and Mason, 2004), and in the US people are concerned about justice as much or even more than about outcomes (Tyler et al., 1985). Regarding the reduction of coca supply in Colombia, Thoumi (2009) mentions the need for a very intense spraying campaign in order to effectively get rid of coca crops, but notes that it would be so disproportional and intense that would violate democratic principles. Hence, if disproportionate punishment is used, trust in the governing authorities is negatively affected, endangering economic outcomes such as investments in productive activities (Knack and Keefer, 1997). Disproportionate punishment could even be inefficient, as Kahan (1997) argues that when punishment is applied with high-certainty but low severity it is more likely to generate a low-crime equilibrium, in contrast with a low-certainty but high-severity scenario. This high-severity vs. low-severity punishment underlies the coming analysis.

This theoretical background sets the stage for empirically testing the balance between, on the one hand, raising legality by teaching people what is right and wrong (expressive function of the law) as well as deterring others by increasing the costs of committing crimes (Becker, 1968), and on the other, reducing compliance when citizens perceive the principle of proportionality to be broken when punishment is extreme with respect to the crime.

# 3 The Colombian coca context and the spraying policy

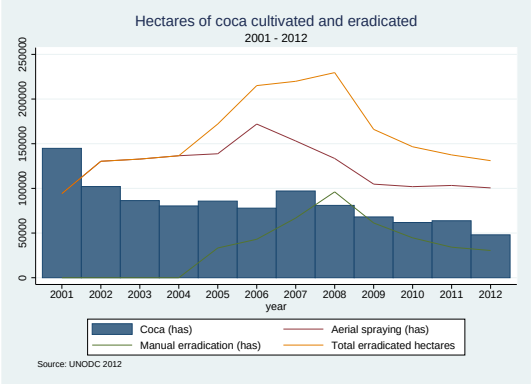
Colombia has been a key player in illegal drug markets as one of the world's largest producers and exporters of cocaine (UNODC, 2014). A period of rapid coca growth in the 1990's spurred an ambitious plan to restrain illegal supply of drugs in Colombia, *Plan Colombia*. According to Mejia et al. (2013), of all coca and cocaine reducing policies implemented (aerial spraying, manual eradication, control of chemical precursors, detection and destruction of laboratories and seizures) aerial spraying was by far the most important. In fact, Mejia and Restrepo (2013) use data from the U.S. General Accountability Office and mention that out of the yearly U.S. disbursements of around $593 million per year between 2000 and 2008, 69% went to eradication programs, without taking into account the initial $800 million that was disbursed in 2008 that also went to anti-narcotic programs.

As described by Mejia et al. (2013) aerial spraying is carried out mainly by US contractor planes who spray mainly Round Up® herbicide on coca fields. The main component of this herbicide is glyphosate and it includes other ingredients that help it penetrate the plant and destroy it. Since it is a herbicide, it equally affects coca crops and all other non-genetically modified crops. The herbicide is absorbed by the plant's foliage and thus is only effective in growing plants. Conversations with authorities and other experts underline the difficulty of spraying only above coca crops; strong winds and the necessity to spray from higher than recommended heights to reduce the risk of being shot down increase the probability of the

herbicide hitting other crops.

Figure 1 shows the evolution of coca crops and the two main stick policies that have been used in the last eleven years, mainly aerial spraying and manual eradication. However, the figure shows that even though there is a downward trend in crops, it still does not show a decisive trend towards a zero coca scenario and it is not entirely driven by eradication efforts. In fact, the UNODC 2014 Colombia drug census finds many areas where coca has fallen in the absence of spraying.[2] It is also important to note that hectares sprayed are always higher than the end of the year reported coca hectares. This is due first to technical reasons, whereby a plant is completely killed after being sprayed four times (there are on average 4 coca harvests in a year, and each spraying makes sure none of these harvests succeed) and also because some farmers react to the policy by replanting and protecting coca plants from chemical spraying damage.[3] The fight between protecting the coca bush or replanting it vs. the efforts deployed by the state to destroy it, is at the heart of this discussion.

Figure 1: Coca Crops and Eradication Efforts




Despite such great efforts, many consider the war on drugs to have failed and to have caused "devastating consequences for individuals and societies around the world" (Global Commission on Drug Policy GCDP, 2011, p. 4). This conclusion also stems from the increasing amount of academic research around the effectiveness of coca-reducing policies. Mejia et al. (2013) use diplomatic friction with Ecuador as an exogenous variation for spraying in the Southern border of the country, and find small but significant effects of spraying on coca crop reduction. However, they can not control for the so called "balloon effect" of migration of crops to other areas and thus state their result as an upper bound. Reyes (2011) uses an instrumental variables approach to estimate the effect of spraying on coca crops, finding spraying not only ineffective but also generating an increase in coca crops. Moreno-Sánchez et al. (2003) find that spraying is ineffective as it leads farmers to crop coca in a more extensive way. Ibanez (2013) uses a unique micro dataset and finds

[2] If one looks even further into this picture, it is clear that even though coca is decreasing, other forms of illegality are increasing, such as illegal gold mining (Idrobo et al., 2014). Thus, achieving reductions in one form of illegality while another one emerges leaves a big question mark on the effectiveness of coercive policies seeking to reduce overall illegality.

[3] Such as washing coca bushes with water after spraying, covering them with a molasses coating or "pruning" them, an operation where, as described by Mejia and Posada (2008), farmers cut the top of the coca bush and, since the only part of the plant that is attacked is the leaves, they are able to harvest it one month later.

that even though eradication reduces coca, the elasticity of supply of these policies is low. All in all, out of all the municipalities in Colombia, 28% have grown coca at least one year with a persistent character and 52% of coca growing municipalities have done it for 10 years or more, despite state control.

Other studies tackle the negative side effects of this policy on the population. Rozo (2013) finds that even though spraying decreases illegal coca crops, the socioeconomic conditions of the population deteriorate and that effects on poverty and health persist even after two years. Camacho and Mejia (2013) study the externalities of spraying on human health and find negative effects reflected in dermatological problems and increased abortions. Additional side effects have been found on other spheres: coca spraying undermines trust in the state and in political institutions (Garcia, 2011), erodes community strategies to control coca farming by other community members (Ibanez and Vasquez, 2014b) and relates to higher levels of generalized dishonesty (Ibanez and Vasquez, 2014c).

So far, none of the models developed to analyze coca growing decisions and effectiveness of coca-reducing policies take into account the possibility of a non-linear relationship between severity of punishment and the decision to switch to legal crops. Reyes (2011) assumes that farmers diversify their crop portfolio and increase other crops when the risks associated with coca are too high and Clemens (2008) uses legal crops as the alternative counterpart for opium in his theoretical model of crop farming. Chumacero (2008) develops a general equilibrium model for production, trafficking and consumption of illegal goods which introduces government actions to counteract illegal drugs both through increasing risks or increasing punishment, but here legal crops are modeled to always increase when coca is reduced by any governmental policy. Bogliciano and Naranjo (2012) also develop a general equilibrium model and even touch on legal production, but in both cases the authors assume that the reasoning behind choosing coca over a legal crop depends merely on risk and relative profits.

Some studies go beyond the analysis of risk and relative profit and find evidence that non-economic and moral aspects shape illegal behavior (Ibanez and Carlsson, 2010; Ibanez and Martinsson, 2013; Ibanez and Vasquez, 2014a; Ibanez and Vasquez, 2014b), but they all assume the choice of the legal crop to be affected by drug-reducing policies only indirectly through their effect on coca, and assume coca and legal crops to be pure substitutes. Dube and Vargas (2013) study the effect of price shocks on civil conflict and rule out that coca cultivation increases after a fall in coffee prices, strengthening the idea that legal and illegal crops do not necessarily substitute each other. Until now there is no evidence that farmers do in fact turn to legal crops when risk of punishment is high, nor that the decision to plant legal crops also depends on the disproportionality of the "stick" policies directed at illegal crops. This study also contributes to the literature by expanding our knowledge on additional side effects caused by coca spraying and by giving an empirical example of how disproportional punishment back fires.

This study takes place amid a regional debate on the effectiveness of drug policies. Never before had the Inter-American Commission on Human Rights (IACHR) granted a hearing regarding the impact of drug policy on human rights, and it happened in March 2014. Bolivia decided to change its constitution to allow traditional coca use within its territory and Uruguay became the first country to adopt a legal and regulated cannabis market.

The need for debate is such, that there will be a UN General Assembly Special Session (UNGASS) on drugs in 2016, with drug policy at center stage and the world's leaders as discussants. Objective evidence of the direct and indirect effects of drug policy are needed in order to design effective and less harmful strategies.

# 4 Data and definitions

## 4.1 Data

This study draws on two different strands of data; one that focuses on legal crops and another that covers coca crops, spraying efforts and other conflict-related data in Colombia. I use aggregate and micro data to tackle both.

Data on annual coca hectares come from the UNODC-SIMCI office in Colombia. They take satellite pictures on a yearly basis and divide the country in grids of 1km x 1km, which they then aggregate at a municipal level. The amount of coca hectares reported for a given year is what is captured in the picture as of December 31, making it a "net" measurement of coca hectares at the end of the year, after coca growing, coca harvesting, manual eradication, aerial spraying and replanting took place.

Aerial spraying is the responsibility of the drug enforcement police. The decision on where and how much to spray is made based on the SIMCI coca figures, but field observation (such as flights over regions with a coca history or where coca was spotted by satellite pictures) is also used to capture coca dynamics. I use the spraying data that the anti narcotics police reports to UNODC-SIMCI for the 2001-2011 period. It was impossible to have access to spraying information from the 1km by 1km grid, and for this reason I use the municipal levels for both coca and spraying.

Information on legal crops at a municipal level comes from the Ministry of Agriculture's annual agricultural evaluations (EVA) dating all the way back to 1970, but I will focus on the 2007-2012 period, since these are the years in which revised data exists. These agricultural evaluations cover 1.122 municipalities (nationwide) and most agricultural products, and collect information on the hectares planted and harvested, as well as on production. I will focus on harvested areas as they are the most comparable among products and will only work with crops and not with forestry or livestock. This information comes annually from a local consensus in which local experts, authorities and producer associations participate, and based on their on-field knowledge assess the amounts planted, harvested and produced of each type of product. They collect information on transitory products on a half-year basis, and permanent products on an annual basis[4]. Even though each municipality has its own experts (since they have to be local and know the area very well), there are standardized data collection forms and rules on the way information should be collected and processed in order to ensure comparability. This allows me to work with a 5-year highly balanced panel dataset that enables the use of fixed effects at a municipality level.

[4]Some people argue that this way of capturing the data is not the best, as each municipality has its own set of experts that in the end decide the amount of agricultural activity in each municipality. However, this is the most disaggregated source of information that there is and the most comprehensive of the country. More information on how the EVAs are collected by the Ministry can be found here: www.cci.org.co.

I focus my analysis only on areas that have had coca at least once since 2001 since it is in also here where the spraying policy is applied. Coca growing areas (and consequently areas where spraying takes place) are not comparable with regions where coca has *never* been grown,[5] since people can choose to move to areas where coca is grown, possibly due to lower levels of state presence, easier access to land, or a higher degree of tolerance to the presence of illegal actors, among other reasons. With this in mind I end up with 112 municipalities that have had coca at least once, have been sprayed and have information on legal crops. This means that results here are not representative of the whole country, but only to coca growing regions. Since it is in these regions where the policy is applied, it is the relevant area of interest. Moreover, these results are interesting even if they do not speak about the whole country, as understanding how law enforcement is perceived in illegality prone areas is key to curbing crime where it abounds.

I use additional secondary information to characterize municipalities in terms of their exposure to armed conflict, and to other variables that can be relevant for agricultural production. Conflict related variables such as displacement, homicides, combats and attacks come from Colombia's President Office's Observatory of Human Rights. I include a security threat index built by the Ministry of Defense, that classifies municipalities in low-middle-high threat, based on presence of armed groups, combats, homicides, land-mines, and other conflict related variables, and also use their information on presence of illegal armed groups (number of combatants). This threat-index then classifies municipalities in three groups, red, yellow and green, from highest to lowest threat. The information regarding population size, population density and other population variables, as well as the distance of each municipality to a productive agglomeration and land prices comes from the Ministry of Agriculture and the Registrar General's Office. I control for institutional quality by including a fiscal performance index calculated by the government of Colombia that indicates better use of public resources as the index takes on higher values.

In order to have a micro look on how individuals change their productive decisions when faced with a macro coca-reducing policy I employ three very different datasets of farmers that are exposed to various levels of coca growing and spraying, as shown in the results section. The three samples are described below.

The first group comes from a survey carried out by UNODC-SIMCI with 239 coca growers in the Putumayo-Caqueta region in Colombia in 2012, in order to estimate the economic structure of the farms in terms of income, costs and profitability, in areas under the influence of coca crops. This region has been highly exposed to coca growing but has limited state support to replace it with legal crops, and is also an area where coca has traditionally been grown and remains as one of the largest coca producing regions. The survey selection process is as follows: UNODC has satellite pictures of 1km x 1km grids, and based on them performs a randomized selection of grids in two steps. First, a 1km x 1km grid is selected

[5] For instance, coca growing areas have 23% less electricity coverage than their counterparts, have 185% more forest cover, are 50% less densely populated in rural areas, are 67% farther away from urban clusters, have a 10% lower fiscal performance, were 13% poorer in 2005 as measured by a multidimensional poverty index than their rural non-coca counterparts, depend 10% more on income transfers from the capital, have a forced displacement intensity 302% higher than non-coca areas, have 52% less roads per squared kilometer, have 3 times more the amount of landmine victims, 3.35 more armed actions and 5 times more combats than non-coca areas, have 444% more FARC presence, 3 times more massacres and a 46% higher homicide rate than their counterparts.

and then, within the grid, conglomerates of two coca farms and two non-coca farms are randomly chosen. Enumerators then go to the field and look for the farms that appeared in the satellite pictures. This survey is particularly useful because it offers accurate data on both coca crops and legal crops by individual farmers, which allows me to use coca involvement information on an individual basis. It also asks farmers whether their coca crops were damaged by aerial spraying in the past. Thanks to an academic agreement with UNODC, I was able to introduce a set of questions in this survey, addressing the issue of state legitimacy by asking people to rank the quality of public utilities and express their trust in the government's capacity to solve some problems that are the responsibility of the state. This allows me to capture if coca spraying shocks reduce state legitimacy, one of the proposed channels.

The second group comes from a survey conducted in 2012 by Econometria Consultores for the evaluation of the Forest Warden Families, the current biggest alternative development program in Colombia. The survey includes 1236 program beneficiaries (who were beneficiaries at the time of the survey), randomly selected from the seventh wave of the Program[6], and stratified by municipality. This group is interesting as it allows me to study to what extent punitive measures –once state support is received– continue to influence the decision to grow legal crops. This group is different in the sense that they have also been exposed to high levels of coca growing, but have received the Forest Warden Families Program, which has provided them with money, workshops and technical assistance in order to replace coca with legal products. The survey is very comprehensive and includes household information for all household members, as well as productive information for all land plots in terms of products grown, amount of land used for their production, etc. Even though the survey asks about individual involvement with coca, not many people answered and responses might also be underestimated, rendering the use of aggregate coca growing measures as advisable.

The third group is a subsample of coffee growers from the Coffee Information System (SICA for its acronym in Spanish) from 2007 to 2013. This dataset is a census and has information on every coffee plot in this period and each plot can be attributed to an individual farmer. It collects information on total plot area, area planted with coffee, the coffee variety used, and the age of the coffee crops, among other variables. This dataset is then merged with information on the type of assistance coffee growers have received from the National Coffee Federation (NCF). From 2009 onwards I am also able to go beyond the area dedicated to coffee and use coffee production per plot; this variable comes from a NCF algorithm based on the coffee variety, crop age, and plot density which determines production on the basis of these characteristics. As I mentioned before, I only focus on regions that have grown coca in at least one point in time, so I take a subsample that covers coffee growers living in areas that have grown coca crops at least once. This leaves me with a panel dataset of 6 periods for 155.278 coffee farmers in 111 municipalities. However, as will be seen in the results

[6]This was the baseline for an impact evaluation, where also 1210 neighboring controls and 1264 distant controls were surveyed. The FWF Program built a targeting index for all municipalities in the country based on observables that define the priority of treating communities within that municipality. Because of resource constraints the program has been rolled-out since 2006 and in fact, since the evaluation and early 2014, 18% of the distant control municipalities have been treated. Distant controls were chosen based on this index and matched with the treatments to find the most similar municipalities. However, I focus only on the beneficiary group, as I am interested in the behavior of famers that are receiving support to stop growing coca, and although I also look at the behavior of distant controls, I do not emphasize the differences between both groups.

section, the levels of coca in coffee growing regions is particularly small when compared to the rest of the coca growing areas in the country, which makes this group interesting to study, because it allows me to test my hypothesis that disproportionate punishment can crowd out investments in legal crops also in places that have better access to markets and where legal crops are more likely to proper.

Table 1: Description of Data sources

| Data | Unit of analysis | Type | Size |
|---|---|---|---|
| Aggregate data | Municipality | Panel: 2002-2012 (coca/spray)<br>Panel: 2007-2012 (legal crops) | 112 municipalities |
| UNODC | Household | Cross-section 2012 | 239 coca farmers |
| Forest Warden Families | Household | Cross-section 2012 | 1,236 beneficiaries |
| Coffee growers | Farm/Household | Panel: 2007-2012 | 155,278 farmers |

Note: In all cases I only use municipalities that have had coca at least once in the available time series

One last point regarding data is that the micro data mentioned has information regarding productive choices (area allocated to legal products in the case of UNODC and FWF, and production in the case of coffee growers), but no information on spraying or spraying disproportionality. Only in the case of the UNODC sample I am able to use self-reported involvement in coca as a control variable, but for the other two I need to use aggregate coca growing levels on a municipality basis. This means that I will analyze how a macro policy affects individual decisions. Even though I do not have spraying information available at an individual level, the way in which the policy is implemented implies that aggregate spraying levels are appropriate to explain individual investment decisions: first, people can see the planes. Even if they are not flying right above them, they can easily sense that neighboring plots are being sprayed and see see how many times the plane flies over the same areas. Second, even if they miss the plane, the spraying is discussed with neighbors and other farmers on market days or other gatherings. Third, given the threats facing spraying aircraft, the spraying passes are released above the recommended height, which reduces the pilot's capacity to spray only designated areas, and increases the chances that winds will carry glyphosate to non-intended sites. Ibanez (2013) uses a similar strategy to circumvent the endogeneity of aggregate eradication on coca-growing decisions and argues that policies can be treated as exogenous when individual household data are available, as the decision of one farmer is marginal and does not increase the probability of being targeted by eradication. Thus, having individual data respond to aggregate levels of spraying seems to be a plausible.

## 4.2 Definitions

This paper studies the effect of spraying *disproportionality*, rather than spraying per se, on legal crops. I define disproportionate spraying as the ratio between spraying in year $t$ and coca reported by SIMCI in year $t-1$, namely $SprayingDisproport = \frac{Spraying_t}{Coca_{t-1}}$.[7] Since

[7] Low levels of this ratio, in particular those between one and four could be interpreted as proportional. The point of the name is to show that I am not focusing on spraying per se but on how spraying relates to coca. Even though higher disproportionality levels would also imply higher probability of being eradicated (risk), disproportionality cannot be interpreted as such, since the probability of eradication cannot be higher than one.

spraying decisions are made based on the previous year's reported coca hectares, it makes sense to use it as a denominator. When looking at the descriptive statistics it is also clear that spraying follows coca hectares with a lag of one year, especially in the years with high coca growing levels.

I also use a dichotomous definition of disproportionality and call it a spraying shock, which I define as 1 for all those that are above the mean of the spraying disproportionality and 0 for those that are at the mean or below. The logic for choosing the mean for the following reasons reasons: first, when looking at the macro data the median of spraying disproportionality is 1.4, whereas the mean is almost three times higher. Those above the mean comprise 22% of the sample, so choosing an ever higher threshold would leave a very small amount of observations in this group. Additionally, the mean falls around 4, which coincides with the amount of times the authorities say they need to spray one field in order to really kill the plant. Therefore, those above the mean are also above the "necessary" amount of spraying for effective coca eradication.

$$SprayShock = \begin{cases} 1 & SprayInt_i > \overline{SprayInt} \\ 0 & SprayInt_i <= \overline{SprayInt} \end{cases}$$

# 5 Methodology

The purpose of this study is to test the effect of spraying disproportionality and spraying shocks on legal crops. I do this with the four groups described in the data section, of which two have a panel structure and two a cross-section structure. In the standard and most common models of crime more punishment leads to less crime, and the criminal activity is replaced with the legal activity using a linear relationship. However, my hypothesis is that punishment has an upper limit that backfires when it is exceeded, or in legal terms, when the punishment ceases to be proportional to the crime. I test this by including a squared-term for the ratio between the punishment and the crime (disproportionality).

The rationale behind using spraying disproportionality rather than spraying levels is twofold: first, it captures the disproportion between a punishment and a crime, which is what I argue leads to a loss of legitimacy, and ultimately to a disregard for legality, as Tyler's arguments would predict. Second, spraying follows coca and it is very hard to disentangle the effect of coca (and subsequently spraying) on legal crops. There is evidence that coca is highly related with violence and armed conflict (Thoumi, 2009; Diaz and Sanchez, 2004; García, 2014) and that the armed conflict has a negative impact on agriculture (Arias et al., 2014; Ibanez et al., 2013; Vasquez, 2010), which makes the identification of the impact of spraying on agriculture hard to pin down. However, disproportionate spraying captures another dimension that is not driven by the presence of coca nor is it related to conflict per se, as shown in the results section, opening the possibility to pin down the effect of a spraying policy's disproportionate use on legal crops.

I argue that the effects of spraying disproportionality on legal crops can be interpreted as causal. First, spraying decisions follow the presence of coca crops and do not take legal crops into account. In fact, the pairwise correlation between the lag of legal crops and spraying disproportionality is negligible (0.03) and not significant, ruling out reverse causality.

However, since legal crops could be substituted by coca (and vice versa) depending on the relative profits and risk of being caught, some endogeneity could be introduced. In order to correct for this I use spraying disproportionality, which, as will be seen in the results section, does not follow coca presence. Second, in the two panel datasets I am able to use a fixed effects model that takes away time-invariant unobservables that might affect the decision to plant legal crops. Worrisome unobservables such as a region's soil quality, altitude, geographic location, overall institutional presence (which changes very slowly over time) and unobservable characteristics that attract people to coca growing areas are accounted for. Third, I restrict my analysis to areas that have seen a coca field at least once in the available years, as mentioned above. Areas where coca has never been grown are structurally different and at first sight incomparable with areas with coca. Therefore, if I only focus on coca regions, these unobserved differences that make coca growing possible in some areas are equal for all municipalities in the analysis, and are differenced out.[8] Fourth, I exploit lags in the panel models and, as a result, can test whether any spraying disproportionality experienced in the past affects current legal crops. Fifth, in addition to macro crop data I use micro sources of data with individual production decisions, which do not determine policy but on the contrary, adapt to it. The use of three very different groups of people to test the effect is in itself a robustness test, and further reduces any potential bias in the sense that individual responses to policy exposure are exogenous. Sixth, I have a rich set of control variables that control for the driving factors behind the decisions to work with legal crops.

I run all specifications in two versions, one with the continuous disproportionate spraying as the explanatory variable, and one with the spraying shock as the independent variable of interest. The first captures how small changes in proportionality affect legal crops and the introduction of the squared term allows me to estimate any possible turning points. The shock captures the effect of simply having been exposed to higher spraying as necessary. The aggregate data and coffee grower groups employ a fixed effects approach and exploit lags in spraying disproportionality and shocks, whereas the UNODC and FWF groups are cross-sections. I present the models used for each group below.

*Panel Data Specification*

I will describe the general specification for the aggregate macro information and then will explain how this same set up is used for each micro sample. As mentioned, I have a five year panel data with aggregated data on both spraying disproportionality and legal crops and I use the following fixed effects model to capture the effect of the former on the latter:

$$Y_{it} = \alpha + \beta_1 I_{it} + \beta_2 I_{it}^2 + \beta_3 I_{it-1} + \beta_4 I_{it-1}^2 + \beta_5 I_{it-2} + \beta_6 I_{it-2}^2 + \beta_7 X_{it} + \eta_t + \mu_i + \varepsilon_{it} \quad (1)$$

where $Y_{it}$ represents the harvested legal crop hectares,[9] expressed as natural logarithm for ease of interpretation in municipality $i$ in year $t$. $I_{it}$ and ${I^2}_{it}$ are the linear and squared

[8] As a robustness check I estimated a Heckman selection model and used the inverted mills ratio as an independent variable in macro data models to control for self-selection and the results remain the same. I estimated one Heckman model per year to ensure that the mills ratio did not disappear with the fixed effects. The inverted mills ratio is not significant in any of the specifications. I do not use this specification as the main result as the inverted mills ratio is highly correlated with some explanatory variables creating potential multicollinearity problems.

[9] As a robustness check I also run the same model with the amount of hectares planted as the dependent variable.

terms of spraying disproportionality as defined above. I include two lags of disproportionate spraying to capture the persistence of the effect or the moment when the effect emerges. It could be possible that people planted their crops at the beginning of the year and experienced spraying later on and thus did not react immediately. $X_{it}$ captures time-varying municipal control variables that should be present in an agriculture output model such as rural and urban population densities, percentage of rural population in municipality, land prices and institutional quality. In this vector I also include lagged coca crops and the lagged change in coca crops, also in natural logarithms.[10] Variables such as distance to markets, size of the municipality, area devoted to national parks, altitude and soil quality are time invariant and thus fall out with the municipality fixed effects. $\eta_t$ and $\mu_i$ are time and municipality fixed effects respectively, and $\varepsilon_{it}$ is the error term, clustered at a municipality level.

When the spraying shock is used instead of spraying disproportionality the empirical specification looks like Equation 2, where $S_{it}$ is a dummy variable that takes a 1 when there is a spraying shock. As in Equation 1 it is also lagged two periods. These dummy variables capture spraying disproportionality, after controlling for $A_{it}$, the natural logarithm of spraying.[11] $Yit$ remains the same, as well as $X_{it}$, the fixed effects and the error term.

$$Y_{it} = \alpha + \beta_1 S_{it} + \beta_2 S_{it-1} + \beta_3 S_{it-2} + \beta_4 A_{it} + \beta_5 A_{it-1} + \beta_6 A_{it-2} + \beta_7 X_{it} + \eta_t + \mu_i + \varepsilon_{it} \quad (2)$$

The coffee growers' subgroup uses the panel specification as Equations 1 and 2. The main change is that the dependent variable is not areas with coffee but coffee production and productivity measured as the number of 60kg bags of coffee produced and bags per hectare. This is a much better indicator of agricultural output which can only be captured with a homogeneous product like coffee. Control variables include individual plot characteristics such as the area dedicated to coffee, the coffee variety, the number of farms used for production, the age of the crop, whether the coffee has been replanted or newly planted, the coffee crop density, and the coffee growers-rural population ratio in the municipality. I also add individual and time fixed effects and additionally cluster standard errors at the municipal level.

*Cross-Section Specification*

The cross section specification are similar to Equations 1 and 2, but drop the individual fixed effects and do not use additional lags because of the high correlation among them in a cross-section setting. The FWF sample is a cross-section collected in 2012. I use disproportionate spraying in 2011 and the total spraying shocks between 2001 and 2011 as treatment variables for the disproportionality and shock specifications respectively. I use survey weights for expansion, which are stratified at a municipal level and thus take care of the intra-municipal correlation. I make sure that the rest of the control variables are

[10] The control variables are chosen following agricultural economics production functions, where urban population represents the demand for agricultural products, the rural population density and percentage of rural population capture the labor supply for agricultural goods and land prices represent the value of the land, a key production factor in the rural sector. I also include institutional quality as it has been extensively shown to matter in growth and production models. This variable comes from the National Planning Department, which has created an institutional quality indicator that takes into account how they manage their finances, savings and other aspects related to fiscal performance.

[11] Spraying is included with the caveats above mentioned in mind. The main variable of interest is the shock, but spraying levels must be controlled for and they serve as a robustness check to the linear term included in the first specification.

at an individual level so that the only variables at the municipal level are the treatment variables. I also control for municipal coca levels in 2006, before the Program started. The control variables included are per capita expenditure per month, perceived land quality, percentage of land with a title, gender and age of the household head, time spent in the same community, participation in productive associations, a morality index built to capture culture of legality and moral perception of coca.

The UNODC sample is also a cross-section collected in 2012. For the spraying disproportionality I use the average of the whole period (2001-2011). Unlike FWF which has a national coverage, this sample is geographically concentrated and using the average spraying disproportionality captures a better picture than using its value in 2011, which dropped vis-à-vis 2010 and previous years in this region. The shocks are also captured by the sum of shocks between 2001 and 2011. Since this survey focused on coca production, I have detailed information on self-reported coca crops, which gives me the possibility to control for coca at an individual level (I control for the amount of years each farmer has cultivated coca and for their involvement with processing coca leaves into coca paste or coca base), which is an advantage compared to the other two micro datasets. I can also control for whether their own crops have been affected by spraying. Additional controls are age and sex of household heads, holding a title over their land, the self reported quality of public utilities, trust in authorities, total disposable land and years living in the farm. Errors are clustered at the municipal level.

*Hypotheses*

My hypotheses can be formulated in terms of expected coefficients. First, I expect the coefficient associated with the linear term of spraying disproportionality to be positive (as should be the coefficient accompanying spraying in Eq. 2). This should capture the commonly assumed relationship between spraying and coca, whereby increased punishment should induce farmers to opt out of coca and invest in legal crops. However, I expect this positive relationship to have an upper limit, and presume the squared term (or the shock variable in Eq. 2) to have a negative coefficient and reduce the area planted with legal crops, as it captures severe and disproportionate punishment. Second, the coefficient related to coca could go in two directions. It could be negative if there is a substitution effect between coca crops and legal crops, especially if production factors such as labor and land are scarce and fixed; in this case, more coca would imply less legal crops (negative coefficient). It could be positive if there is resource abundance or if coca is being closely camouflaged with legal crops in order to avoid detection (planting coca under banana trees so that the foliage covers the coca plants in the aerial satellite pictures). The coefficient on spraying in the shock specification should be positive; once the shock is controlled for, spraying should induce a switch from illegal to legal crops.

# 6 Results and Discussion

My empirical strategy is set out as follows. First I present a general description of the municipalities and the farmers surveyed, followed by descriptive results on spraying, spraying disproportionality and coca levels and show that at a first sight spraying disproportionality

does not follow coca. I then strengthen these results with a fixed effects model that stresses the lack of positive correlation between coca and spraying disproportionality. With this evidence I continue with testing the relationship between spraying disproportionality and legal crops in the four samples, starting with the aggregate macro data followed by the micro data samples, ordered from highest disproportionality (UNODC) to lowest (coffee growers).

## 6.1 Characteristics of municipalities and surveyed farmers

Coca-growing municipalities are also legal crop producers. The top ten crops are corn, plantain, cassava, beans, rice, cocoa, sugar cane, coffee, tomatoes and avocado; these are the same in non-coca growing municipalities, except that in the latter cold-weather crops such as potatoes enter the list. In the majority of coca-growing municipalities legal crops account for most of the agricultural production; only in 6 municipalities[12] the area dedicated to coca is larger than the area dedicated to legal crops, in the rest, the average area dedicated to coca amounts to 3% of the area used for legal crops. Around 31% of the rural population lives in coca-growing municipalities, and according to UNODC (2013) 61,700 households are directly involved with coca. In 2013 coca production amounted to 3% of the agricultural GDP (UNODC, 2014). Table 2 presents descriptive statistics of the main independent variables used in the models for coca growing municipalities.

Table 2: Summary Statistics of Coca Growing Municipalities

| | mean | sd | min | max |
|---|---|---|---|---|
| Coca hectares | 425.05 | 1000.80 | 0 | 14606 |
| Sprayed hectares | 1510.66 | 2704.42 | 0 | 29416 |
| Cultivated area (ha) | 32457.84 | 55398.99 | 1 | 696975 |
| Spraying Disp | 3.73 | 14.23 | 0 | 306 |
| Threat Yellow Zone | 0.33 | 0.47 | 0 | 1 |
| Threat Red Zone | 0.46 | 0.50 | 0 | 1 |
| Distance to Urban Center (km) | 69.72 | 65.64 | 0 | 397 |
| Fiscal Performance Index | 58.85 | 9.31 | 0 | 87 |
| Urban Population | 14185.78 | 50945.82 | 0 | 615795 |
| Rural Population | 11667.85 | 9540.34 | 0 | 85386 |
| Population density in rural area | 19.84 | 30.53 | 0 | 357 |
| Num. Armed Actions | 1.19 | 3.18 | 0 | 46 |
| Num. FARC | 21.08 | 59.76 | 0 | 948 |
| Num. ELN | 4.47 | 11.42 | 0 | 115 |
| Num. BACRIM | 5.32 | 15.08 | 0 | 144 |
| Num. Combats | 3.85 | 9.61 | 0 | 119 |
| Num. Landmines | 3.05 | 8.21 | 0 | 111 |

The farmers in the UNODC are the most exposed to coca as seen in Figure 5, and for 58% of the sample, growing coca is their main economic activity. The majority are male

[12] These municipalities are situated in the departments of Amazonas, Cauca and Vichada. Amazonas and Vichada are in or close to the amazon rainforest, which is for environmental reasons not under large-scale agricultural exploitation. Cauca has become an important coca cultivation hotspot recently.

(85%) and most (75%) only have primary education or no education at all. As is the case in many coca growing areas, half of the sample was born in a different place and migrated to the region on average 22 years before, which coincides with the initial growth of coca in these areas around the 80's. Only 30% have titles over their land. Before migrating 50% were farmers, and only 5.5% were already working with illegal crops, but 60% said they had migrated due to poverty or unemployment. These farmers are still exposed to poor living conditions: only 3% have access to drinking water and 13.5% to electricity, and even though there are health facilities, schools and roads in the majority of places, farmers perceive them as very low quality. The average size of their farm is 13 hectares, but only 1.6 hectares are cultivated with either permanent or transitory crops.

The Forest Warden Families have been on average exposed to smaller coca quantities in their regions, but they are also a marginalized population. Most of them (82%) live in dispersed rural areas, 56% reach their farm through a gravel path, 32% through a gravel road, 10% through a river, and only 2% access it through a paved road. Only 43% live above poverty[13] and 82% have primary schooling or less. They have also been exposed to high levels of violence, with 26% of the sample reporting having experienced a violent calamity. The FWF farmers follow the same productive pattern observed for the aggregate data: 33% grow transitory crops, 18% grow plantain, 12% grow coffee and 8.6% grow cocoa, and 76% of the households use part of these crops to feed their family. As is the case for the UNODC sample, only 30% hold a title for their land. The median FWF farm has 2 hectares, with 1 hectare dedicated to productive activities.

Even though the coffee growers census does not collect socioeconomic data on the farmers, it can be merged with the SISBEN dataset, which collects all the socioeconomic information in order to target beneficiaries for social programs, allowing these farmers to also be characterized. Although this is the population with the least exposure to coca crops and spraying, coffee farmers in municipalities where coca has been grown are also marginalized, as 91.8% are poor, according to the ICV. Earnings amount to approximately 49 USD per month and they have studied 3.1 years on average. Farms measure 6.5 hectares, but only 1.2 hectares are actually used to grow coffee. As in the other two samples, only 29% have a title over their land.

## 6.2 Descriptive evidence

Figure 2 shows coca, spraying and spraying disproportionality levels between 2001 and 2011. Some things are interesting to note from this Figure: spraying follows coca in the expected way but spraying disproportionality and spraying shocks seem to follow a completely different logic; they increase until 2007 even though both coca and spraying where decreasing, and they do not seem to follow coca patterns. Spraying disproportionality and spraying shocks increase until 2007 when they reach a maximum, and decrease thereon, with the exception of 2010. Figure 3 shows the geographical distribution of coca, spraying and spraying disproportionality in 2007, where it is seen that the areas with highest coca

[13] Measured by the ICV, the livelihoods index, a multi-poverty index constructed by the National Planning Department whose components where asked in the survey.

hectares coincide with the areas of spraying but less so with areas with high disproportionality.

Figure 2: Spraying, spraying shocks, spraying disproportionality and coca grown per year

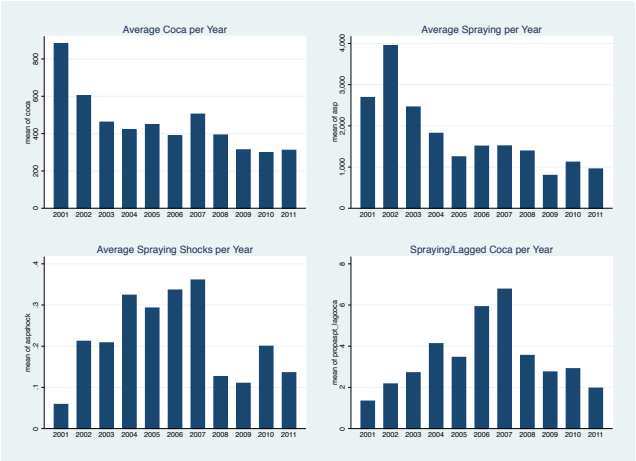
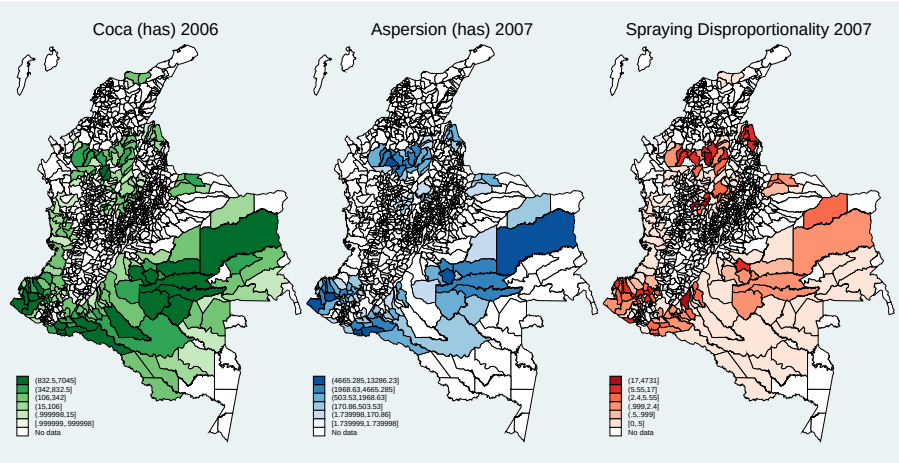
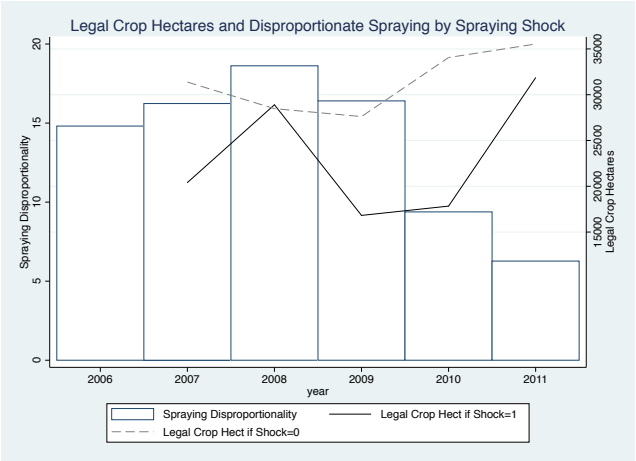



Figure 3: Coca and spraying disproportionality



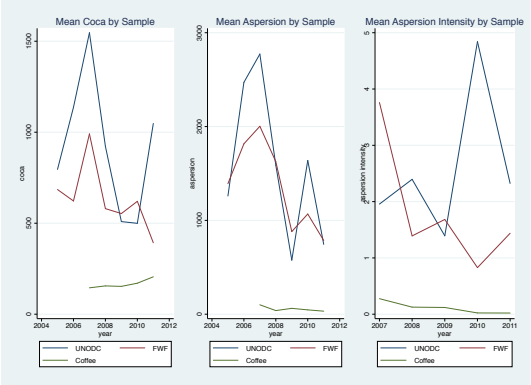

Now I turn to legal crops and look at their patterns for all municipalities that have grown coca at least once, and divide them between those who experience a shock and those who do not. Figure 4 shows that those that experience a shock have on average less legal crops than those that do not. It is interesting to note that the big fall in legal crop harvested areas in 2009 for those who experienced a shock followed the year of highest spraying disproportionality. Even though both groups where decreasing their legal crop areas, those who were exposed to a shock showed a much steeper decrease than those that were not. It is also quite interesting to note that as spraying disproportionality decreases, crops recover for both groups, but it is especially those exposed to shocks that bounce back remarkably fast. Without claiming causality, this suggests that increases (decreases) in spraying disproportionality have quite an important lagged effect on legal crops, especially for those municipalities that have been exposed to spraying shocks.

Figure 4: Legal Crops and spraying Shocks




As mentioned in the data section, the three micro samples are quite different and this also shows in the levels of coca, spraying and spraying disproportionality they have been exposed to. As expected, the UNODC sample has the highest exposure to coca and spraying, because they are in the Putumayo-Caqueta region, a historical coca growing area. The Forest Warden Families sample follows a similar pattern to that of UNODC, but of a smaller magnitude. The FWF includes coca growing regions and regions at high risk of having coca, while also focusing on areas that have been recovered by the state in recent years, which explains the divergence in coca trends with regards to the UNODC sample in the last year. Spraying disproportionality has also been highest among UNODC and FWF samples. As expected. coffee growers in municipalities where coca has been grown show lower exposure to coca, spraying and disproportionality than farmers in the UNODC and FWF samples. These three samples offer great richness in the analysis, as I can check how farmers' productive decisions react to disproportionate spraying in three different environment-related scenarios: very high exposure, medium-high exposure and low exposure.

Figure 5: Coca, spraying and spraying disproportionality for each different micro sample



## 6.3 Empirical results: macro data

### 6.3.1 Determinants of spraying, spraying disproportionality and spraying shocks

I first start with exploring the determinants of spraying and spraying shocks. Table 3 presents three regressions: the first column explains spraying, the second spraying disproportionality and the third spraying shocks, all of them using a fixed effects panel data model for all municipalities with coca production at some point between 2002 and 2011.[14] I follow Reyes' (2011) logic that spraying happens within distances where spraying planes can be protected from being shot down.[15] This means that spraying should be highest around urban centers where the state has more control and low where there is significant presence of illegal armed groups or where the threat to security is highest (all of these are also correlated with distance up to a certain extent). I use other variables following Bogliciano and Naranjo (2012) such as coca production, crime rate and displacement.

I find that spraying is higher in places where the threat to the state is medium (yellow zone) and not high (red zone), and it actually decreases where distance from an urban center is very long (squared term). As can be seen in the descriptive statistics, lagged coca induces spraying in the following year. Increased presence of illegal armed groups FARC, ELN and criminal groups (BACRIM) also reduces spraying levels. Where combats are not so high spraying is high, meaning perhaps that where combats are taking place the state is present, trying to recover its territory from the illegal armed groups. As a result spraying aircraft may be protected by state forces, but only in those situations in which the intensity of the fight is not extreme.

Spraying disproportionality and a spraying shock do not seem to respond to the same variables, in fact, some have the opposite effect and the explanatory power of the overall model is quite low. In the first place, neither disproportionate spraying nor spraying shocks are determined by lagged coca levels (results hold if coca is squared or if I introduce the lagged change in coca), ruling out the thought that a shock is meant to counteract high levels of illegal crops. Moreover, a spraying shock is not likely to happen in situations where the threat to the state is high, and if it does, it will take place near the urban center. In contrast to spraying, presence of the FARC, BACRIM or ELN is not related to a spraying shock. Only combats and armed actions relate positively to a shock.

I went further into possible differences between those that had experienced a shock and those that had not, took key variables for agricultural production at their earliest levels (2004 and before) and looked at whether there were any significant differences between them. I found no differences between the groups for rural land prices, forced displacement intensity, homicide rates, rural and urban population sizes, rural population density, roads (in kilometers), primary roads, number of years growing coca, forest density, distance to urban centers, fiscal performance, rural poverty index in 2005, armed actions and presence of ELN and FARC guerrilla groups.

[14] A table with the marginal effects of all the variables included in the regressions can be found in the appendix.

[15] Reyes uses distance to military bases instead of distance to cities. However, I find that distance to the closest urban cluster (not necessarily the closest city, but the closest agglomeration as defined by the City System Mission) has a similar effect to that found in Reyes' (2011) first stage.

Table 3: Spraying and Spraying Shocks

| | (1) Spraying | (2) Spraying Disp | (3) Spraying Shock |
|---|---|---|---|
| Threat Yellow Zone | 2.6659** | -2.2436 | -1.9887*** |
| | (1.0947) | (1.9081) | (0.1695) |
| Threat Red Zone | 0.0489 | -24.4853*** | -2.6468*** |
| | (1.2704) | (4.4903) | (0.3460) |
| Threat Yellow Zone × Distance to urban (ln) | 1.1711*** | -0.7568 | -0.7060*** |
| | (0.3896) | (0.5265) | (0.0647) |
| Threat Red Zone × Distance to urban (ln) | 0.9808** | 3.1280* | -0.7879*** |
| | (0.4706) | (1.6800) | (0.1248) |
| Threat Yellow Zone x Distance to urban (ln) 2 | -0.1209*** | 0.0898 | 0.0801*** |
| | (0.0444) | (0.0651) | (0.0073) |
| Threat Red Zone x Distance to urban (ln) 2 | -0.0803 | -0.0541 | 0.0926*** |
| | (0.0530) | (0.1707) | (0.0139) |
| ln Coca (t-1) | 0.3967** | -2.2830* | -0.1806*** |
| | (0.1719) | (1.2844) | (0.0600) |
| Rural density | -0.0763 | 0.0910 | -0.0000 |
| | (0.1970) | (0.4363) | (0.0573) |
| Num. armed actions | -0.0068 | -0.1230* | -0.0205** |
| | (0.0424) | (0.0625) | (0.0082) |
| Num. FARC | 0.0035 | 0.0058 | 0.0013 |
| | (0.0030) | (0.0078) | (0.0012) |
| Num. FARC × Num. FARC | -0.0000* | -0.0000 | -0.0000 |
| | (0.0000) | (0.0000) | (0.0000) |
| Num. ELN | -0.0348* | -0.0474 | 0.0009 |
| | (0.0188) | (0.0469) | (0.0035) |
| Num. BACRIM | 0.0375** | 0.0230 | 0.0054 |
| | (0.0143) | (0.0309) | (0.0041) |
| Num. BACRIM × Num. BACRIM | -0.0003** | -0.0003 | -0.0001* |
| | (0.0001) | (0.0002) | (0.0000) |
| Num. Combats | 0.0303 | 0.0942 | 0.0018 |
| | (0.0280) | (0.0700) | (0.0103) |
| Num. Combats × Num. Combats | 0.0002 | -0.0006 | 0.0000 |
| | (0.0003) | (0.0006) | (0.0001) |
| Num. Mines | 0.0670** | 0.0350 | 0.0197* |
| | (0.0320) | (0.0781) | (0.0114) |
| Num. Mines × Num. Mines | -0.0014** | -0.0000 | -0.0003 |
| | (0.0005) | (0.0013) | (0.0002) |
| Constant | 3.3822 | 12.9916** | 1.1720 |
| | (2.5901) | (6.5325) | (0.8521) |
| Observations | 246 | 258 | 258 |
| Num.Clusters | 107 | 112 | 112 |
| R2 Overall | 0.17 | 0.02 | 0.01 |
| R2 Within | 0.30 | 0.19 | 0.18 |
| R2 Between | 0.22 | 0.01 | 0.00 |

Municipality fixed effect panel models. Clustered standard errors at municipality level in parentheses.

Significance levels * p<0.10, ** p<0.05, *** p<0.01

Variable definitions:HHI is the Herfindahl and Hirschman index of crop concentration; Rural density is the population density in th

Proportion rural is the proportion of the population in a municipality that lives in the rural area;

Perc. income from transfers is the share of the municipality's income that comes from the Central Government

There a few variables with differences: municipalities that experienced a shock rely four percentage points less in transfers from the central government, are 400 meters above sea level higher, had higher rural poverty in 1993 and are qualified 0.7 points higher in the threat to the state index that ranges from one to ten. In the models I control for the variables that are different either as control variables or as fixed effects.

These results show that spraying disproportionality or a spraying shock does not follow the same logic as spraying, but is rather a phenomenon that is not easy to explain, at least with the socioeconomic and conflict variables at hand, and seems to include an element of randomness which could have come from the pilot himself or the flight conditions during the overpass. This randomness could also be a military intelligence move that I cannot quantify. For the purpose of this study, this is evidence that supports that a spraying shock is exogenous to the farmers' legal crop growing decisions.

### 6.3.2 Spraying disproportionality and legal crops at a macro level

Table 4 presents the first piece of evidence regarding the effect of disproportionate spraying on the area harvested with legal crops. The first three columns follow the specification in Equation 1 that uses the continuous spraying (dis)proportionality variable as the main explanatory variable, but they differ in the dependent variable used. Since the effects of spraying could vary depending on the type of crop being used, I test the effects first on all legal crops, on transitory and on permanent crops. All regressions lead to the same conclusion: very high levels of spraying disproportionality or spraying shocks reduce legal crops, whereas low levels (or proportional levels) increase legal crops. This effect is statistically significant in the second lag for all products, and in the first and second lag for transitory products. I find that the relationship has an inverted U shape[16], where mild levels up spraying induce legal crops, but disproportionate levels reduce them. Figure 6 shows that when spraying disproportionality is above seven, legal crops are reduced. [17]

The last three columns use spraying shocks as the main independent variable, as specified in Equation 2. The signs remain the same but the effect of the shock lasts only one year, and is mainly driven by permanent crops (the effect on transitory crops is larger, but due to larger variance it is not significant). The effect of this shock is quite large, as it reduces legal crops in 17.4%. Spraying induces legal crops, as seen with the linear term of the continuous disproportionality.

[16] I tested a linear and cubic specification as a robustness check. In the linear specification only the first lag had a negative sign, but none of the spraying disproportionality variables (t, t-1, t-2) where significant. In the cubic specification I obtained a positive linear term, negative quadratic term (significant in the first lag) and positive cubic term, but never statistically significant. I remain confident that the quadratic specification is what best suits the theory of disproportionality.

[17] As a robustness check I estimate a Heckman selection model for each year in the period of analysis to get an inverted mills ratio for the whole period. I then include the inverted mills ratio as a control variable to control for possible selection effects that may not have been controlled for with the fixed effects and find that spraying disproportionality reduces legal crops contemporaneously as well as in the second lag for all products (see Table A.2 in the Appendix).

Table 4: Legal Crops, disproportionality of spraying and spraying Shocks

| | (1) All | (2) Transitory | (3) Permanent | (4) All (Shock) | (5) Trans (Shock) | (6) Perm (Shock) |
|---|---|---|---|---|---|---|
| Spraying Disp | 0.035 | -0.000 | 0.022 | | | |
| | (0.025) | (0.059) | (0.028) | | | |
| Spraying Disp 2 | -0.002 | 0.000 | -0.002 | | | |
| | (0.002) | (0.003) | (0.002) | | | |
| Spraying Disp (t-1) | 0.039 | 0.078* | 0.042 | | | |
| | (0.036) | (0.044) | (0.031) | | | |
| Spraying Disp 2 (t-1) | -0.003 | -0.006* | -0.003 | | | |
| | (0.002) | (0.003) | (0.002) | | | |
| Spraying Disp (t-2) | 0.073*** | 0.098** | 0.046* | | | |
| | (0.025) | (0.039) | (0.024) | | | |
| Spraying Disp 2 (t-2) | -0.003*** | -0.006*** | -0.002** | | | |
| | (0.001) | (0.002) | (0.001) | | | |
| Spraying Shock | | | | -0.195** | -0.233 | -0.158* |
| | | | | (0.092) | (0.156) | (0.095) |
| Spraying Shock (t-1) | | | | -0.139 | -0.118 | -0.018 |
| | | | | (0.124) | (0.167) | (0.105) |
| Spraying Shock (t-2) | | | | 0.066 | -0.110 | 0.078 |
| | | | | (0.107) | (0.160) | (0.081) |
| ln Spraying | | | | 0.091*** | 0.054 | 0.073** |
| | | | | (0.031) | (0.043) | (0.032) |
| ln Spraying (t-1) | | | | 0.025 | 0.010 | 0.026 |
| | | | | (0.030) | (0.049) | (0.024) |
| ln Spraying (t-2) | | | | 0.044 | 0.063 | 0.024 |
| | | | | (0.034) | (0.051) | (0.030) |
| Change in ln Coca | -0.069 | -0.044 | -0.066 | -0.059 | 0.003 | -0.058 |
| | (0.064) | (0.108) | (0.059) | (0.053) | (0.084) | (0.054) |
| ln Coca (t-1) | -0.135** | -0.127 | -0.066 | -0.230*** | -0.169 | -0.163*** |
| | (0.064) | (0.112) | (0.056) | (0.074) | (0.136) | (0.062) |
| Product cluster (HHI) | 1.803*** | -2.269** | 1.866* | 1.691** | -2.530*** | 2.544*** |
| | (0.608) | (0.938) | (1.019) | (0.670) | (0.936) | (0.674) |
| ln Rural Land Price (t-1) | -0.052 | -0.044 | -0.046 | -0.059 | -0.067 | -0.036 |
| | (0.045) | (0.071) | (0.045) | (0.061) | (0.083) | (0.065) |
| Change in Fiscal Performance | -0.005 | -0.013** | -0.004 | -0.005 | -0.012* | -0.003 |
| | (0.005) | (0.005) | (0.004) | (0.004) | (0.006) | (0.004) |
| Fiscal Performance (t-1) | -0.005 | -0.016* | -0.008 | -0.003 | -0.014 | -0.003 |
| | (0.008) | (0.009) | (0.008) | (0.007) | (0.010) | (0.007) |
| Change in ln Rural Pop | -0.163 | 3.831 | -1.488 | 0.383 | 4.043 | -0.121 |
| | (6.501) | (6.283) | (5.760) | (6.180) | (6.106) | (5.468) |
| ln Rural Pop (t-1) | 0.415 | 3.238 | -1.749 | 1.014 | 3.794 | -0.665 |
| | (6.617) | (6.417) | (5.712) | (6.210) | (6.125) | (5.478) |
| Rural density | -0.060 | -0.450*** | 0.116 | -0.102 | -0.411 | 0.019 |
| | (0.154) | (0.153) | (0.175) | (0.186) | (0.250) | (0.171) |
| Change in ln Urban Pop | 15.502 | 34.021 | 16.983 | 8.320 | 35.603 | 5.268 |
| | (19.868) | (23.890) | (22.558) | (19.691) | (26.393) | (18.348) |
| n Urban Pop (t-1) | 2.628 | 5.917 | 2.978 | 2.109 | 5.213 | 1.917 |
| | (5.896) | (6.087) | (4.901) | (5.518) | (5.385) | (4.636) |
| Proportion rural | -1.996 | 13.269 | -1.793 | -2.532 | 8.853 | -2.468 |
| | (24.826) | (24.353) | (20.449) | (23.050) | (22.384) | (19.780) |
| Perc. income from transfers | 0.003 | -0.000 | 0.002 | 0.004 | -0.000 | 0.002 |
| | (0.002) | (0.003) | (0.002) | (0.002) | (0.003) | (0.002) |
| Constant | -15.316 | -79.247*** | -2.379 | -15.792 | -76.270*** | -1.987 |
| | (19.107) | (23.650) | (17.556) | (22.157) | (23.239) | (18.970) |
| Observations | 283 | 279 | 283 | 272 | 269 | 272 |
| Num.Clusters | 83 | 82 | 83 | 80 | 78 | 80 |
| R2 Overall | 0.33 | 0.11 | 0.07 | 0.34 | 0.09 | 0.17 |
| R2 Within | 0.24 | 0.21 | 0.17 | 0.25 | 0.19 | 0.26 |
| R2 Between | 0.27 | 0.12 | 0.06 | 0.30 | 0.15 | 0.07 |

Clustered standard errors in parentheses. Significance levels * p<0.10, ** p<0.05, *** p<0.01

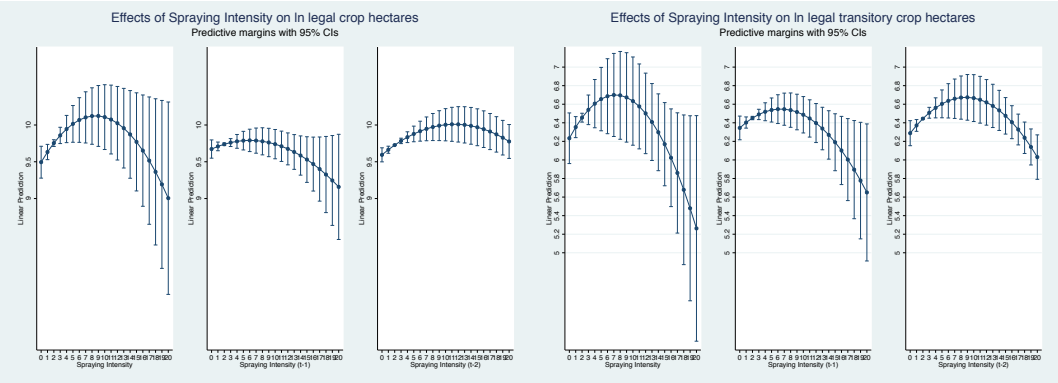
HHI is the Herfindahl and Hirschman index of crop concentration; Rural density is the population density in the rural sector; Proportion rural is the proportion of the population in a municipality that lives in the rural area;

Perc. income from transfers is the share of the municipality's income that comes from the Central Government

There also seems to be a substitution effect between lagged coca and legal crops. This is an expected result as people have a fixed amount of land and they choose between coca and other crops or activities, or through coca's close relationship with conflict.

The negative coefficient of the squared disproportionate spraying could mean two things: that spraying intensity increases legal crops at a decreasing rate or that legal crops decrease after a turning point. I find evidence for the latter as shown in Figure 6 that presents the predicted margins of the relationship between spraying disproportionality and harvested legal crops. The predicted margins are shown for the majority of the municipalities[18] and it is clear that the turning point is relevant for the analyzed sample. When spraying is between six and ten times the amount of coca found, the policy starts reducing legal crops. This turning point is shorter in the first lag of spraying disproportionality: when for each hectare cultivated with coca six to seven hectares are spayed, the number of hectares cultivated with legal crops in the next year drop. This figure also shows that the contemporary spraying and the first lag also behave as expected by the disproportionality concept, but the confidence intervals are too large for the effect to be statistically significant.

Figure 6: Predictive Margins of Spraying disproportionality on Legal Crops




As a robustness test I control for various conflict related variables.[19] Results become even stronger, as disproportionate spraying reduces crops significantly in the first and second lags (see Table A.3 in the Appendix). Regarding prices, it is also important to note that there is no evidence that the reduction of legal crops follows a drop in legal crop prices, as prices for both coffee and cocoa, the flagship products in alternative development regions, were increasing in the years of this analysis.[20] In terms of coca prices, the relevant price is the fresh coca leaf price, which has been monitored by UNODC since 2005. This price has remained stable between 2007 and 2011, ranging from 1.2 US$/kg in 2007, to 1.3 US$/kg in 2011. Prices are set by the illegal armed groups or narcotrafficants in a monopsony-type arrangement, where coca farmers have no say in setting the price. The stability of this period means that behavioral changes in terms of legal crop cultivation do not stem from a change in coca leaf prices. As an additional robustness check I run the same regression

[18] 98% of the municipalities analyzed report a spraying disproportionality smaller than 25. I run robustness checks leaving out municipalities with extreme disproportionality values and the results hold.

[19] I do not use this as my main specification, since there is a high multicollinearity between coca and conflict variables, so I leave coca as an explanatory variable in the main specification.

[20] I have not been able to find information on prices at a municipal level. Prices are aggregated by major markets, and not enough geographical variation is present in order to include them in the analysis.

with planted legal crop hectares instead of harvested area and the effects are the same (see Table A.4 in the Appendix).

## 6.4 Empirical results: Micro Data

Micro data allow a much stronger test of the spraying disproportionality effect on legal crops, as the analysis turns to the effect of a global or macro policy on the individual decision to grow legal crops. In this section I start by presenting the spraying disproportionality effects on the UNODC surveyed coca growing farmers in the Putumayo-Caqueta region of Colombia in 2012, followed by the effects on Forest Warden Families, finishing with a look at the effect on coffee growers.

One thing to keep in mind when analyzing the following results is that legal crop decisions are made at an individual level, but spraying and spraying disproportionality are captured at a municipality level, as this is the smallest unit of spraying that I was able to access. This means that the effect I capture is the lower bound of disproportionality on legal crops, as it is likely that many of the surveyed respondents were not personally affected by aerial spraying. Still, as already mentioned, farmers can change their legal crop planting behavior following a regional spraying campaign. Conversations with farmers in coca growing areas make me confident that people know what areas are being sprayed, how often and how severely.

### 6.4.1 UNODC cost survey with coca growers

Table 5 presents the effects of spraying intensity on legal crops for the UNODC sample using the cross section version of Equation 1, where I find similar effects as those observed in the macro data. Since this is not a panel for the individual responses that come from the survey, I can only observe the effect of spraying disproportionality on legal crops in 2012. Looking at the secondary data structure, there is high correlation between disproportionate spraying, spraying and coca in different years. For this reason I decide to test the effect of the sum of spraying shocks on legal crops, as mentioned in the methodology section. [21]

I find that one additional spraying shock between 2002 and 2011 reduces the area planted to legal crops by 13%. Once spraying shocks are taken into account, a 1% increase in spraying increases legal crops by 0.35%. In this case too, spraying can crowd-in legality as long as it is not disproportionate or extreme, as captured by a spraying shock. This effect is mainly driven by permanent crops, which could suggest that in this areas proportional spraying induces an idea of longer term eradication, which is necessary for permanent crops that require larger investments in time and resources. When people are exposed to too many shocks, people opt out of such investments, but do not change their transitory crops, as they could also be for their own consumption. The effect of the continuos variable is not as strong as the sum of the spraying shocks for this sample; despite having the expected signs, only the squared term is statistically significant when looking at all crops.

[21] I also test the effect of spraying shocks in 2011, the year before the survey, and the results hold.

Table 5: Effect of spraying disproportionality on legal crops in UNODC sample

| | All Crops | | Transitory | | Permanent | |
|---|---|---|---|---|---|---|
| | (1) Disprop | (2) Shock | (3) Disprop | (4) Shock | (5) Disprop | (6) Shock |
| Total spray shocks | | -0.127** | | -0.026 | | -0.102** |
| | | (0.047) | | (0.038) | | (0.029) |
| ln Spray 2011 | | 0.358*** | | 0.163* | | 0.195** |
| | | (0.081) | | (0.082) | | (0.063) |
| Spraying Disproportional | 0.551 | | 0.262 | | 0.289 | |
| | (0.301) | | (0.178) | | (0.307) | |
| Spraying Disproportional 2 | -0.122* | | -0.056 | | -0.066 | |
| | (0.055) | | (0.034) | | (0.053) | |
| Coca affected by spraying (1) | 1.094*** | 1.091*** | 0.679*** | 0.683*** | 0.415*** | 0.408*** |
| | (0.148) | (0.122) | (0.140) | (0.135) | (0.072) | (0.068) |
| Processes coca leaf (2) | -0.498* | -0.421** | -0.183 | -0.172 | -0.315* | -0.249* |
| | (0.213) | (0.169) | (0.108) | (0.105) | (0.154) | (0.112) |
| Years growing coca | -0.012 | -0.015 | -0.015*** | -0.015*** | 0.003 | 0.001 |
| | (0.010) | (0.010) | (0.004) | (0.003) | (0.007) | (0.007) |
| Female | -0.315 | -0.363 | -0.277** | -0.298** | -0.038 | -0.065 |
| | (0.213) | (0.214) | (0.115) | (0.113) | (0.181) | (0.176) |
| Age | 0.022*** | 0.020*** | 0.002 | 0.001 | 0.021*** | 0.019*** |
| | (0.004) | (0.005) | (0.002) | (0.003) | (0.004) | (0.004) |
| Years in Community | -0.007 | -0.007 | -0.008*** | -0.008*** | 0.001 | 0.001 |
| | (0.005) | (0.005) | (0.001) | (0.001) | (0.005) | (0.005) |
| Farm area (ha) | 0.023** | 0.025** | 0.010 | 0.011* | 0.012** | 0.013** |
| | (0.008) | (0.008) | (0.006) | (0.006) | (0.004) | (0.004) |
| Perceived State Capacity | 0.499 | 0.493 | 0.102 | 0.108 | 0.397 | 0.384 |
| | (0.283) | (0.278) | (0.077) | (0.072) | (0.298) | (0.292) |
| Perceived Quality Public SS | 0.383** | 0.372* | 0.064 | 0.066 | 0.319* | 0.306* |
| | (0.155) | (0.160) | (0.054) | (0.053) | (0.156) | (0.156) |
| Has Title over land | 0.733** | 0.742** | 0.434** | 0.440** | 0.298* | 0.301* |
| | (0.307) | (0.303) | (0.166) | (0.165) | (0.148) | (0.147) |
| Constant | -1.129 | -2.653*** | -0.059 | -0.809 | -1.069 | -1.844*** |
| | (0.604) | (0.510) | (0.160) | (0.556) | (0.626) | (0.502) |
| R2 | 0.37 | 0.38 | 0.34 | 0.35 | 0.21 | 0.22 |
| Observations | 236 | 236 | 236 | 236 | 236 | 236 |
| Num.Clusters | 8 | 8 | 8 | 8 | 8 | 8 |

Clustered standard errors in parentheses. Significance levels * p<0.10, ** p<0.05, *** p<0.01

Variable definitions: (1) Dummy that takes the value of 1 if responden reported their coca crops affected. (2) Takes value of 1 when person processes coca leaf into coca paste. State capaticty and perceived public service quality explained in data section.

This sample has very detailed information on coca cultivation and production on an individual basis so it makes more sense to use individual coca information than aggregate

data. I find that those who report having their coca fields affected by spraying in the past year increase the area planted with legal crops, which goes in line with the finding that proportionate spraying increases legal crops. I also find that people who not only grow but also process coca leaves, allocate less land to legal crops. This suggests that even though spraying might lead to more legal crops, this might not be because people are becoming more "legal" in their minds, but because they are just avoiding risk. Those who not only grow but also process coca may still have some opportunities despite the spraying, and are not yet opting for legality. I also control for key variables for explaining investments in legal crops such as land titles, quality of services and land size and find all of them to be positive and significant.

### 6.4.2 Forest Warden Families

The Forest Warden Families is the biggest alternative development program currently underway in Colombia. It targets coca growing areas and regions that are at high risk of growing coca (because of the balloon effect) and gives its beneficiaries money on the condition to keep their lands coca-free. Additionally, they attend workshops on the culture of legality and receive technical assistance in the hope that substituting legal products for coca will be sustainable. Even though the government targets municipalities, only some communities in each municipality receive the program, which means that there could still be coca-growing areas in the targeted municipalities, which, as a result, would continue being exposed to spraying. As mentioned, FWF communities may be exposed to spraying because they i) see the planes flying to neighboring regions, ii) hear stories from neighboring communities or iii) get sprayed themselves by mistake (pilot miscalculation, or strong winds that carry the glyphosate to their fields). In fact, even though FWF should not have received any spraying since joining the program, 10% say that spraying has been one of the main problems preventing their new productive activities from flourishing. A big difference between the UNODC and the FWF sample is that even though the latter are also exposed to low quality of public services and more than half of them are considered to be poor (53%), at least they have received support in finding an alternative livelihood and therefore have seen another face of the state. This could make a big difference when it comes to be willing to follow the law and live under legality, as suggested by Ibanez and Vasquez (2014c).

The effect of spraying disproportionality on legal crops is presented in Table 6. Column one presents the effects of the disproportionate spraying one year prior to the survey (2011) and column two presents the effect of the total amount of shocks on legal crops. I find that spraying disproportionality in 2011 and the cumulative amount of spraying shocks decreases legal crops in 2012. However, in this case spraying does not have a positive effect as was the case in the macro data and the UNODC sample.

Table 6: Effect of spraying disproportionality on legal crops in the Forest Warden Families Sample

| | (1) Spraying Disproportionality | (2) Spraying Shock |
|---|---|---|
| Total spraying shocks | | -0.1559*** |
| | | (0.0518) |
| ln Spraying 2011 | | -0.0883* |
| | | (0.0522) |
| Spraying Disprop 2011 | 0.1228 | |
| | (0.1439) | |
| Spraying Disprop 2 2011 | -0.0485** | |
| | (0.0222) | |
| ln Coca 2006 | 0.3287*** | 0.4929*** |
| | (0.0396) | (0.0744) |
| ln Monthly pc Expenditure | 0.2893*** | 0.2196*** |
| | (0.0680) | (0.0686) |
| Immorality (1) | -0.0794*** | -0.0541* |
| | (0.0298) | (0.0310) |
| Perceived Good Quality Land (2) | 0.2111** | 0.2563*** |
| | (0.0833) | (0.0858) |
| Perc. Land with Title | 0.0082*** | 0.0086*** |
| | (0.0010) | (0.0010) |
| Male HH Head | 0.1610* | 0.1628* |
| | (0.0825) | (0.0843) |
| Years at Home | 0.0016 | 0.0030 |
| | (0.0025) | (0.0025) |
| Age Head of HH | 0.0135*** | 0.0107*** |
| | (0.0032) | (0.0032) |
| Belongs to Productive Association | 0.1694* | 0.1779* |
| | (0.1013) | (0.1076) |
| No Coca for Moral Reasons (3) | 0.0975 | 0.1101 |
| | (0.0877) | (0.0897) |
| Constant | -5.7790*** | -5.2474*** |
| | (0.8371) | (0.8354) |
| R2 | 0.34 | 0.32 |
| Num.Observations | 678 | 678 |
| Expanded pop | 3946 | 3946 |
| Num.Strata | 15 | 15 |

Coefficients weighted by survey expansion factors. Standard errors stratified at municipality level in parentheses. Significance levels * p<0.10, ** p<0.05, *** p<0.01. Variable definitions: (1)Immorality measured as the total number of immoral behaviors tolerated. (2) Dummy that takes value of 1 if respondents perceive their land to be of good quality. (3) Dummy with value of one when the reason given by a person for not cultivating coca is related with morality.

A possible explanation for this is that FWF have a contractual agreement with the government by which they committed to keeping their land free of coca and voluntarily agreed to eradicate in return for support with legal crops. Aerial spraying could thus be seen as a violation of the state's commitment, as spraying not only destroys illegal crops but legal ones as well. Once in the field, stories of FWF crops being sprayed are not uncommon, giving rise to feelings of deceit among community members. I control for coca in 2006, the year before the seventh phase of the program started, in order to capture coca without

the effects of the program. It seems that higher levels of coca before the inception of the program led to higher legal crop growing levels in 2011, suggesting crop substitution.[22]

Since the government was interested in capturing the culture of legality aspect, the survey included a series of questions regarding the amount of unethical actions that people found morally wrong. It is interesting to note that in the case of FWF, the higher the number of unethical activities not judged as immoral, the lower the levels of legal crop cultivation. When the same regression is run for the neighboring controls (people in the same municipalities but in communities that did not receive the program) this variable is insignificant, suggesting that the program's efforts to promote a culture of legality are playing a role in people's productive decisions.

### 6.4.3 Coffee Growers in coca growing areas

The last sample deals with coffee growers, a group of special interest in Colombia as it is one of the country's most important export products. For various reasons, the majority of the coffee growing areas have had very low presence of coca crops. However, some of them have been affected and I focus my analysis only on these ones. Table 7 shows the effect of spraying disproportionality and spraying shocks on two coffee production-related variables, following the specification in equations 1 and 2. The first variable is the amount of 60kg bags of coffee produced by the farmer as a measure of production (controlling for plot size) and the second the amount of 60kg bags per hectare, a measure of productivity. These are much more accurate measures of agricultural output than area, but it can only be used with this sample because the product is comparable among all producers.[23]

Table 7 shows that the effect of spraying disproportionality, despite having the same signs as the other samples (positive in low disproportionality and negative in high) only generates a loss in production and productivity when it is captured via spraying shocks and not via the continuous disproportionality variable. It could be that overall proportionate spraying levels and low exposures to coca lead to only capturing negative effects when one identifies shocks. Spraying itself also does not seem to encourage legal coffee production, although a marginal positive effect is observed at the one year lag of spraying.

[22]The evaluation also collected data on distant controls and near controls. In the Appendix I show results for both the treatment group and the neighboring control group, which was exposed to exactly the same levels of spraying disproportionality in the municipality level. However, this comparison should be handled with care, as the impact evaluation showed spill over effects on this group, and thus the program might affect the outcome variable as well. The neighboring controls reduce legal crops in the face of a spraying shock, but not with the disproportionality variable. The distant control group exhibit very high levels of spraying disproportionality before the survey was undertaken and thus are not comparable in this sense. Program participation could only be related to legal crops through the relationship of legal crops and violence, since the avoided operations in red zones. Still, control municipalities were also chosen with this in mind. I also did an additional check and calculated the inverse mills ratio for participating in the program which I then add as an independent variable (see Appendix). The reducing effect of severe spraying remains. I do not use this specification as the main specification because the inverted mills ratio is highly correlated with the observable variables that determine participation and which I also control for in the main specification. Since these variables are important for determining participation given program rules, and I account for them in the main model (gender of household head, as female heads of household were targeted, age of household head, land with title), selection effects are already accounted for. See more on the comparability of the treatment and control groups in Ibanez and Vasquez (2014c).

[23]Even though coffee bags are a better way to capture overall coffee production than coffee area, I run the same regressions using coffee area as a dependent variable so as to obtain comparability with the other samples and find no effect of spraying intensity on the amount of areas cultivated with coffee.

Table 7: Effect of spraying intensity on coffee growers in coca affected coffee growing municipalities

| | 60kg Bag of Coffee | | Bags per Hectare | |
|---|---|---|---|---|
| | (1) Disprop | (2) Shock | (3) Disprop | (4) Shock |
| Spraying Shock | | -1.004** | | -0.880** |
| | | (0.457) | | (0.419) |
| Spraying Shock (t-1) | | -1.240** | | -0.920** |
| | | (0.535) | | (0.424) |
| ln Spraying | | 0.700 | | 0.719* |
| | | (0.437) | | (0.409) |
| ln Spraying (t-1) | | 0.610 | | 0.473 |
| | | (0.478) | | (0.394) |
| Spraying Disprop | -0.041 | | -0.089 | |
| | (0.412) | | (0.281) | |
| Spraying Disprop2 (t) | -0.010 | | -0.006 | |
| | (0.041) | | (0.028) | |
| Spraying Disprop (t-1) | 0.026 | | -0.002 | |
| | (0.137) | | (0.029) | |
| Spraying Disprop2 (t-1) | -0.001 | | 0.000 | |
| | (0.003) | | (0.000) | |
| Spraying Disprop (t-2) | 0.033 | | | |
| | (0.123) | | | |
| Spraying Disprop2 (t-2) | -0.001 | | | |
| | (0.002) | | | |
| ln Coca (t-1) | 0.364 | 1.051** | 0.071 | 0.657 |
| | (0.290) | (0.474) | (0.137) | (0.482) |
| Change in ln Coca | 0.473** | 0.820* | 0.179** | 0.755** |
| | (0.219) | (0.397) | (0.087) | (0.302) |
| ln Area with Coffee | 2.176** | 2.933*** | | |
| | (0.851) | (0.620) | | |
| Num. Farms (1) | 1.846*** | 1.533*** | -0.460** | -0.202 |
| | (0.362) | (0.182) | (0.187) | (0.342) |
| Num. Coffee Growers in Region | -0.001 | -0.004* | -0.000 | -0.004** |
| | (0.001) | (0.002) | (0.000) | (0.002) |
| Perc. Rural Population | 26.574 | 22.392 | -7.566 | 21.792 |
| | (58.279) | (59.966) | (36.008) | (57.057) |
| Plot Age (years) | 0.202*** | 0.049* | 0.121*** | 0.109*** |
| | (0.052) | (0.026) | (0.018) | (0.022) |
| Owns Land | -1.132*** | -0.622 | -0.127** | -0.402*** |
| | (0.395) | (0.444) | (0.052) | (0.069) |
| New Crop (2) | 3.078*** | 2.722*** | -0.155** | -0.451 |
| | (0.229) | (0.859) | (0.059) | (0.391) |
| Renewed Crop (3) | 3.644*** | -2.092*** | -0.714 | -2.863*** |
| | (1.317) | (0.576) | (0.446) | (0.257) |
| Perc. with Colombia-Type Coffee (4) | 0.365 | 2.290 | 0.377 | 3.581* |
| | (1.173) | (1.655) | (1.000) | (2.022) |
| Crop Density (5) | 0.001*** | 0.001*** | 0.001*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Constant | -22.036 | -8.711 | 9.459 | -3.528 |
| | (44.222) | (41.084) | (28.103) | (40.202) |
| Observations | 142332 | 34981 | 154200 | 34981 |
| Num.Clusters | 60981 | 20780 | 65619 | 20780 |
| R2 Overall | 0.26 | 0.04 | 0.02 | 0.02 |
| R2 Within | 0.14 | 0.17 | 0.07 | 0.18 |
| R2 Between | 0.23 | 0.03 | 0.02 | 0.03 |

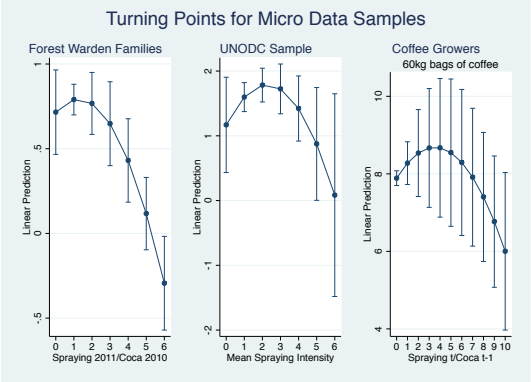
Clustered standard errors in parentheses. Significance levels * p<0.10, ** p<0.05, *** p<0.01
(1) Number of farms worked by the farmer. (2) Established new coffee crops in field.
(3) Renewed existing coffee plantation.
(4) Percentage of land that has Colombia-type coffee, a more resistant coffee variety.
(5) Area with coffee/Productive area.

One possible reason for the weaker effects for coffee growers is that they are exposed to the lowest levels of coca cultivation and also of spraying. Moreover, the production data starts

in 2009, precisely when it seemed that spraying disproportionality was following coca and spraying trends, and consequently its effects could be quite low, if any.

To wrap up the results from the micro data sets, Figure 7 shows the turning points for each of the samples. All turning points affect people in the sample and do not happen in an implausible value. It is also interesting to note that the turning points happen at different values of spaying disproportionality depending on the sample; FWF beneficiaries are the first to start decreasing their legal production, and they do so when spraying disproportionality is at around 1, which is expected as they feel their voluntary decision to achieve a coca-free territory is not being corresponded by the state. The UNODC sample decreases production when spraying is about twice the amount of coca found and coffee growers decrease coffee production when spraying is 4 times as much coca. This means that even though the turning point with macro data shows a much higher turning point (spraying 7 times as much coca), this could obscure regional variation, where sensitivity to the policy might be much higher. The spraying strategy itself assumes a necessary 4 over passes to achieve efficient coca reduction, a number that will already backfire in some regions with legal crop reduction.

Figure 7: Turning Points for Micro Samples




## 6.5 Possible Channels

Which are the channels that may be causing this reduction in legal crops once high intensity levels of spraying are reached? Although I lack all the necessary information to pin down the channels with full certainty, I can grasp the surface of possible mechanisms at hand, even if no strong conclusions or causality claims can be drawn. I focus on three possible channels: displacement, environmental damage (and crop damage) and loss of legitimacy.

*Displacement*

One possibility is that such intense spraying events might have led people to move out of their territory; in fact, there is some evidence that some among the displaced mention spraying as the reason for moving. Dion and Russler (2008) find that during the implementation of Plan Colombia aerial spraying reduced coca crops mainly through generating displacement. Palacios (2012) also provides evidence in this direction and mentions a report from an NGO for IDPs (CODHES) that denounces the displacement of 13.000 people due to aerial fumigation. I used the official data collected by the government of Colombia on

forced internal displacement in order to test its relationship with disproportional spraying. The variable used is the rate of expulsion from one municipality per 100.000 inhabitants. I cannot disaggregate this variable by the cause of displacement (sometimes captured in official documents) and use the variable that includes all people that were displaced by violence (and not for economic reasons). However, the aggregated variable is also useful since according to informal conversations with government officials, many displaced do not report spraying as the reason for displacement, as they fear being treated as coca-growers and criminals and therefore potentially losing State support.

Table 8 presents the effect of spraying disproportionality on forced displacement using the aggregated panel dataset. Disproportionate spraying seems to have a short term effect on displacement, that is reversed after two years, which suggests that part of the loss in legal crops could be due to a loss in rural workforce.[24]

Table 8: Effect of spraying disproportionality and Displacement

| | (1)<br>ln Displacement |
|---|---|
| Spraying Disp | 0.082*** |
| | (0.025) |
| L.Spraying Disp | -0.003 |
| | (0.031) |
| L2.Spraying Disp | -0.039** |
| | (0.017) |
| ln Coca (t-1) | 0.298*** |
| | (0.110) |
| Change in Coca | 0.436*** |
| | (0.109) |
| Num. FARC | -0.001 |
| | (0.001) |
| Num. ELN | 0.006 |
| | (0.004) |
| Num. BACRIM | 0.003* |
| | (0.002) |
| Num. Combats | 0.008** |
| | (0.003) |
| L.ln Rural Land Price | -0.164 |
| | (0.104) |
| Constant | 6.432*** |
| | (0.823) |
| Observations | 174 |
| Num.Clusters | 79 |
| R2 Overall | 0.10 |
| R2 Within | 0.46 |
| R2 Between | 0.02 |

Clustered standard errors in parentheses. Significance levels * p<0.10, ** p<0.05, *** p<0.01

Table 4 shows that the negative effect of disproportionality actually lasts at least two years, suggesting that there may be something else at play. Still, this effect of contemporaneous displacement could be the reason why the linear component of spraying at time t is not

[24]There is no evidence of a quadratic relationship between spraying intensity and displacement. The linear term has a negative sign and the squared term a positive one, but none of the terms are significant in none of the lags. However, there is no theoretical reason to defend a quadratic relationship.

positively significant in the macro data but becomes significant after the first lag, since it is after one year of the intense spraying that displacement starts to reverse.

When I include displacement in the original specification (see Table A.6 in the Appendix), I find that it reduces legal crops only when they are transitory, a result that has already been found in the literature (Ibanez et al., 2013), but it does not take away the significance of spraying disproportionality, suggesting that there is more to the story than only displacement of the labor force.

*Environmental damage*

A second possibility is that since glyphosate falls indiscriminately on the land and is non-selective, it affects both illegal and legal plants. High levels of spraying may have damaged the soil and prevented both legal and illegal productive crops from developing. Studies on the effect of glyphosate on the environment are not conclusive. Relyea (2005) finds negative effects on amphibious populations, Navarrete-Frías et al. (2005) show effects on deforestation. Farmers complain about animals dying and crops' yields declining in the subsequent season. An ICRC report[25] mentions that spraying passes over the fields are not accurately targeted, leading to the destruction of legal crops, including those that are part of alternative development projects. Still, other studies indicate that the effect is not long lasting (Busse et al., 2001) or that crops recover quickly after spraying (Franz et al., 1997). The inconsistency may be due to differences in the amount of glyphosate used. Monsanto, the company that produces the product Round Up® used in the aerial spraying, issued a response to Relyea's study indicating that the product was not to be used over water and that the study had been done with very high Round Up® concentrations. Since in this context the product is not being used for gardening or agricultural purposes, Monsanto's own concerns regarding the use of Round Up® may underlie the potential environmental damage caused by spraying.

My focus is on spraying disproportionality, not measured as high levels of spraying, but as the proportion of spraying to coca. In this sense, high disproportionality does not necessarily mean highest levels of spraying but rather a very high disproportion between spraying and coca. If the negative effects I find are due to environmental damage, a reduction of legal crops should arise when using spraying, rather than spraying disproportionality. When I test the relationship between spraying levels and legal crops using the Equation1 specification in Table 4 (but changing disproportional spraying by spraying levels), I find that there are no significant effects of spraying and spraying squared on the same year nor on the first lag, precisely where environmental damage was most likely to happen (see Table 9.[26] In fact, two years after high levels of spraying there is an *increase* in legal crops, as the government expects. This results stresses the finding that disproportionality matters. This also rules out the possibility that people are not planting because they are afraid to get sprayed again, since large amounts of spraying would give people the same signal and, if it is not disproportional, it even seems to increase legal crops in the medium term.[27]

[25] ICRC. Colombia: cultivos lícitos de campesinos afectados por aspersiones aéreas contra la coca. http://www.icrc.org/spa/resources/documents/feature/2012/colombia-report-2011-displacement-feature-3.htm

[26] The same comments for past panel data specifications apply to this model. In particular, I do not include variables that are time invariable such as municipal size, since they drop out with the fixed effects, and reduce collinearity between spraying and coca by keeping coca in changes instead as in absolute terms.

[27] I cannot rule out that subsistence crops are destroyed, given their small scale and the possibility of not

Table 9: Effect of spraying on Legal Crops

| | (1) All | (2) Transitory | (3) Permanent |
|---|---|---|---|
| ln Spraying | 0.088 | 0.254 | -0.003 |
| | (0.094) | (0.157) | (0.100) |
| ln Spraying × ln Spraying | -0.006 | -0.024 | 0.001 |
| | (0.009) | (0.015) | (0.010) |
| L.ln Spraying | 0.001 | 0.241 | -0.071 |
| | (0.082) | (0.243) | (0.096) |
| L.ln Spraying × L.ln Spraying | -0.002 | -0.022 | 0.007 |
| | (0.009) | (0.020) | (0.009) |
| L2.ln Spraying | -0.214* | -0.080 | -0.057 |
| | (0.111) | (0.174) | (0.121) |
| L2.ln Spraying × L2.ln Spraying | 0.021** | 0.011 | 0.006 |
| | (0.010) | (0.016) | (0.011) |
| D.ln Coca | 0.010 | 0.027 | -0.008 |
| | (0.044) | (0.053) | (0.045) |
| LD.ln Coca | -0.012 | -0.022 | 0.001 |
| | (0.050) | (0.070) | (0.042) |
| Constant | -11.913 | -69.345*** | 2.592 |
| | (21.172) | (22.666) | (19.194) |
| Observations | 273 | 270 | 273 |
| Num.Clusters | 82 | 80 | 82 |
| R2 Overall | 0.30 | 0.08 | 0.15 |
| R2 Within | 0.22 | 0.19 | 0.23 |
| R2 Between | 0.26 | 0.10 | 0.05 |

Clustered standard errors in parentheses. Control variables included.
Significance levels * p<0.10, ** p<0.05, *** p<0.01

*Legitimacy Loss*

The third channel, loss of legitimacy, is highly likely in coca growing areas where, according to Garcia (2014), people are mainly exposed to the coercive face of the state and would tend to develop a contentious relationship with the authorities, as they see their basic livelihood (illegal crops) being destroyed by the state. The loss of legal crops due to spraying, especially in subsistence farming, increases discontent, as food security is also under attack by a state policy. I explore this channel with the UNODC sample, where legitimacy questions where asked. Even though the sample is not representative of all coca growing areas in Colombia, results are nonetheless suggestive of what happens when spraying is used intensively in areas that have commonly been marginalized by the state and where coca has been the norm for a large part of their history.

It is interesting to note the type of relationship that people in the surveyed area have with the state (Table 10). In terms of public utilities, most people recognize the existence of transportation and education services, and to a lesser degree, of drinking water and electricity, and the very low access to both. However, once they are asked to rank the

appearing in aggregate data sets or not even being mentioned by farmers when asked about their agricultural activities. In fact, in the UNODC sample while 58% of the legal production goes to self-consumption for the farmers that have experienced a spraying shock, farmers who have not experienced a shock only consume 33% of their legal crop production. Moreover, farmers could get involved with legal crops through working for others during harvest season in non-coca areas, but capturing this effect would need a more general framework that is beyond the scope of this study.

quality of these services, where 1 is very bad and 5 is very good, not one single service was ranked as high as having a medium quality of 3, and all except for education are rated below 2. This indicates that, to begin with, people's perception of what the state provides to them is not particularly good. The survey also asks about the capacity of the state to solve problems related to public services (water, electricity, education, health, productive alternatives and unemployment, nutrition and security). In all cases except for education, half or less than half of the surveyed perceive the state as capable of solving the problem. In fact, out of the 6 possible problems, on average people think that the state can solve 2.87.

Table 10: Relationship to state in UNODC Sample

| Public goods, State Capacity and Alternatives to Coca | |
|---|---|
| Existence of public services | |
| Drinking water | 2.9% |
| Health | 84.0% |
| Electricity | 13.4% |
| Education | 92.9% |
| Transportation | 95.8% |
| Quality of Public Services (1 very bad, 5 very good) | |
| Drinking water | 0.07 |
| Health | 1.87 |
| Electricity | 0.45 |
| Education | 2.84 |
| Transportation | 1.90 |
| Perceived capacity of the state to solve problems related to: | |
| Quality of Public Services | 50.8% |
| Access and quality of education | 61.3% |
| Health | 50.0% |
| Productive alternatives/Unemployment | 39.2% |
| Nutrition problems | 45.4% |
| Security Problems | 43.9% |
| Total Problems it can solve (max.6) | 2.87 |
| Alternatives to Coca given by the state | |
| Has received support to substitute coca | 0.4% |
| Voluntary eradication program exists | 4.2% |
| Productive project exists | 8.8% |
| Someone in HH in PP | 6.3% |
| Wants to stop growing coca | 78.7% |

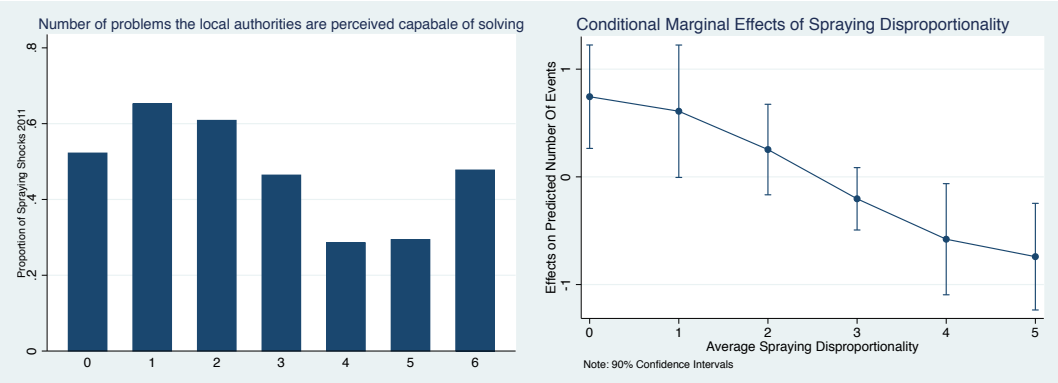
Source: UNODC, SIMCI

The problems where state capacity is perceived as the lowest relate to productive alternatives, which is highly related to legal options outside coca. When asked directly about the alternatives offered to them by the state in order to stop coca cultivation, even though 78.7% claim wanting to stop growing coca only 0.4% have received support, and 4.2% point out that a voluntary eradication program exists in their region. This is worrisome because people in these regions perceive only the coercive side of the state, which may lead them to have a wrong view of the state's motivations, a key element for wanting to follow the law.

A coca farmer once said that he understood that what he was doing was wrong, and knew that he could be punished for it, but that he only saw the state when he saw the planes. Then he added, "why don't they send a plane full of seeds and fertilizers after the spraying plane? Then we could at least get some support from the government."

Results suggest that disproportionate spraying further alienates people from the state. Figure 8 Panel A shows how many problems people think the state can solve (out of a given list). It turns out that if one focuses on the inner values, higher exposure to spraying shocks in the year prior to the survey reduces the people's belief that the state can deliver.[28] Additionally, a negative binomial regression of spraying intensity (and other controls) on how many problems the state can solve give rise to Panel B of Figure 8, which clearly shows a negative relationship between spraying intensity and trust in the state's capacity. The descriptive statistics presented above depict an already troubled relationship between the state and the people in this area because of the former's lack of presence and efficacy. Those results together with this Figure point to a possible story of resentment, or, as Veldab-Brown (2006) noted, a loss of "hearts and minds" from farmers that see their livelihoods threatened but find no support for alternative options ahead. If this is the case, if this is in fact the channel that is driving legality out of the fields, the state needs to carefully balance coca-reducing efforts with legitimacy-enhancing actions.

Figure 8: Spraying Disproportionality and State Legitimacy




*Coca crops*

One last question is what is happening with coca and whether the only thing that is going on is a substitution between legal crops and coca. Although this is not the focus of my study, as this question has already been answered with very rigorous instruments and identification strategies, as mentioned in Section 3, it is still interesting to look at the relationships that appear once using spraying disproportionality rather than spraying levels.[29] Using the macro data, the relationship between spraying disproportionality and coca crops is U shaped but neither the linear nor the squared term are significant in any of the lags. This relationship can only be tested with the UNODC sample, where individual involvement with

[28] The extreme values are hard to interpret, as there are people who may have very absolute positions vis-à-vis the state or that do not want to support/oppose the government and therefore express a complete/null state capacity.

[29] Ibanez (2010) and Ibanez (2013) use the ratio between coca hectares and coca sprayed as their variable of interest to capture its effect on coca crops. The difference with this study is that it does not include the squared term, and used both spraying and coca hectares contemporaneously in the ratio.

coca is asked and is reliable. I find that spraying disproportionality reduces the proportion of people cultivating coca by 18%, and there is no evidence of a non-linear effect. This indicates that it is possible that legal crops are substituting coca crops when spraying is proportionate, but when spraying turns disproportionate, investments in any agricultural product, either legal or illegal go down.

# 7 Conclusion

This paper analyzes the effect of severe punishment on legal behavior using the case of drug policy in Colombia, namely aerial spraying of coca crops. Until now it was thought for the most part that if risks, costs and other moral factors were high enough, people would opt out of illegality in favor of legality; in this case, that if the costs and risks of cultivating coca are too high, farmers would go back to a legal crop. This study endogenizes the legal outside option and makes it dependent on the disproportionality of punishment. Severe punishment that is disproportionate to the crime committed violates the proportionality principle, necessary for the law and the state to be perceived as fair and legitimate. Legitimacy is in turn a main determinant in people's willingness to obey the law and live according to a culture of legality and the rule of law. Thus, once people are exposed to extreme punishment, even though illegality might decrease, legality could also be crowded out. This study tests this balance and finds exactly what legal scholars would predict: extremely severe punishment crowds out legality, while mild punishment crowds it in.

I test this relationship using aggregate data on all agricultural crops in Colombia, and three micro data sets with very different types of farmers: coca growers, beneficiaries of an alternative development program to substitute legal crops for coca and coffee growers. The findings are the same across all groups. I also test some channels that drive this relationship and find that disproportionate spraying displaces farmers but only for a short period of time, generating a loss in legal crops as a result of a loss of rural labor force. I do not find evidence that the reduction of legal crops after severe punishment may be due to environmental damage, although more research should be done in this direction for more precise estimations. Finally, results support the loss of legitimacy channel, whereby disproportionate spraying undermines trust in the state.

These results have direct policy implications. It has long been said that achieving order and compliance with the law relying only on force and without state legitimacy is extremely costly and inefficient. Such levels of punishment are unsustainable, undemocratic and unfair, and could therefore trigger negative spill over effects that reduce overall legality. I find that disproportionate spraying and spraying shocks, instead of inducing farmers to opt in for legal crops, actually make them opt out. In fact, an aspersion shock reduces legal crop harvests 16%, a large effect especially when one considers that Colombia's agricultural sector rarely grows above 4% in one year. If spraying is kept within "fairness" limits, it has the opposite effect and crowds in legality. Drug policy should be shaped accordingly and extreme spraying shocks should be avoided at all cost if a sustainable reduction in coca and in other types of illegality is to be achieved.

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# Appendix

Table A.1: Marginal Effects of Interaction terms in spraying and spraying shock models

| | (1) Spraying | (2) Spraying Disproportionality | (3) Spraying Shock |
|---|---|---|---|
| Yellow | 0.759*** | 0.311 | -0.019 |
| | (0.075) | (0.365) | (0.020) |
| Red | 0.847*** | 1.176 | -0.090 |
| | (0.242) | (2.758) | (0.101) |
| Distance to urban (ln) | -0.757 | 1.713 | 1.016*** |
| | (0.555) | (1.477) | (0.128) |
| L.ln Coca | 0.397** | -2.283* | -0.181*** |
| | (0.172) | (1.284) | (0.060) |
| Rural density | -0.076 | 0.091 | -0.000 |
| | (0.197) | (0.436) | (0.057) |
| Num. armed actions | -0.007 | -0.123** | -0.021** |
| | (0.042) | (0.063) | (0.008) |
| Num. FARC | 0.003 | 0.005 | 0.001 |
| | (0.003) | (0.007) | (0.001) |
| Num. ELN | -0.035* | -0.047 | 0.001 |
| | (0.019) | (0.047) | (0.004) |
| Num. BACRIM | 0.033*** | 0.019 | 0.005 |
| | (0.013) | (0.027) | (0.004) |
| Num. Combats | 0.033 | 0.086 | 0.002 |
| | (0.025) | (0.062) | (0.009) |
| Num. Mines | 0.051* | 0.035 | 0.017* |
| | (0.027) | (0.065) | (0.010) |
| Observations | 246 | 258 | 258 |

Clustered standard errors in parentheses. Significance levels * p<0.10, ** p<0.05, *** p<0.01

Table A.2: Effect of spraying disproportionality on legal crops controlling for selection into coca cultivation

| | (1) All | (2) Transitory | (3) Permanent | (4) All (shock) |
|---|---|---|---|---|
| Spraying Disp | 0.051* | 0.034 | 0.030 | |
| | (0.029) | (0.062) | (0.033) | |
| Spraying Disp 2 | -0.003* | -0.002 | -0.002 | |
| | (0.002) | (0.003) | (0.002) | |
| Spraying Disp (t-1) | 0.052 | 0.090* | 0.040 | |
| | (0.038) | (0.046) | (0.033) | |
| Spraying Disp 2 (t-1) | -0.004 | -0.007** | -0.003 | |
| | (0.002) | (0.003) | (0.002) | |
| Spraying Disp (t-2) | 0.080*** | 0.105** | 0.047* | |
| | (0.026) | (0.042) | (0.024) | |
| Spraying Disp 2 (t-2) | -0.003*** | -0.006*** | -0.002* | |
| | (0.001) | (0.002) | (0.001) | |
| Spraying Shock | | | | -0.160 |
| | | | | (0.100) |
| Spraying Shock (t-1) | | | | -0.126 |
| | | | | (0.130) |
| Spraying Shock (t-2) | | | | 0.134 |
| | | | | (0.118) |
| ln Spraying | | | | 0.102*** |
| | | | | (0.033) |
| ln Spraying (t-1) | | | | 0.034 |
| | | | | (0.030) |
| ln Spraying (t-2) | | | | 0.039 |
| | | | | (0.035) |
| imills | 0.199 | 0.258 | 0.191 | 0.160 |
| | (0.275) | (0.482) | (0.265) | (0.254) |
| Change in ln Coca | -0.067 | -0.044 | -0.062 | -0.075 |
| | (0.067) | (0.114) | (0.061) | (0.054) |
| ln Coca (t-1) | -0.157** | -0.171 | -0.071 | -0.271*** |
| | (0.060) | (0.107) | (0.057) | (0.070) |
| Constant | -8.453 | -90.297*** | -1.490 | -8.272 |
| | (18.776) | (26.427) | (19.777) | (21.871) |
| Observations | 266 | 262 | 266 | 254 |
| Num.Clusters | 79 | 78 | 79 | 76 |
| R2 Overall | 0.24 | 0.09 | 0.04 | 0.25 |
| R2 Within | 0.24 | 0.23 | 0.17 | 0.25 |
| R2 Between | 0.17 | 0.11 | 0.04 | 0.22 |

Clustered standard errors in parentheses. Significance levels * p<0.10, ** p<0.05, *** p<0.01
Includes same controls as in the specification in main text.

Table A.3: Effect of spraying disproportionality on legal crops controlling for conflict variables

| | (1)<br>All | (2)<br>Transitory |
|---|---|---|
| Spraying Disp | -0.014 | |
| | (0.070) | |
| Spraying Disp 2 | -0.001 | |
| | (0.007) | |
| Spraying Disp (t-1) | 0.082* | |
| | (0.049) | |
| Spraying Disp 2 (t-1) | -0.005* | |
| | (0.003) | |
| Spraying Disp (t-2) | 0.085** | |
| | (0.041) | |
| Spraying Disp 2 (t-2) | -0.004** | |
| | (0.002) | |
| Spraying Shock | | -0.315** |
| | | (0.145) |
| Spraying Shock (t-1) | | -0.032 |
| | | (0.220) |
| Spraying Shock (t-2) | | 0.159 |
| | | (0.176) |
| ln Spraying | | 0.068 |
| | | (0.049) |
| ln Spraying (t-1) | | 0.074* |
| | | (0.041) |
| ln Spraying (t-2) | | -0.006 |
| | | (0.044) |
| Change in ln Coca | -0.173 | -0.086 |
| | (0.107) | (0.101) |
| ln Coca (t-1) | -0.177* | -0.294*** |
| | (0.096) | (0.105) |
| Threat Yellow Zone | -0.333 | 0.046 |
| | (0.364) | (0.144) |
| Threat Red Zone | -0.431 | 0.000 |
| | (0.409) | (.) |
| Num. armed actions | 0.000 | -0.008 |
| | (0.009) | (0.009) |
| Num. FARC | -0.000 | 0.000 |
| | (0.001) | (0.001) |
| Num. ELN | -0.009 | -0.006 |
| | (0.008) | (0.010) |
| Num. BACRIM | 0.000 | -0.001 |
| | (0.002) | (0.002) |
| Num. Landmines | -0.003 | -0.002 |
| | (0.009) | (0.008) |
| Constant | -21.594 | -40.904 |
| | (32.777) | (32.441) |
| Observations | 172 | 164 |
| Num.Clusters | 79 | 75 |
| R2 Overall | 0.32 | 0.29 |
| R2 Within | 0.37 | 0.35 |
| R2 Between | 0.26 | 0.24 |

Clustered standard errors in parentheses. Significance levels * p<0.10, ** p<0.05, *** p<0.01
Includes same controls as in the main text specification.

Table A.4: Effect of spraying disproportionality on planted and cultivated legal crops

| | (1) Cultivated | (2) Planted | (3) Cultivated | (4) Planted |
|---|---|---|---|---|
| Spraying Disp | 0.035 | 0.027 | | |
| | (0.025) | (0.021) | | |
| Spraying Disp × Spraying Disp | -0.002 | -0.002 | | |
| | (0.002) | (0.002) | | |
| L.Spraying Disp | 0.039 | 0.032 | | |
| | (0.036) | (0.031) | | |
| L.Spraying Disp × L.Spraying Disp | -0.003 | -0.003 | | |
| | (0.002) | (0.002) | | |
| L2.Spraying Disp | 0.073*** | 0.065*** | | |
| | (0.025) | (0.021) | | |
| L2.Spraying Disp × L2.Spraying Disp | -0.003*** | -0.003*** | | |
| | (0.001) | (0.001) | | |
| Spraying Shock | | | -0.195** | -0.131 |
| | | | (0.092) | (0.083) |
| L.Spraying Shock | | | -0.139 | -0.095 |
| | | | (0.124) | (0.102) |
| L2.Spraying Shock | | | 0.066 | 0.068 |
| | | | (0.107) | (0.082) |
| ln Spraying | | | 0.091*** | 0.061** |
| | | | (0.031) | (0.027) |
| L.ln Spraying | | | 0.025 | 0.025 |
| | | | (0.030) | (0.026) |
| L2.ln Spraying | | | 0.044 | 0.039 |
| | | | (0.034) | (0.033) |
| D.ln Coca | -0.069 | -0.114** | -0.059 | -0.117*** |
| | (0.064) | (0.053) | (0.053) | (0.044) |
| L.ln Coca | -0.135** | -0.172*** | -0.230*** | -0.248*** |
| | (0.064) | (0.062) | (0.074) | (0.068) |
| Constant | -15.316 | -26.204 | -15.792 | -25.824 |
| | (19.107) | (20.274) | (22.157) | (23.164) |
| Observations | 283 | 283 | 272 | 272 |
| Num.Clusters | 83 | 83 | 80 | 80 |
| R2 Overall | 0.33 | 0.39 | 0.34 | 0.39 |
| R2 Within | 0.24 | 0.36 | 0.25 | 0.34 |
| R2 Between | 0.27 | 0.35 | 0.30 | 0.37 |

Clustered standard errors in parentheses. Significance levels * p<0.10, ** p<0.05, *** p<0.01

Same controls as in main specification using macro dataset included.

Table A.5: FWF, Near Controls and FWF controlling for the inverse mills ratio

| | Disproportion | | | | Shock | | |
|---|---|---|---|---|---|---|---|
| | (1) FGB | (2) FGB | (3) N.Control | (4) N.Control | (5) FGB | (6) FGB | (7) N.Control |
| Total spray shocks | | | | | -0.156*** | -0.088 | -0.203*** |
| | | | | | (0.052) | (0.056) | (0.078) |
| lnSpray 2011 | | | | | -0.088* | -0.246*** | 0.101 |
| | | | | | (0.052) | (0.056) | (0.081) |
| SprayInt 2011 | 0.123 | 0.138 | -0.242 | -0.034 | | | |
| | (0.144) | (0.156) | (0.247) | (0.046) | | | |
| SprayInt2 2011 | -0.049** | -0.051** | 0.034 | | | | |
| | (0.022) | (0.024) | (0.037) | | | | |
| lnCoca 2006 | 0.329*** | 0.334*** | 0.228*** | 0.250*** | 0.493*** | 0.649*** | 0.160 |
| | (0.040) | (0.043) | (0.059) | (0.057) | (0.074) | (0.075) | (0.098) |
| lnExpenditure pc | 0.289*** | 0.304*** | 0.444*** | 0.449*** | 0.220*** | 0.248*** | 0.433*** |
| | (0.068) | (0.073) | (0.086) | (0.086) | (0.069) | (0.072) | (0.085) |
| Immorality | -0.079*** | -0.065* | 0.027 | 0.027 | -0.054* | -0.051 | 0.031 |
| | (0.030) | (0.035) | (0.059) | (0.059) | (0.031) | (0.034) | (0.060) |
| Good land | 0.211** | 0.311*** | 0.194 | 0.193 | 0.256*** | 0.374*** | 0.187 |
| | (0.083) | (0.091) | (0.150) | (0.150) | (0.086) | (0.091) | (0.147) |
| Perc.land with title | 0.008*** | | 0.006*** | 0.006*** | 0.009*** | | 0.006*** |
| | (0.001) | | (0.002) | (0.002) | (0.001) | | (0.002) |
| Male | 0.161* | | 0.193 | 0.167 | 0.163* | | 0.158 |
| | (0.083) | | (0.249) | (0.251) | (0.084) | | (0.248) |
| Years home | 0.002 | 0.005** | -0.009** | -0.009** | 0.003 | 0.005** | -0.009** |
| | (0.002) | (0.002) | (0.004) | (0.004) | (0.002) | (0.002) | (0.004) |
| Age | 0.013*** | | 0.009* | 0.009* | 0.011*** | | 0.010* |
| | (0.003) | | (0.005) | (0.005) | (0.003) | | (0.005) |
| Productive association | 0.169* | 0.055 | -0.040 | -0.029 | 0.178* | 0.106 | -0.022 |
| | (0.101) | (0.101) | (0.365) | (0.347) | (0.108) | (0.106) | (0.381) |
| Coca immoral | 0.098 | 0.064 | -0.174 | -0.160 | 0.110 | 0.108 | -0.146 |
| | (0.088) | (0.094) | (0.165) | (0.159) | (0.090) | (0.095) | (0.158) |
| Inverted mills ratio | | 0.875*** | | | | 0.980*** | |
| | | (0.181) | | | | (0.184) | |
| Constant | -5.779*** | -6.138*** | -5.717*** | -6.049*** | -5.247*** | -6.029*** | -5.742*** |
| | (0.837) | (0.911) | (1.135) | (1.087) | (0.835) | (0.897) | (1.079) |
| R2 | 0.34 | 0.27 | 0.24 | 0.23 | 0.32 | 0.26 | 0.25 |
| Num.Observations | 678 | 677 | 647 | 647 | 678 | 677 | 647 |
| Expanded pop | 3946 | 3941 | 2433 | 2433 | 3946 | 3941 | 2433 |
| Num.Strata | 15 | 15 | 15 | 15 | 15 | 15 | 15 |

Standard errors in parentheses. Significance levels * p<0.10, ** p<0.05, *** p<0.01
Immorality is the sum of all the immoral behaviors justified; Good land is a perceived land quality;
Coca immoral: person will not grow coca for moral reasons

Table A.6: Effect of Spraying on Legal Crops controlling for Displacement

| | (1) All | (2) Transitory | (3) Permanent |
|---|---|---|---|
| Displacement Intensity Rate | -0.00000 | -0.00002*** | -0.00000 |
| | (0.00001) | (0.00001) | (0.00001) |
| Spraying Intensity | 0.02328 | -0.01925 | 0.00773 |
| | (0.02418) | (0.05612) | (0.02540) |
| Spraying Intensity × Spraying Intensity | -0.00157 | 0.00109 | -0.00125 |
| | (0.00158) | (0.00303) | (0.00176) |
| L.Spraying Intensity | 0.03834 | 0.06402 | 0.03458 |
| | (0.03710) | (0.03997) | (0.03273) |
| L.Spraying Intensity × L.Spraying Intensity | -0.00322 | -0.00482* | -0.00242 |
| | (0.00236) | (0.00262) | (0.00206) |
| L2.Spraying Intensity | 0.06895*** | 0.08739** | 0.04107 |
| | (0.02506) | (0.03963) | (0.02567) |
| L2.Spraying Intensity × L2.Spraying Intensity | -0.00304*** | -0.00505** | -0.00187* |
| | (0.00095) | (0.00197) | (0.00110) |
| D.ln Coca | -0.08599 | -0.05428 | -0.08024 |
| | (0.06030) | (0.10491) | (0.05416) |
| L.ln Coca | -0.14270** | -0.12014 | -0.07067 |
| | (0.05867) | (0.10747) | (0.05408) |
| Product cluster (HHI) | 1.82436*** | -2.42036** | 1.83724* |
| | (0.60759) | (0.97263) | (1.02575) |
| ln rural land price | -0.07206 | -0.04756 | -0.06467 |
| | (0.06613) | (0.06805) | (0.05605) |
| L.ln rural land price | -0.01419 | -0.01605 | -0.01301 |
| | (0.04689) | (0.06867) | (0.05382) |
| D.Fiscal Performance | -0.00307* | -0.00563* | -0.00027 |
| | (0.00185) | (0.00300) | (0.00255) |
| D.ln Rural population | 2.39481 | 8.84990*** | 1.30272 |
| | (2.17976) | (2.08456) | (2.33124) |
| L.ln Rural population | 2.92075 | 8.20095*** | 1.05549 |
| | (2.31070) | (2.23784) | (2.31605) |
| Rural density | -0.04909 | -0.46552*** | 0.11731 |
| | (0.15208) | (0.15551) | (0.17700) |
| D.ln Urban population | -30.31876 | -4.46447 | -11.19529 |
| | (34.29803) | (58.47595) | (23.18362) |
| LD.ln Urban population | 46.49870 | 35.57698 | 26.85826 |
| | (28.16442) | (49.81691) | (17.14282) |
| Proportion rural | -14.27488** | -9.53724 | -14.75272** |
| | (5.49498) | (6.06290) | (6.37611) |
| | (0.00216) | (0.00303) | (0.00257) |
| Constant | -8.38622 | -60.35034*** | 5.18263 |
| | (19.15551) | (18.57112) | (19.07358) |
| Observations | 283 | 279 | 283 |
| Num.Clusters | 83 | 82 | 83 |
| R2 Overall | 0.31 | 0.09 | 0.05 |
| R2 Within | 0.26 | 0.21 | 0.17 |
| R2 Between | 0.25 | 0.11 | 0.05 |

Clustered standard errors in parentheses. Significance levels * p<0.10, ** p<0.05, *** p<0.01