The Health Consequences of Aerial Spraying of Illicit Crops: The Case of Colombia

Adriana Camacho and Daniel Mejia

Abstract

This paper exploits the variation in aerial spraying across time and space in Colombia and employs a panel of individual health records in order to study the causal effects of aerial spraying of herbicides (Glyphosate) on short-term health-related outcomes. Our results show that exposure to the herbicide used in aerial spraying campaigns increases the number of medical consultations related to dermatological and respiratory-related illnesses and the number of miscarriages. This finding is robust to the inclusion of individual fixed effects, which compares the prevalence of these medical conditions for the same person under different levels of exposure to the herbicide used in the aerial spraying program over a period of 5 years. Also, our results are robust to controlling for the extent of coca cultivation of illicit crops in the municipality of residence.

JEL Codes: I15, H75

Keywords: Aerial spraying, Eradication policies, health, Plan Colombia, Glyphosate.

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Foreword by Michael Clemens

A cornerstone of joint US-Colombia antinarcotics efforts has been the aerial spraying of illicit crops with the pesticide glyphosate. Hundreds of thousands of acres of the Colombian countryside have been sprayed since the two governments created Plan Colombia in 1999. In March of 2015, the International Agency for Research on Cancer determined that glyphosate is "probably carcinogenic to humans", raising questions about the health effects of the US-Colombia spraying campaign. Colombia thereafter suspended aerial spraying of this kind. But the effects of many years of spraying remain uncertain.

In this working paper, commissioned by CGD's Beyond the Fence study group, the authors study the health effects of glyphosate spraying in Colombia. They combine data on aerial spraying patterns with individual-level on all medical consultations, emergency room visits, hospitalizations and procedures that took place in any health service institution between 2003 and 2007. They find that glyphosate spraying is associated with significant increases in dermatological problems, respiratory problems, and miscarriages. They control for all time-invariant characteristics of the individuals in question, such as place of residence or pre-existing health status, which strengthens the interpretation of the results as reflecting a causal relationship between glyphosate exposure and health problems. The research was carried out while both of the authors were associate professors of economics at the Universidad de los Andes, in Bogotá, Colombia.

CGD created Beyond the Fence in 2013 to generate rigorous new research on how policy decisions on the regulation of illicit markets ripple back and forth between the US and Latin America, to inform a policy debate on more bilateral approaches to innovative regulation. The group brings together some of the world's leading social scientists and policy innovators. The dual meaning of the name represents a desire for researchers to investigate the effects of policy that cross the fence, and for policymakers to reach beyond unilateral enforcement approaches.

1. Introduction

One of the main strategies that have been used in Colombia to fight illegal drug production and reduce the supply of cocaine is the aerial spraying of herbicides on coca crops, the raw material for producing cocaine.[1] Under the so-called Plan Colombia,[2] the average annual number of hectares sprayed with herbicides during the last decade has been 128,000. At its peak, in 2006, 172,000 hectares were aerially sprayed with Glyphosate, the herbicide used in the aerial spraying program in Colombia (see Figure 1). The effectiveness of this approach has been thoroughly defended by the U.S. and heatedly attacked and questioned by NGOs and opponents of the so-called "war on drugs". Nevertheless, the debate about the effectiveness of aerial spraying campaigns and its collateral effects has often been based on ideological grounds, and has very rarely taken the available and emerging scientific evidence seriously. However, both structural evaluations (Mejia and Restrepo, 2011) and reduced-form estimation techniques that exploit exogenous sources of variation to assess the impacts of this strategy in reducing coca cultivation in Colombia indicate that aerial spraying campaigns have very small effects on coca cultivation(Reyes, 2011, Rozo, 2013 and Mejia et al., 2015).

On top of its very small effectiveness, this "chemical war", as it has often been called by opponents of the war on drugs, has been blamed for all sorts of collateral negative effects. Examples include the distrust of State and Government institutions by affected populations[3], non-negligible negative effects on the environment[4] (especially on amphibian populations through the contamination of water sources) and negative health effects on affected populations exposed to the herbicides. However, it is important to note that most of the evidence on these collateral effects comes from field work that has both problems of internal and external validity. Field work and anecdotal evidence on the effects of aerial spraying on health outcomes are plagued by confounding factors that makes difficult to blame aerial spraying as a direct cause of the mentioned maladies. One of the most prominent confounding factors is the coca cultivation itself. More precisely, given the high spatial correlation between coca cultivation and the occurrence of aerial spraying campaigns, it is easily arguable that if coca cultivation and cocaine production themselves make indiscriminate use of pesticides and other agricultural inputs and chemical precursors, then these activities can be the ones generating the negative health and environmental consequences observed by NGOs and other groups in the field. In short, most of the evidence (anecdotal, from field work and empirical) is plagued by issues of endogeneity and

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[1] Poppy seeds in the case of heroin production and coca bushes in the case of cocaine production

[2] Plan Colombia is the name of a joint strategy launched in 2000 between the governments of Colombia and the U.S. for the fight against illegal drugs and organized crime.

[3] See Landy (1988), Navarrete-Frías et al. (2005), Felbab-Brown (2009) and García (2011), among others.

[4] See Relyea (2005), Navarrete-Frías et al. (2005), Cox (2005) and Imming (2010) for studies documenting the effects of aerial spraying with Glyphosate on the environment (deforestation, pollution of water sources, etc.) and on animal species.

omitted variables that have made it hard to reach causal conclusions regarding the effects of spraying campaigns on health outcomes.

In this paper we use a large administrative panel data set that contains individual health records, together with very precise information on the location and exact timing of aerial spraying events (at a daily and municipal level) in order to disentangle the causal effect of aerial spraying of herbicides on a broad range of health outcomes. Our identification strategy tackles the problems of endogeneity present in the previous literature, as it relies on the fact that aerial spraying is not announced, which enables us to use it as a quasi-natural experiment to test the causal impact of exposure to Glyphosate on human health. Furthermore, we have administrative records from medical consultations for a five year period, which allows us to observe individuals more than once during our period of analysis. Furthermore, we have significant variation in the extent of aerial spraying, both over time and across municipalities. Our identification strategy of the causal effect of aerial spraying on health outcomes relies on the fact that we observe individuals more than once in our dataset, and thus, by being able to include individual fixed effects, we are controlling for individual unobservable characteristics that do not change over time, such as baseline health. This, in our view, is the closest one can get to a randomized experiment (which, for obvious reasons, would be impossible to implement in this context).

On the one hand, our health data contains the individual-level registers of medical consultations for more than 45 million (individual-time) observations. This is an unbalanced panel over a period of five years where, in total, we observe approximately 9.4 million individuals. On the other hand, we have the official records from the Colombian National Police for the number of squared kilometers daily sprayed by municipality over a period of five years, between January 2003 and December 2007. These are precisely the years with the highest levels of aerial spraying during the last 15 years under the so-called Plan Colombia. With the combination of these two panel data sets we estimate individual fixed effects regressions that test whether there is an increase in the probability of having a health problem related to the exposure to the herbicides used in the aerial spraying program for the same individual, exposed to different levels of aerial spraying at different moments in time. We also include month and year fixed effects that control for seasonal illnesses or harvesting seasons. Our findings coincide with the medical literature and robustly indicate that aerial spraying of Glyphosate increases the probability of having dermatological and respiratory problems and miscarriages. These results are robust to different specifications of the empirical model and to the inclusion of a wide range of controls, including the extent of coca cultivation at the municipality level. It is important to highlight that given the nature of our data, we are unable to capture long-term effects that might translate into lower life expectancy, quality of life or productivity.

There are four main strengths and contributions of our paper relative to the existing literature. First, to the best of our knowledge, this is the first paper in the literature that uses a quasi-experiment to estimate the effect of spraying of illicit crops on health outcomes in a drug-producing country. In particular, given that the exact timing and magnitude of spraying campaigns is difficult to anticipate, spraying events are arguably an exogenous shock from an individual's point of view, and this strengthens our identification strategy and the internal validity of our results. Second, the large sample size of our dataset also allows us to find very robust and precise results in the econometric specifications, even if the actual effects are small. We use a dataset containing administrative records for all health service institutions in Colombia from 2003 to 2007, accounting for more than 45 million visits to the doctor and approximately 2.5 million completed and non-completed birth registrations. By using information from the whole Colombian population we have results with more external validity than the ones that are performed in the field or in labs by epidemiologists or medical doctors. Third, our daily data is appropriate for establishing a precise link between the date and magnitude of aerial spraying and the date in which individuals go to the hospital to see the doctor or visit the Emergency Room. Finally, from the administrative health records we are able to construct an individual-level panel for individuals that go to a health service provider more than once during our period of analysis. The possibility of comparing the same individual across time, by estimating an individual fixed-effects model, isolates all genetic, behavioral and other time invariant unobserved individual heterogeneity. This automatically rules out from our study many confounding factors and omitted variable biases present in cross-sectional studies.

The paper proceeds as follows. Section 2 reviews the relevant medical and epidemiological literature related to the effects of the exposure to herbicides on health outcomes and outlines our paper's contribution to the literature. Section 3 presents the Colombian context and describes the aerial spraying program. Section 4 describes in detail the data used in our empirical exercise; Section 5 discusses the basic theoretical framework behind our empirical strategy. Section 6 reports and analyzes the main results. Finally, the last section presents the concluding remarks.

2. Medical and epidemiological literature on the collateral effects of Glyphosate on health outcomes

A wide variety of medical studies have documented the negative impacts of exposure to Glyphosate on human health, although there is no definitive consensus in the literature. Therefore this paper can provide some answers to an ongoing debate. The prior medical literature consists primarily of either cross-sectional studies comparing the prevalence of health outcomes among those with and without prior exposure to herbicides (especially Glyphosate) or laboratory animal experiments. Sanborn et al. (2004) and Sanborn et al. (2007) argue that herbicides use causes dermatological problems; among these, they highlight multiple cross-sectional studies demonstrating higher prevalence of burnings, irritations and skin redness in exposed groups. Experimental evidence on animals and observational studies with humans with accidental skin contact with Glyphosate reviewed by Cox (1995) find effects of redness, swelling, and irritation of the skin after exposure. Sherret (2005) reports anecdotal evidence of respiratory ailments following aerial spraying campaigns in Colombia, including bronchial irritation. This is corroborated by some experimental evidence on Glyphosate inhalation in animals, as reviewed by Cox (1995). However, a recent review by

Mink et al. (2011) argues that the current medical literature displays no consistent pattern between Glyphosate exposure and respiratory conditions.

Some researchers have also addressed the effects of exposure to herbicides on miscarriages and fetus malformations. Laboratory studies have displayed the toxicity of Glyphosate to human reproductive cells; for example, Benachour and Seralini (2009) find that exposure to Glyphosate causes premature death in umbilical, embryonic and placental cells at low doses similar to residues in herbicide-treated food. Animal studies documented in Cox (1995) show decreased female fertility and lower birth weights after ingestion of products that have been exposed to Glyphosate. Sanborn et al. (2004), Regidor et al. (2004), Sanborn et al. (2007), and Solomon et al. (2007) indicate that exposure to herbicides before conception is correlated with miscarriages during the first trimester of pregnancy. They also find that the direct exposure of the father to large amounts of herbicides is linked to a greater risk of fetal death, an effect that is larger if the exposition took place within a three months period preceding conception. Cases of anencephaly associated with direct exposition of the mother to herbicides during the preconception period (between the 3 months previous to the conception and the third month of pregnancy) have also been reported in the medical literature. Furthermore, Sanborn et al. (2004) provide evidence of an association between the spraying of herbicides and problems of fecundity and lower levels of sperm concentration. In contrast, Williams et al. (2012) cite cross-sectional and laboratory studies suggesting that Glyphosate exposure is not related to miscarriages or developmental effects at the exposure levels of herbicide use. Similarly, Solomon et al. (2007) indicate that the levels of concentration of Glyphosate used in aerial spraying campaigns in Colombia are so low that they don't carry a significant risk to human health.

Sanborn et al. (2004) and Sanborn et al. (2007) find (minor) evidence of the negative effect of exposure to Glyphosate on the levels of depression, anxiety, neural disorders, minor tact sensibility, abnormal reflexes and psychomotor dysfunction. As to neurodegenerative diseases, they find evidence of a connection between the exposure to pesticides at work and Parkinson's and Alzheimer's diseases later in life.

Finally, a recent review of the evidence finds limited evidence in humans for the carcinogenicity of Glyphosate (International Agency for Research on Cancer - IARC, 2015). More precisely, the review of the available evidence finds that exposure to the herbicide leads to increased risks for non-Hodgkin lymphoma. These findings led the IARC to reclassify Glyphosate in category 2A: probably carcinogenic to humans.

The contribution of our paper to the literature relies on the strong emphasis that we place on performing a clean identification strategy. To the best of our knowledge, this is the first paper in the literature that exploits a quasi-natural experiment to address the potential endogeneity issues that arises when estimating the effect of aerial spraying of illicit crops with herbicides on human health outcomes. While our results corroborate some of the results found in the medical literature (e.g., the negative effects of exposure to Glyphosate on dermatological and respiratory problems and on miscarriages), our dataset and empirical strategy does not allow us to study the health effects on other health conditions for which it is difficult to precisely pin down the time that elapses between exposition to the herbicide and the appearance of the symptoms.

3. Colombian context and the aerial spraying program[5]

Following the large increase in coca cultivation that took place in Colombia during the second half of the 1990s and the increasing involvement of the *Fuerzas Armadas Revolucionarias de Colombia* – FARC and paramilitary groups in this illegal business, in September of 1999 the governments of Colombia and the U.S. launched a joint strategy which would come to be known as the *Plan Colombia.* According to an official report from the U.S. Government Accountability Office (GAO), U.S. funding for the military component of Plan Colombia was (on average) US$540 million per year between 2000 and 2008. The Colombian government, for its part, invested approximately US$812 million per year in the fight against drugs and drug-related organized crime groups. Taken together, these expenditures represented approximately 1.2 percent of Colombia's average annual GDP between 2000 and 2008. As such, *Plan Colombia* is the largest anti-drug intervention that has ever been made in a drug-producing country.

The strategies implemented under *Plan Colombia* included aerial spraying campaigns with herbicides to kill coca crops, manual eradication campaigns, control of chemical precursors used in the processing of coca leaf into cocaine, the detection and destruction of cocaine processing laboratories, and seizing of drug shipments en route to foreign countries. Aerial spraying has been by far the main anti-drug strategy in terms of financial resources invested among these strategies. On average, 128 thousand hectares have been sprayed with herbicides per year, with a peak of 172 thousand hectares sprayed in 2006.

Spraying campaigns are carried out by American contractors, such as *DynCorp,* using small aircraft. Coca crops are sprayed with substances such as Roundup, whose main active ingredient is Glyphosate. The herbicide also contains the surfactant POEA, which helps the Glyphosate penetrate the coca plants' foliage. This herbicide inhibits an enzyme involved in the synthesis of the aromatic amino acids, thus killing the plant. Glyphosate is absorbed through foliage and is only effective on actively growing plants (e.g., it is not effective in preventing seeds from germinating). Though Roundup, the commercial name of the herbicide, was designed to kill weeds and grasses, including coca bushes, it may also affect other legal crops that are not Glyphosate-resistant. However, aerial spraying with Glyphosate is targeted at areas where coca crops have been detected using satellite images, implying that areas with coca crops are much more likely to be sprayed and destroyed by this enforcement strategy. Thus, farmers that decide to grow coca bushes face the risk of their crops being destroyed by the herbicide used in aerial spraying campaigns. In the face of aerial spraying, farmers may still grow coca bushes and play their luck, or mitigate the effects of the herbicide using a variety of techniques. For instance, some farmers that know that the area is

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[5] This section is adapted from Mejia et al. (2014).

being targeted by the program spray molasses on the coca bushes to prevent the herbicide from penetrating the foliage and killing the plant. Also, if farmers cut the stem of the plant a few hours after the spraying event, the plant grows back again and can be harvested again a few months later. However, these alternatives are costly, and other farmers may decide to reallocate their crops to areas less likely to be sprayed or to start cultivating solely legal crops that are not targeted by the spraying campaigns. Economic theory suggest that in the face of higher risk of spraying with herbicides, marginal farmers should either reallocate their coca crops or reduce their cultivation, while other farmers would continue growing coca nonetheless.

4. Data

4.1. Administrative registry of medical consultations, emergency room visits and hospitalizations

The Individual Register of Health Services Provision (RIPS, as per the acronym in Spanish) contains the individual-level registers of medical consultations, Emergency Room (ER) visits, hospitalizations and procedures that took place in any health service institution in Colombia between 2003 and 2007. Each registry contains information about the appointment (date, municipality, diagnosis according to the ICD-10[6], institution that treated the patient and consultation fee) and about the patient (age, gender and type of health insurance). It is important to note that we do not have information nor can we infer anything about individuals that did not attend a health service institution during our period of study.

The quality of our administrative data is important for the credibility of our results. Several considerations regarding the cleaning process of our data are important to take into account. Appendix A describes the cleaning process. In addition to checking the consistency within the data, we used the Demographic and Health Survey (DHS) as an independent source of information to assess the number of people that visit health services in Colombia. For year 2005, 15.5% of the population reported to have a need to solve a health condition; out of this percentage 65.9% went to visit the doctor to solve this health condition. By using the total population in Colombia in 2005, we get that approximately 4.3 million Colombians went to the doctor that year. This does not take into account the fact that an individual might go to the doctor more than once in a given year.

Table 1 reports the final number of observations in the RIPS database after the cleaning process for the years 2003 to 2007, which accounts for 15 to 20 million observations per year. For further details on the cleaning process of the dataset refer to Appendix A.

With the diagnoses reported in our medical consultation panel and based on the medical literature summarized above, we construct three groups of diagnostics potentially affected by

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[6] ICD-10 is the International Statistical Classification of Diseases and Related Health Problems (ICD), a medical classification list by the World Health Organization (WHO). It contains codes for diseases, signs and symptoms, abnormal findings, complaints, social circumstances, and external causes of injury or diseases.

the aerial spraying program: dermatologic, respiratory, and miscarriages. These three broad categories will be the main focus of our analysis, as we concentrate on health outcomes that appear in the short run (e.g., a few days or months after exposure to the herbicide used in the aerial spraying program in Colombia). Other health-related problems that may take more time to develop are left out of our analysis, as it is difficult to precisely identify the time between herbicide exposure and the appearance of certain medical conditions. Each group collects a variety of diagnosis that were selected using the ICD-10 codes and in accordance with the medical literature findings. Appendix B includes a table with the list of the diagnosis considered in the estimations, as well as the proportion that each of them represents in the total number of events in our panel.

The upper panel from Table 2 and 3 show descriptive statistics for the main variables used in our empirical exercise for different subsamples: Complete sample (Panel A); sample of municipalities with positive levels of aerial spraying (Panel B); non-migrant population sample (Panel C); sample of high-income municipalities (Panel D); and sample of low-income municipalities (Panel E). We create a dummy variable that equals 1 if the person appears in our panel with a diagnosis related to a dermatological or respiratory condition, and 0 if the person appears in the panel with some other diagnosis. Then we use the number of visits to a health service institution in a year to construct the number of dermatological and respiratory diagnoses as a proportion of the total number of visits in a given year. As shown in Table 2, dermatological and respiratory consultations related to aerial spraying correspond to approximately 1.3% and 3.8% of all reported diagnosis, respectively.

With respect to miscarriages, these are severely underreported in our panel. As a result, we construct a miscarriage variable using information from prenatal care visits and hospitalizations related to births from the RIPS dataset. We assume that a miscarriage occurred if we see a mother attending a prenatal care visit in a health service institution, but we do not find a birth registered in the hospitalization sample later on. However, we should stress that our proposed measure could overstate the number of miscarriages, as it does not take into account that some women might attend prenatal care visits and then give birth in locations different from hospitals, clinics and other formal medical institutions. Also, our measure assumes that all births are reported. Although this variable will not give us a direct count of the number of miscarriages, the correlation between our constructed measure of miscarriages and reported miscarriages at the municipal level is above 90%.

4.2. Aerial spraying and coca cultivation data

We have very detailed information on each event of aerial spraying of illicit crops for our study period. The data on spraying campaigns is recorded by geo-coding devices that are built-in in the aircrafts used for the aerial spraying campaigns. The information on the location (municipality) and number of hectares sprayed is recorded during the flight and then collected by the national authorities when the plane lands. This information was obtained from the Colombian Anti-Narcotics Police, a special unit inside the Colombian National Police in charge of designing and implementing most of the strategies used in the fight against illegal drug production and trafficking in the country. These records include the exact date and time of the spraying event, the municipality of occurrence, the number of hectares sprayed and the type of illicit crop sprayed (coca, marijuana or opium poppy).

The coca cultivation information was obtained from SIMCI, the United Nations Office in Colombia in charge of measuring the extent of coca cultivation. Coca cultivation is measured using satellite images that are taken at the end of each calendar year. The satellite pictures cover the entire Colombian territory and are analyzed by computer programs and experts that can very precisely identify and distinguish coca crops from other crops (legal or illegal).

It is very important to clarify that all our estimations control for the extent of coca cultivation at the municipality level. If coca cultivation and aerial spraying are positively correlated (as it is indeed the case), controlling for the level of coca cultivation is important to prevent the estimation of our coefficient of interest from being biased. If we were not controlling for coca cultivation, the health effect of exposure to chemical precursors used in the process of transforming coca leaf into coca base would be captured by our coefficient of interest (e.g., the one that accompanies aerial spraying).

Tables 2 and 3 report descriptive statistics for the daily mean of the area spraying according to the relevant exposure time window (in square kilometers), and the proportion of municipal area cultivated with coca for different subsamples. We define the relevant time windows of Glyphosate exposure according to the findings in the medical literature over each specific health condition from the medical literature (15 days for dermatologic and respiratory problems, and eight (8) months prior to the last prenatal care visit) and one (1) month later (because we do not have certainty on the exact date of the miscarriage), which gives a total time window of nine (9) months.

4.3. Municipal controls

In all our estimations we control for a broad range of variables at the municipal level that can affect health outcomes, and thus omitting them may lead to biased estimates of our coefficients of interest. These controls come from a municipal panel constructed by CEDE (Research Center on Economic and Development at Universidad de los Andes), which provides information on economic, geographical and social characteristics at the municipal level in Colombia for our period of study. Some of the variables that we control for include: population, municipal tax revenues, rurality index, and Government expenditures on health. We also include time-invariant municipal controls such as size in square kilometers. This control will disappear under the individual fixed effect estimation if the individual resides in the same location (e.g., in our non-migrant sample).

5. Health production function and empirical specification

The health production function was first introduced by Grossman (1972). Under this framework, health is assumed to be a function of several factors. The first one is the baseline health status of the individual, which is closely related to genetic factors. The second factor is leisure, understood as time spent on activities that improve health conditions such as exercising, cooking and sleeping, among others. The third factor is medical care. This factor corresponds to goods and services that individuals can purchase in order to improve their health; for example, good quality of doctors, hospitals, medicines, vaccines and healthy food and habits.

While it is extremely difficult to measure the baseline health status, we deal with it by exploiting the panel structure of our data and using individual fixed effects in our estimations. Fixed effects account for all individual characteristics that do not change over our study period (e.g., genetics, previous investments, health conditions, health care when young, etc.). This empirical strategy represents a big advantage with respect to cross sectional studies that compare unrelated individuals for whom these factors cannot be accounted for.

$$h_{imt} = \Gamma(Y_{it}, l_{it}, u_i, s_{mt}) \qquad (1)$$

Instead of trying to estimate a structural form of the health production function, we estimate a reduced form of the following health production function:

where the subscript *i* refers to the individual, *m* to the municipality of residence, and *t* to the time period. *h* is the proportion of respiratory or dermatological diagnosis in given period of time for an individual *i* that appears in our panel in municipality *m* and at time *t*. *Y* are goods that can affect health; *l* correspond to health inputs that require time; *u* is an individual health endowment; and *s* is an environmental shock that, in our case, corresponds to having being exposed to the herbicide used in aerial spraying campaigns in the municipality of residence.

For this setup to be understood as a quasi-experiment, or, in other words, for aerial spraying to be exogenous, we need to assume orthogonality between *s*, the environmental shock, and the error term. In this case, we are assuming that individuals cannot anticipate with certainty the time and extent of exposure to the aerials praying campaigns. By controlling for characteristics at the municipal level and using municipality or individual fixed effects, there should be very few concerns about the systematic variation between spraying and other characteristics that will bias the estimations of our coefficients of interest. One remaining issue for our identification strategy is the possibility of having self-selection into the sample. This concern would be valid if individuals that go to the doctor are different from the ones that do not go. So our analysis is only valid for individuals that attend a health service institution. In addition to this general concern of sample selection, we could also have selective migration if the most susceptible individuals to the effects of exposure to the herbicide used in aerial spraying campaigns decide to migrate. Calculations from our sample show that 7.4% of the individuals in our sample appear in different municipalities throughout our study period. In order to check the robustness of our results we run our regressions for non-migrant individuals and compare them with the full sample results. This comparison allows us to check for the potential bias that selective migration might have in our results. The expectation is that estimations that use only non-migrant individuals will show larger effects of exposure to Glyphosate used in aerial spraying campaigns on health outcomes.

The reduced form linear relation of our preferred specification of the health production function will be the following model:

$$h_{imt} = \beta_0 + \beta_1 s_{mt} + \beta_2 X_{imt} + \beta_3 Z_{mt} + \gamma_{year} + \gamma_{month} + \gamma_i + \varepsilon_{imt} \tag{2}$$

β_1 is our coefficient associated with our variable of interest, the amount of aerial spraying, *s,* in municipality *m* at time *t*. This variable is measured as the average area (in square kilometers) sprayed during a relevant window of exposure previous to a medical consultation that takes place at time *t*. X_{imt} and Z_{mt} are individual and municipal controls that vary over time, respectively. Among the individual controls we include age, age square, gender, and type of health insurance. Similarly, we include municipal level controls, including population, area of the municipality, per capita tax revenues, proportion of rural population in the municipality, per capita tax revenues for each municipality, per capita public expenditures on health and education services and the proportion of municipal area cultivated with coca crops[7]. Including coca cultivation as a control is important in order to prevent our coefficient of interest from being biased. The high correlation between the extent of aerial spraying and coca cultivation at the municipal level (together with the fact that coca cultivation and cocaine production make indiscriminate use of pesticides, herbicides and chemical precursors) may create a spurious relationship between spraying campaigns and health outcomes if we didn't control for these two variables in our estimations. We also include year, γ_{year} , and month, γ_{month} , dummies to control for unobservable factors changing overtime, such as seasonal patterns of diseases. γ_i are individual fixed effects that control for all unobservable factors varying across individuals that are constant over time. The individual fixed effect model in equation (2) is our preferred specification. This specification compares the health outcomes for a given individual when exposed to different levels of aerial spraying at different moments in time. As explained before, this identification strategy improves over cross sectional studies that include municipality fixed effects, which require very strong assumptions about shocks being equally perceived by individuals or about shocks being homogeneous across all individuals in a given municipality. ε_{imt} is an error term assumed to be orthogonal to our independent variable of interest.

We restrict the time window between an aerial spraying event and a medical consultation to a given number of days in our baseline estimations; the time window chosen is consistent with

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[7] Total coca cultivation in Colombia is measured every year in December (UNOCD and Government of Colombia, 2011). Therefore, we calculate the proportion of municipal area cultivated with coca as the average of the current and previous year cultivation, which would correspond to the initial and final measure of area cultivated for the year of study.

previous findings in the medical literature. For dermatological and respiratory diagnosis we use a time window between the spraying event and the medical consultation of 15 days in our baseline estimations. In the case of miscarriages, we use eight (8) months prior to the last prenatal care visit and one (1) month later (because we do not have certainty on the exact date of the miscarriage), which gives a total time window of nine (9) months. The reason for using this time window for the case of miscarriages is that the medical literature has found that the effect of aerial spraying on miscarriages can start up to three (3) months prior to conception, and a loss is consider a miscarriage during the first five (5) months of pregnancy. In order to check the robustness of our results with respect to respiratory and dermatologic problems, we estimate the individual fixed effects model in equation (2) for time windows of 30, 45 and 60 days between the aerial spraying event and a medical consultation

6. Results

We use three different dependent variables corresponding to medical diagnosis that have been identified in the medical literature to be related to the exposure to Glyphosate in the short run. Table 4 presents our baseline estimations of equation 2 for dermatological and respiratory diagnosis. Columns 1 and 2 correspond to dermatological diagnosis and columns 3 and 4 to respiratory diagnosis. Results in all columns include individual fixed effects, year fixed effects and all individual and municipal controls. Columns 1 and 3 do not include as municipal controls the amount of coca cultivation in the municipality of residence, whereas columns 2 and 4 do.

Table 4 has three panels. The first one (Panel A) presents the results with the full sample of municipalities (e.g., all municipalities in Colombia). Panel B presents the results when we restrict our sample to only those municipalities that had positive levels of spraying at any moment in our study period, and Panel C when we only use non-migrant individuals (e.g., individuals that did not change their municipality of residence during our study period).

Regarding the dependent variable, instead of counting the number of dermatological and respiratory diagnosis, we prefer to measure our dependent variable as the proportion of these diagnoses in the last 15 days with respect to the total number of times that the person went to the doctor in the *previous* year. Having a measure of diagnoses as a proportion of total visits to the doctor eliminates any bias related to the fact that not everyone goes to the doctor with the same frequency.

The first column in Panel A of Table 4 shows that, on average, a one square kilometer increase in the area sprayed with Glyphosate increases the proportion of dermatological diagnosis in the 15 days window following exposure to the herbicide by 0.0005. This effect is statistically significant at the 1% confidence level. When we include the extent of coca cultivation (column 2) as control, our coefficient of interest remains the same and it is still significant at the 1% level. If we take the result of our preferred specification in column 2, our results imply that a one standard deviation increase in the area sprayed with Glyphosate in a 15-day time window prior to a medical consultation increases the proportion of dermatological consultations by 0.3% (from a baseline average of 1.2%). Although this effect seems small, it is highly significant.

Columns 3 and 4 in Panel A of Table 4 present our baseline results for the case of respiratory diagnosis. The results indicate that a one square kilometer increase in the area sprayed with Glyphosate increases the proportion of dermatological diagnosis in the 15 days window following exposure to the herbicide by 0.002. The effect on the proportion of respiratory diagnosis is statistically significant at the 5% confidence level. This result is robust and does not change significantly once we include as a control the extent of coca cultivation in the municipality of residence (column 4). If we take the result from column 4, a one standard deviation increase in aerial spraying leads to an increase in the proportion of medical consultations with respiratory diagnosis by 0.43% (from a baseline average of 3.6%).

Panel B in Table 4 presents the results when we restrict our sample only to those municipalities that had positive levels of aerial spraying at any moment during our study period. This panel shows that the results obtained using the whole sample are robust to using only those municipalities with positive levels of aerial spraying. In fact, the estimated coefficient remains roughly the same. The estimated coefficient implies that a one standard deviation increase in the area sprayed with Glyphosate increases the proportion of dermatological consultations by 0.66% and by 0.92% in the case of respiratory diagnosis. In other words, when we restrict our sample to municipalities that had positive levels of aerial spraying, the effect of spraying on the proportion of medical consultations related to dermatological problems remains small, but is 2.2 times larger than the one obtained using all municipalities in Colombia. The same occurs in the case of respiratory diagnosis.

Table 5 presents the results for miscarriages. As explained before, we use eight (8) months prior to the last prenatal care visit and one (1) month later (because we do not have certainty on the exact date of the miscarriage), which gives a total time window of nine (9) months. In the case of miscarriages, we focus on individuals that did not change municipality of residence, as not doing so might generate measurement error in the extent of exposure to the herbicide used in the aerial spraying campaigns. In other words, given that we don't know the exact migration date (only that an individual changed her municipality of residence), we cannot precisely assign the true level of exposure to Glyphosate that a migrant woman faced during her pregnancy.[8]

The results in Table 5 show that aerial spraying has a strong and statistically significant effect on miscarriages. In the case of miscarriages we focus on the results for the non-migrant population sample (Panel B), but we also report in Table 5 the results of the estimations for the whole sample of individuals. As mentioned before, our measure of miscarriages might be overestimated. For this reason we only analyze the estimated coefficient as proportions of

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[8] Although we will show robustness checks using the non-migrant sample for the case of dermatological and respiratory diagnosis, this is less of a concern for these two conditions given that in these two cases we use a 15 day time window between exposure to spaying campaigns and the medical consultation.

the baseline rate. The results from Table 5 imply that a one standard deviation increase in aerial spraying increases miscarriages by 4.4% in the whole sample of municipalities, and by 10% in municipalities with positive levels of aerial spraying.[9] All estimated effects in the case of miscarriages are statistically significant at the 1% confidence level.

6.1 Robustness checks

One concern that may arise from the results presented in Tables 4 and 5 is their external validity. One way to partially address this is to estimate the same group of regressions dividing the sample between low and high income municipalities. Table 6 presents the results of our estimations for the case of the proportion of dermatological and respiratory diagnosis when we divide the sample between high income municipalities (Panel A) and low income municipalities (Panel B). The two panels in this table have the same structure of the results presented in Table 4, that is, columns 1 and 3 present the results without controlling for the level of coca cultivation in each municipality for dermatological and respiratory diagnosis respectively, while columns 2 and 4 control for the extent of coca cultivation.

The estimated effects of aerial spraying on dermatological and respiratory diagnosis are only significant in the case of low income municipalities, although in high income municipalities the estimated effects are again positive but not statistically significant. In the case of low income municipalities, a one square kilometer increase in the area sprayed with Glyphosate increases the proportion of dermatological diagnosis in the 15 days window following exposure to the aerial spraying campaigns by 0.00042 in our preferred specification, and by 0.002 in the case of respiratory diagnosis. In order to compare the economic significance of the results one should take into account the baseline levels of aerial spraying in the two groups of municipalities. For the group of low income municipalities, the results presented in Panel B in Table 6 imply that a one standard deviation increase in the area sprayed with Glyphosate results in a 0.37% increase in the proportion of dermatological diagnosis in the following 15 days after the spraying event (from a baseline average of 1.2%), and a 0.57% increase in proportion of respiratory diagnosis (from a baseline average of 3.8%).

Table 7 presents the results for the case of miscarriages as the dependent variable when we further divide the sample between low and high income municipalities, again using the sample of non-migrant individuals. In this case, the effects of aerial spraying on miscarriages are significant for both, high and low income municipalities. Columns 1 and 2 present the results for low income municipalities and columns 3 and 4 for high income municipalities. In the case of Table 7 we present the results using the non-migrant sample of individuals. The results in Table 7 show that a one standard deviation increase in aerial spraying increases miscarriages by 5.7% in low income municipalities and by 4.3% in high income municipalities. These effects are all statistically significant at the 1% confidence levels.

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[9] The results on miscarriages when we use the whole sample of individuals (Panel A) imply that a one standard deviation increase in aerial spraying increases miscarriages by 2.8% in the whole sample of municipalities, and by 7.7% in municipalities with positive levels of aerial spraying.

In order to show that our results on the proportion of dermatological and respiratory diagnosis are not biased by selective migration (if it happens to be the case that the most susceptible individuals to the effects of exposure to the herbicide decide to migrate in order to avoid the consequences of exposure to the herbicide), Table 8 presents the results of estimating equation 2 using only the non-migrants subsample of individuals.

The results in Table 8 confirm all previous findings. Namely, that aerial spraying has a positive and significant effect on the proportion of dermatological and respiratory diagnosis. According to the results from columns 2 and 4 in Table 8, a one standard deviation increase in aerial spraying increases by 0.25% the proportion of dermatological diagnosis (from a baseline average of 1.2%), and by 0.44% the proportion of respiratory diagnosis. These results are significant at the 5% confidence level.

We also test whether the effect of aerial spraying campaigns on dermatologic and respiratory diagnosis lasts beyond the 15 day time window explored before, Table 9 presents the results of estimating equation 2 using time windows of 30 days (Panel A) and 45 days (Panel B) between exposure to the spraying campaigns and the associated medical consultation. This table presents the results of our preferred specifications, where we control for the extent of coca cultivation in each municipality. In the case of dermatological diagnosis, the effect of exposure to the spraying campaigns within 30 days prior to the medical consultation is positive but not statistically significant, whereas for respiratory diagnosis the effect is positive and statistically significant at the 10% confidence level. In Panel B, where we explore the effect over a 45-days time window, the effects are again positive but not statistically significant. As expected from the medical literature, the results presented in Table 9 show that the effects of exposure to Glyphosate used in the aerial spraying program in Colombia, are only significant within a 15-days time window after exposure in the case of dermatological diagnosis and within a 30-days time window in the case of respiratory diagnosis. These two are conditions where the time that elapses between exposure to the herbicide and the appearance of the symptoms is relatively short and identifiable.

Finally, we present the results of a placebo test where we use as the dependent variable the proportion of two conditions that, in principle, should be completely unrelated to exposure to the spraying campaigns: Accidents and fractures. The results in Table 10 show that exposure to the spraying campaigns within a 15-days time window does not lead to an increase in the fraction of medical consultations related to these two conditions. These results show that the estimated effects obtained in Tables 4 through 8 do not come from the very high statistical power that we have, but from a causal relationship between exposure to Glyphosate used in the aerial spraying program in Colombia and some medical conditions.

7. Concluding remarks

This paper evaluates the effects that aerial spraying of herbicides to reduce illicit crops cultivation has on health outcomes in Colombia. Using a unique dataset of individual level health registries together with daily information on the extent of aerial spraying campaigns at the municipality level, we estimate individual fixed effects regressions that are the closest counterpart to an experiment. Our results indicate that exposure to the herbicides used in aerial spraying campaigns lead to an increase in dermatological and respiratory problems and miscarriages. The estimated effects of aerial spraying on these three medical conditions are highly significant and robust to different subsamples and specifications.

The results in our paper imply that the aerial spraying of herbicides as a strategy to reduce coca cultivation in Colombia has a negative collateral effect on health outcomes of populations exposed to the herbicide. Other papers in the literature have shown that aerial spraying campaigns are ineffective in reducing coca cultivation. The most conservative (and positive) estimates of the effects of aerial spraying on coca cultivation indicate that for each additional hectare sprayed with herbicides, coca cultivation is reduced by about 0.035 hectares (Mejia et al., 2014). This implies that in order to reduce by one hectare the amount of coca cultivation, almost 30 hectares would have to be sprayed. Furthermore, the same authors estimate that the average cost of eliminating one hectare of coca crops through the aerial spraying program is about USD$74,000.

While this version of the paper was being completed, the Colombian government announced that it will stop the aerial spraying program. The decision was taken based on the possible health effects that the program might be having on the populations exposed to the herbicide used in the aerial spraying campaigns. The findings in this paper indicate that it is indeed the case that the aerial spraying program has negative health consequences.

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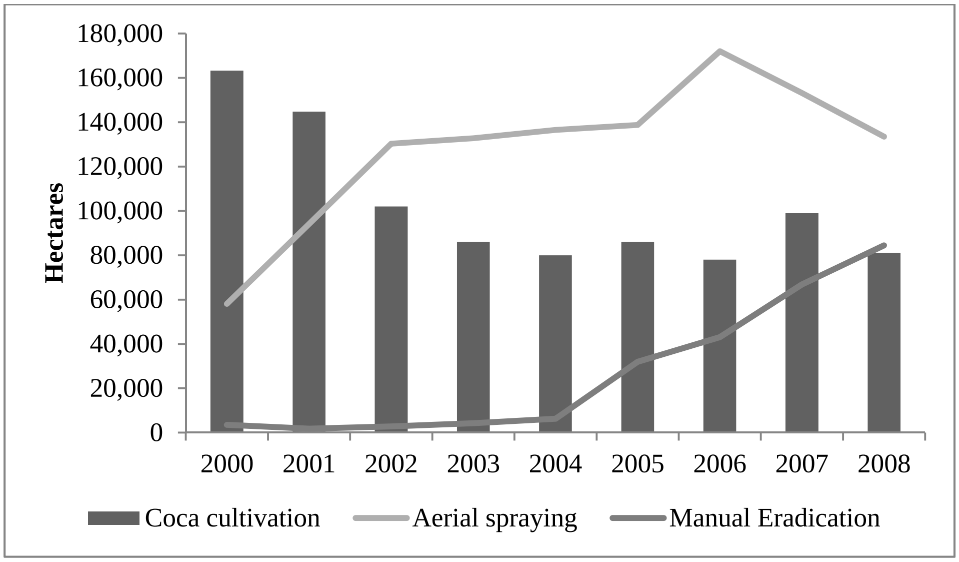
Figure 1: Coca cultivation, aerial spraying and manual eradication in Colombia 2000 – 2008



Source: SIMCI-United Nations for Drugs and Crime (UNODC)

Table 1: Number of observations in the RIPS database[10]

Year	# of observations
2003	13,392,688
2004	13,521,192
2005	16,655,556
2006	15,861,089
2007	16,775,938
Total # of observations	76,206,463

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[10] Table 1 presents the number of observations after the cleaning process of the RIPS database (see Appendix 1).

Table 2: Descriptive statistics for the dermatologic and respiratory panels in different subsamples

Panel A: Complete sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Proportion dermatologic	45,180,630	0.0122338	0.0817446	0	1
Proportion respiratory	45,180,630	0.0363155	0.1353547	0	1
Daily average aerial spraying in last 15 days	45,180,630	0.003577	0.0744563	0	9.552
Proportion of coca cultivation in municip.	45,180,630	0.0002532	0.0028906	0	0.1727068

Panel B: Sample of municipalities with positive levels of aerial spraying

Variable	Obs	Mean	Std. Dev.	Min	Max
Proportion dermatologic	8,098,541	0.0133297	0.0853633	0	1
Proportion respiratory	8,098,541	0.0386203	0.1389586	0	1
Daily average aerial spraying in last 15 days	8,098,541	0.0199554	0.1749312	0	9.552
Proportion of Coca cultivation in municip.	8,098,541	0.0013548	0.0066867	0	0.1727068

Panel C: Sample of municipalities with non migrant population

Variable	Obs	Mean	Std. Dev.	Min	Max
Proportion dermatologic	42,216,785	0.0123558	0.0820245	0	1
Proportion respiratory	42,216,785	0.0368187	0.1359991	0	1
Daily average aerial spraying in last 15 days	42,216,785	0.0036355	0.0752698	0	9.552
Proportion of Coca cultivation in municip.	42,216,785	0.0002533	0.0028724	0	0.1727068

Panel D: Sample of High income municipalities

Variable	Obs	Mean	Std. Dev.	Min	Max
Proportion dermatologic	22,690,615	0.0122205	0.0817092	0	1
Proportion respiratory	22,690,615	0.0337418	0.1304988	0	1
Daily average aerial spraying in last 15 days	22,690,615	0.0003355	0.0109448	0	1.881
Proportion of Coca cultivation in municip.	22,690,615	0.00000708	0.0002006	0	0.0089483

Panel E: Sample of Low income municipalities

Variable	Obs	Mean	Std. Dev.	Min	Max
Proportion dermatologic	22,490,016	0.0122472	0.0817803	0	1
Proportion respiratory	22,490,016	0.0389122	0.1400354	0	1
Daily average aerial spraying in last 15 days	22,490,016	0.0068474	0.104856	0	9.552
Proportion of Coca cultivation in municip.	22,490,016	0.0005015	0.004077	0	0.1727068

Table 3: Descriptive statistics for the miscarriages panels in different subsamples

Panel A: Complete Sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Miscarriages	3,352,570	0.1651622	0.371327	0	1
Daily average aerial spraying in last 9 months	3,352,570	0.0039845	0.0391343	0	1.005
Proportion of Coca cultivation in municip.	3,352,570	0.0003863	0.004008	0	0.1727068

Panel B: Sample of municipalities with positive levels of aerial spraying

Variable	Obs	Mean	Std. Dev.	Min	Max
Miscarriages	3,163,568	0.1650342	0.3712115	0	1
Daily average aerial spraying in last 9 months	3,163,568	0.0040289	0.0395836	0	1.005
Proportion of Coca cultivation in municip.	3,163,568	0.0003792	0.0039435	0	0.1727068

Panel C: Sample of municipalities with non migrant population

Variable	Obs	Mean	Std. Dev.	Min	Max
Miscarriages	3,163,568	0.1650342	0.3712115	0	1
Daily average aerial spraying in last 9 months	3,163,568	0.0040289	0.0395836	0	1.005
Proportion of Coca cultivation in municip.	3,163,568	0.0003792	0.0039435	0	0.1727068

Panel D: Sample of municipalities with positive levels of aerial spraying for non-migrants

Variable	Obs	Mean	Std. Dev.	Min	Max
Miscarriages	622,011	0.1696964	0.3753661	0	1
Daily average aerial spraying in last 9 months	622,011	0.0204909	0.0873601	0	1.005
Proportion of Coca cultivation in municip.	622,011	0.0018593	0.0087018	0	0.1727068

Panel E: Sample of High income municipalities

Variable	Obs	Mean	Std. Dev.	Min	Max
Miscarriages	1,621,638	0.1604853	0.3670556	0	1
Daily average aerial spraying in last 9 months	1,621,638	0.0002627	0.0033197	0	0.1645811
Proportion of Coca cultivation in municip.	1,621,638	0.00000933	0.0002206	0	0.0089483

Panel F: Sample of Low income municipalities

Variable	Obs	Mean	Std. Dev.	Min	Max
Miscarriages	1,541,930	0.1698183	0.3754733	0	1
Daily average aerial spraying in last 9 months	1,541,930	0.0079897	0.0563252	0	1.005
Proportion of Coca cultivation in municip.	1,541,930	0.0007681	0.0056178	0	0.1727068

Table 4: Effects of aerial spraying on the proportion of dermatologic and respiratory diagnosis

Panel A: Complete sample of municipalities

Dependent variable:	**Dermatologic diagnosis**		**Respiratory diagnosis**	
	(1)	**(2)**	**(3)**	**(4)**
Average spraying (15 days)	0.00049*** (0.00018)	0.00048*** (0.00018)	0.00209** (0.00094)	0.00210** (0.00094)
Percentage of the municipality with coca crops		0.03885 (0.03758)		-0.06669 (0.05264)
# of observations	45,180,630	45,180,630	45,180,630	45,180,630
R-squared	0.000	0.000	0.001	0.001
# of individuals	9,399,859	9,399,859	9,399,859	9,399,859

Panel B: Sample of municipalities with positive levels of aerial spraying

Dependent variable:	**Dermatologic diagnosis**		**Respiratory diagnosis**	
	(1)	**(2)**	**(3)**	**(4)**
Average spraying (15 days)	0.00050*** (0.00018)	0.00050*** (0.00017)	0.00204** (0.00086)	0.00204** (0.00087)
Percentage of the municipality with coca crops		0.03169 (0.05339)		0.04666 (0.07701)
# of observations	8,098,541	8,098,541	8,098,541	8,098,541
R-squared	0.000	0.000	0.001	0.001
# of individuals	1,804,782	1,804,782	1,804,782	1,804,782

Standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

All regresions include the following controls: age, age square, health regime, municipal tax income, population, area in square rurality index, municipal spending on education and health, year and month dummy

Table 5: Effects of aerial spraying on miscarriages

Panel A: Complete sample

Dependent variable: Miscarriages	**Complete sample**		**Municipalities with positive levels of aerial spraying**	
	(1)	**(2)**	**(3)**	**(4)**
Average spraying (9 months)	0.12139*** (0.04243)	0.11890*** (0.04163)	0.15007*** (0.04041)	0.15158*** (0.03721)
Percentage of the municipality with coca crops		0.91870 (0.82469)		3.50893** (1.37864)
# of observations	3,352,570	3,352,570	3,352,570	3,352,570
R-squared	0.025	0.025	0.027	0,0311
# of individuals	780,558	780,558	780,558	780,558

Panel B: Non-migrant population sample

Dependent variable: Miscarriages	**Non-migrants sample**		**Non-migrants sample with positive levels of aerial spraying**	
	(1)	**(2)**	**(3)**	**(4)**
Average spraying (9 months)	0.16774*** (0.05838)	0.18433*** (0.04964)	0.17707*** (0.05003)	0.19434*** (0.04313)
Percentage of the municipality with coca crops		6.83612*** (2.53821)		7.18591*** (2.58495)
# of observations	3,163,568	3,163,568	3,163,568	3,163,568
R-squared	0.027	0.027	0.032	0.032
# of individuals	742,616	742,616	742,616	742,616

Standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

All regresions include the following controls: age, age square, health regime, municipal tax income, population, area in square km, rurality index, municipal spending on education and health, year and month dummy

Table 6: Effects of aerial spraying on the proportion of dermatologic and respiratory diagnosis in high income and low income municipalities

Panel A: High income municipalities

Dependent variable:	Dermatologic diagnosis		Respiratory diagnosis	
	(1)	(2)	(3)	(4)
Average spraying (15 days)	0.00589	0.00607	0.00168	0.00202
	(0.00612)	(0.00602)	(0.00543)	(0.00540)
Percentage of the municipality with coca crops		-0.82843*		-1.55937
		(0.42971)		(1.53588)
# of observations	22,690,615	22,690,615	22,690,615	22,690,615
R-squared	0.000	0.000	0.001	0.001
# of individuals	4,872,856	4,872,856	4,872,856	4,872,856

Panel B: Low income municipalities

Dependent variable:	Dermatologic diagnosis		Respiratory diagnosis	
	(1)	(2)	(3)	(4)
Average spraying (15 days)	0.00043***	0.00042***	0.00211**	0.00212**
	(0.00013)	(0.00013)	(0.00095)	(0.00095)
Percentage of the municipality with coca crops		0.02652		-0.06774
		(0.04055)		(0.05719)
# of observations	22,490,016	22,490,016	22,490,016	22,490,016
R-squared	0.000	0.000	0.001	0.001
# of individuals	5,002,012	5,002,012	5,002,012	5,002,012

Standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

All regresions include the following controls: age, age square, health regime, municipal tax income, population, area in square rurality index, municipal spending on education and health, year and month dummy

Table 7: Effects of aerial spraying on miscarriages in high income and low income municipalities

Dependent variable: Miscarriages	Non-migrant sample, low income municipalities		Non-migrant sample, high income municipalities	
	(1)	(2)	(3)	(4)
Average spraying (9 months)	0.15386***	0.17125***	2.26129***	2.09361***
	(0.05147)	(0.04392)	(0.55670)	(0.68365)
Percentage of the municipality with coca crops		6.90424***		34,27862
		(2.47105)		(34.64296)
# of observations	1,541,930	1,541,930	1,621,638	1,621,638
R-squared	0,029	0,029	0,03	0,03
# of individuals	386,781	386,781	368,372	368,372

Standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

All regresions include the following controls: age, age square, health regime, municipal tax income, population, area in square km, rurality index, municipal spending on education and health, year and month dummy

Table 8: Effects of aerial spraying on the proportion of dermatologic and respiratory diagnosis (Non-migrant population sample)

Dependent variable:	**Dermatologic diagnosis**		**Respiratory diagnosis**	
	(1)	**(2)**	**(3)**	**(4)**
Average spraying (15 days)	0.00041**	0.00041**	0.00217**	0.00217**
	(0.00018)	(0.00018)	(0.00091)	(0.00091)
Percentage of the municipality with coca crops		-0.06892		-0.02103
		(0.10118)		(0.12879)
# of observations	42,216,785	42,216,785	42,216,785	42,216,785
R-squared	0.000	0.000	0.001	0.001
# of individuals	8,969,399	8,969,399	8,969,399	8,969,399

Standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

All regresions include the following controls: age, age square, health regime, municipal tax income, population, area in square rurality index, municipal spending on education and health, year and month dummy

Table 9: Effects of aerial spraying on the proportion of dermatologic and respiratory diagnosis for 30 and 45 days' time window

Panel A: 30 days time window

Dependent variable:	**Dermatologic diagnosis (1)**	**Respiratory diagnosis (2)**
Average spraying (30 days)	0.00009	0.00253*
	0,00019	0,00148
Percentage of the municipality with coca crops	0.03932	-0.06694
	0,03749	0,05272
# of observations	45,180,630	45,180,630
R-squared	0,0002	0,0204
# of individuals	9,399,859	9,399,859

Panel B: 45 days time window

Dependent variable:	**Dermatologic diagnosis (1)**	**Respiratory diagnosis (2)**
Average spraying (45 days)	0.00033	0.00182
	0,00024	0,00153
Percentage of the municipality with coca crops	0.03918	-0.06551
	0,03751	0,05240
# of observations	45,180,630	45,180,630
R-squared	0,0002	0,0204
# of individuals	9,399,859	9,399,859

Standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

All regresions include the following controls: age, age square, health regime, municipal tax income, population, area in square km, rurality index, municipal spending on education and health, year and month dummy

Table 10: Placebo test – Effects of aerial spraying on the proportion of accidents and fractures

Dependent variable:	**Accidents**		**Fractures**	
	(1)	**(2)**	**(3)**	**(4)**
Average spraying (15 days)	0,00005	0.00005	-0.00006	-0.00006
	(0.00006)	(0.00006)	(0.00007)	(0.00007)
Percentage of the municipality with coca crops		0.01468		0.00229
		(0.00903)		(0.00774)
# of observations	45,180,630	45,180,630	45,180,630	45,180,630
R-squared	0.001	0.001	0.001	0.001
# of individuals	9,399,859	9,399,859	9,399,859	9,399,859

Appendix A: Cleaning the RIPS database

Table A.1. reports the initial distribution of observations in the RIPS database of hospitalization, emergency room and doctor visits for each year of the panel. There are almost 88 million observations for the period 2003-2007.

Table A.1.: Initial distribution of the observations in the RIPS database

Year	# of observations
2003	15,604,624
2004	15,073,600
2005	18,232,997
2006	20,136,840
2007	18,857,543
Total # of observations	87,905,604

We now describe the five criteria used to clean the database:

1. Eliminate duplicates: If the same observation appears more than once in the database.

2. Eliminate inconsistencies by gender: If the person appears several times in the panel (with the same id), but his/her gender is not consistent over time.

3. Eliminate inconsistencies in age: If the person appears several times in the panel (with the same id), but there are inconsistent age gaps from one year to the next or between years.

4. Eliminate by invalid year, type of health regime or municipality or state code: If an observation belongs to a year that is not covered by the panel (which goes from 2003 to 2007); if an observations belongs to a non-valid type of regime (valid types of health regime are: 1-contributive, 2-subsidized, 3-uninsured, 4-particular, 5-other, 6-displaced); if an observation has an invalid municipal or state code, given that we would not be able to link this observation with the level aerial spraying and coca cultivation.

5. Flag and eliminate individuals who appear frequently in the database and do not seem to suffer from a chronic disease: If an individual appears more than 40 times in the panel, but less than half of all visits correspond to the same diagnosis.

Table A.2. reports the number of observations resulting after each stage of the cleaning process for each year in the panel, as well as the changes in the total number of observations at each stage. After cleaning the data we end up with 75 million observations.

Table A.2.: Resulting # of observations after each stage of the cleaning process of the RIPS database

		Criteria used for dropping observations for:				
	Raw data	**Duplicates inconsistencies**	**Gender inconsistencies**	**Age inconsistencies**	**Year, health insurance and municipality inconsistencies**	**Non-cronic disease inconsistencies (Visits > 40)**
2003	15,604,624	14,254,818	14,072,568	13,405,473	13,405,339	13,392,688
2004	15,073,600	14,076,802	13,866,713	13,581,426	13,573,153	13,521,192
2005	18,232,997	17,131,222	16,883,553	16,676,901	16,674,072	16,655,556
2006	20,136,840	16,484,105	16,278,870	15,939,438	15,939,424	15,861,089
2007	18,857,543	17,382,016	17,174,260	16,983,990	16,983,455	16,775,938
Total	87,905,604	79,328,963	78,275,964	76,587,228	76,575,443	76,206,463

The final step in the cleaning process is to check for individual inconsistencies in gender and age across years. That is, drop individuals that from one year to the next have inconsistencies on age and gender. Checking for inconsistencies on age we lose 1,671,077 observations, and by gender we lose 861,642. This leaves us with a RIPS dataset that contains 73,673,782 observations.

Appendix B: List of diagnosis considered in the estimations

Table B.1.: List of the diagnosis considered in the estimations (in bold) and the respective proportion that each of them represents in the total number of events in the RIPS database

Chapter	Blocks	Title	Frequency	Percent
I	A00–B99	Certain infectious and parasitic diseases	4,960,821	6.74
II	C00–C99	Neoplasms	396,836	0.54
III	D00–D89	Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	885,8920	1.2
IV	E00–E90	Endocrine, nutritional and metabolic diseases	2,604,835	3.54
V	F00–F99	Mental and behavioural disorders	1,074,272	1.46
VI	G00–G99	Diseases of the nervous system	1,522,774	2.07
VII-VIII	H00–H95	Diseases of the eye and ear	3,803,417	5.16
IX	I00–I99	Diseases of the circulatory system	4,968,850	6.74
X	**J00–J99**	**Diseases of the respiratory system**	**7,356,792**	**9.99**
XI	K00–K93	Diseases of the digestive system	9,360,217	12.7
XII	**L00–L99**	**Diseases of the skin and subcutaneous tissue**	**2,462,229**	**3.34**
XIII	M00–M99	Diseases of the musculoskeletal system and connective tissue	4,688,290	6.36
XIV	N00–N99	Diseases of the genitourinary system	5,415,162	7.35
XV	**O00–O99**	**Pregnancy, childbirth and the puerperium**	**1,010,316**	**1.37**
XVI	P00–P96	Certain conditions originating in the perinatal period	184,197	0.25
XVII	Q00–Q99	Congenital malformations, deformations and chromosomal abnormalities	292,124	0.4
XVIII	R00–R99	Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	5,630,113	7.64
XIX	S00–T98	Injury, poisoning and certain other consequences of external causes	2,850,333	3.86
XX	V01–Y98	External causes of morbidity and mortality	147,272	0.2
XXI	Z00–Z99	Factors influencing health status and contact with health services	14,059,040	19.08
			73,673,782	100