JOURNAL ON EDUCATION IN EMERGENCIES

The Effects of Aerial Spraying of Coca Crops on Child Labor, School Attendance, and Educational Lag in Colombia, 2008-2012

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Source: *Journal on Education in Emergencies*, Vol. 6, No. 1 (October 2020), pp. 84-117

Published by: Inter-agency Network for Education in Emergencies

Stable URL: http://hdl.handle.net/2451/61507

DOI: https://doi.org/10.33682/arm2-m7tn

THE EFFECTS OF AERIAL SPRAYING OF COCA CROPS ON CHILD LABOR, SCHOOL ATTENDANCE, AND EDUCATIONAL LAG IN COLOMBIA, 2008-2012

Claudia Rodriguez

ABSTRACT

Since 1999, one of the main strategies the Colombian government has used to mitigate coca cultivation is to spray the crops with herbicide, which is carried out from airplanes. In this paper I evaluate the consequences of this strategy for rural households in areas where coca is cultivated, specifically the effects of aerial spraying on child labor and education. Since the areas where spraying takes place are fundamentally different from those where it does not, I use a two-stage least squares model, instrumenting for aerial eradication with the number of days high-speed winds in the municipality made spraying difficult. These were days in which the wind was one standard deviation above the municipality's monthly average. This corrects for possible sources of endogeneity due to selection bias. The results of this study show that aerial spraying was associated with a one percentage point increase in the likelihood that children ages 12-17 would work instead of going to school. Crop spraying was further associated with a 0.15 percentage point increase in the probability that older siblings in families living in a coca-growing area would fall behind in school, and a five percentage point increase in the probability that younger siblings would drop out of school. Thus, the findings of this research, based on data that cover the period from 2008 to 2012, suggest that the war on drugs has the potential to generate new barriers to educational access for children who live in areas where aerial spraying occurs.

Received September 20, 2018; revised January 30, 2019; accepted May 17, 2019; electronically published October 2020.

Journal on Education in Emergencies, Vol. 6, No. 1

ISSN 2518-6833

INTRODUCTION

The presence of illicit coca crops is a complex problem for Colombia, given that the coca leaf is the main input in the production of cocaine, the illegal trafficking of which leads to violence and crime (Angrist and Kugler 2008; Mejía and Restrepo 2013). In the last two decades, the Colombian government has adopted policies that combat drug trafficking by reducing the drug supply, primarily by fighting the cultivation of coca leaf crops. This paper studies the consequences of this forced eradication, the government's main mitigation strategy, for child labor and education in areas where coca is cultivated.

As the name indicates, the state carries out the forced eradication of coca crops without the participation of the rural population that cultivates it. There are two types of forced eradication, aerial and manual. Aerial eradication, which involves spraying coca crops with an herbicide called glyphosate, is carried out from planes that fly over the territory. Manual eradication is done by Colombia's armed forces, who enter the growing regions and manually remove or spray the coca plants. I focus in this article on aerial eradication, as it was used most frequently until 2015 and, thus, is relevant for the data analyzed here, which cover the period from 2008 to 2012.

Intensive aerial eradication was introduced in 1999 as part of Plan Colombia, a monetary and military aid program jointly designed by the US and Colombian governments to end drug trafficking using several strategies, which included mitigating cultivation of the coca leaf (Camacho and Mejía 2017). Between 2000 and 2015, the United States invested around US$9.6 billion in the implementation of Plan Colombia (DNP 2016), thereby demonstrating the transnational nature of the policy. Eradication seemed to be an efficient practice, as the coca plants died when sprayed. The strategy was used extensively for 16 years, even though it was only effective for the short term, as the crops were replanted each season.

Studying the impact the eradication policy had on rural households is fundamental, since evidence shows that these households perceived a drop in their income when the crops were sprayed; in other words, they experienced an income shock (Tobón and Restrepo 2011; Espinosa 2009). A qualitative study by Espinosa (2009, 42) described the situation of rural families after the intervention in La Macarena, a region 300 kilometers south of Bogotá, where coca had been cultivated for more than 30 years, making it a focus of the state intervention: "Army planes fumigated

[the] crops and in the process the glyphosate . . . killed several chickens, sickened several cows, contaminated the water well and ruined several hectares of corn." There is similar evidence in other regions of the country that eradication over time led to a loss of employment and assets without reducing the targeted illicit crops, as the conditions in the drug market encouraged farmers to replant the coca (Rivera 2005; Osorio 2003).

According to the National Administrative Department of Statistics (DANE 2017), 10.2 percent of children in Colombia between the ages of 5 and 17 were working in 2012. The literature claims that the primary reason for child labor is poverty (Basu and Van 1998; Ray 2000; Edmonds and Pavcnik 2005), which makes it particularly relevant in the context of coca-growing households, which have high levels of poverty. In addition, regions where coca is cultivated have higher unsatisfied basic needs indices, less access to public services like electricity and roads, and a limited presence of state institutions (Zuleta 2017).[1] This becomes especially relevant in a context of violence and war, as children who work in illegal economies are more likely to earn a living outside the law later in life (Sviatschi 2019). Therefore, it is crucial to study the consequences of the war on drugs' forced eradication of coca crops for child labor and education among children living in coca-growing regions.

The field of education in emergencies (EiE) is focused on the ways crises caused by armed conflict or natural disasters affect access to education. Lewin (2009, 171) defines access to education as "entry and progress at an appropriate age, regular attendance, satisfactory completion, opportunities to study beyond primary school and more equitable distribution of opportunities." EiE researchers highlight how antidrug policies in the framework of the war on drugs have created a state of emergency for the affected population. Although this article does not attempt to evaluate all components of Lewin's definition, it does estimate the impact the war on drugs has on school attendance and progress at the appropriate age for children laboring in the cultivation of coca.

This analysis uses data from DANE's Quality of Life Survey (QLS) for the period 2008-2012, which includes information on child labor and education for children ages 12-17. I crossed this information with municipal data on illicit crops and

1 The unsatisfied basic needs index determines if the needs of a population are covered. Households that do not reach a minimum threshold are classified as poor.

their eradication, which I obtained from the Colombian Drug Observatory and the International Center for Strategic Anti-Narcotics Studies of the Anti-Narcotics Police. This information has two important limitations: first, it is not possible to identify what sector children were working in, and second, it is not possible to be certain if members of a household were indeed growing coca; we can only know that the household was located in a rural part of a coca-growing municipality. Therefore, I cannot determine whether children were involved in illicit or criminal activities.

Between 2008 and 2012, coca cultivation was already ingrained in the economy of rural areas in Colombia, which supports an analysis of the intersection between education, child labor, and coca crop spraying. Focusing on this time period makes it easier to understand the dynamics of Colombia's coca economy before the peace agreement was signed between the government of Colombia and the Revolutionary Armed Forces of Colombia (known as FARC) in 2012. This fact, particularly the expectation that they would benefit from the peace accords if they were growing coca, changed the incentives of farmers in coca-growing areas and possibly led them to increase their crops after the accords where announced (UNODC 2018; Zuleta 2018; Garzón and Llorente 2018). It is also likely that the peace process influenced the government's war on drugs strategy, given that crop spraying decreased dramatically in 2012-2013 and remained low until 2015. Therefore, this article studies the relationships between spraying, child labor, and education prior to 2012.

Using these data, I first ran a municipality and year fixed effects regression to analyze the impact coca crop eradication had on the likelihood a household would send children to work, to school, or to work and school simultaneously, and on educational lag, which refers to children not making progress in school at the appropriate age. I then correct for endogeneity in the spraying decision and for the fact that municipalities where the coca crop was eradicated were fundamentally different from those where it was not.[2] I estimate a two-stage least squares model, instrumenting for aerial eradication with days of strong wind in the municipality because spraying did not take place on those days. Therefore, winds are correlated with eradication but not with child labor or education.

2 Endogeneity occurs when the relationship between two variables is not causal. This is due to three main reasons: double causality, omitted variable, or measurement error on either variable (Angrist and Pischke 2009).

The results show that aerial spraying of coca crops is associated with an increased likelihood that children in a household are working, but no effect was found on the likelihood that they would attend school, that they would be in a lower grade than expected for their age, or that they would do housework. There also is evidence that crop spraying increases the likelihood that older siblings lag behind in school and reduces the likelihood that younger siblings will go to school.

This research contributes to discussions about the war on drugs in various ways. First, it contributes to the careful assessment of a policy that directly affects coca farmers, especially the children in their households. Second, I created a municipal-level wind database using information provided by NASA, which enabled me to use winds as an instrument for aerial spraying, this being the first time this instrument was used in scholarly work. This work also contributes to the discussion on economic shocks, child labor, and education, and to the field of EiE, by providing evidence on the barriers to education that have existed during the war on drugs.

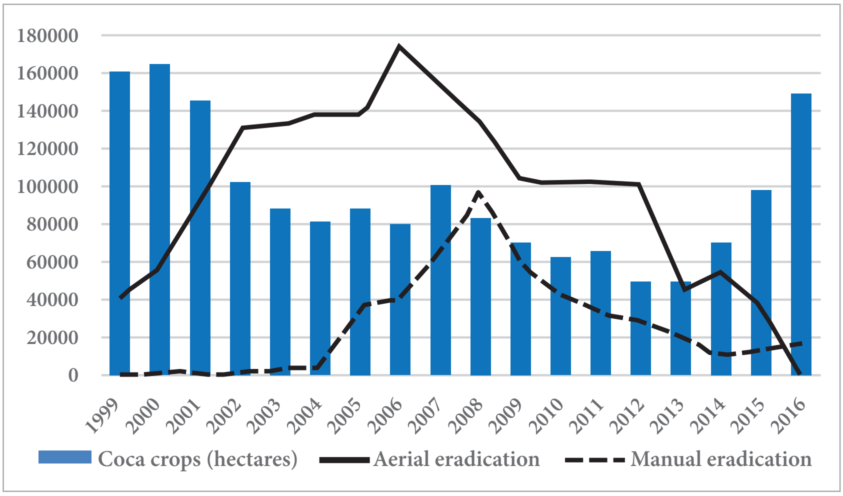
The paper is divided into seven sections: the first contextualizes aerial spraying in Colombia and the coca economy. The second reviews the literature on coca crop eradication policy and the consequences of economic downturns for child labor and education. The third section describes the QLS data for Colombia, the fourth specifies the empirical methodology, and the fifth explains the results. The sixth section offers additional specifications, and the last section presents the study conclusions.

AERIAL SPRAYING OF ILLICIT CROPS IN COLOMBIA AND THE COCA ECONOMY

As mentioned above, the United States during the Clinton administration and the Colombian government under Andrés Pastrana signed Plan Colombia in 1999, with the aim of working together to reduce the supply of drugs (Camacho and Mejía 2017). Under this agreement, approximately US$9.6 billion was invested in the eradication of coca crops by aerial spraying, which was the main strategy for destroying illicit crops in Columbia until 2015. That year, the National Council on Narcotic Drugs passed Resolution 0006 (Consejo Nacional de Estupefacientes 2015), which prohibited using glyphosate in the aerial spraying of crops because it had negative consequences for the health of the population. In the 17 years its use was allowed, more than 1,700,000 hectares of coca were sprayed.[3]

Figure 1 shows the measure of illicit crops and spraying. It shows that spraying was used intensively in the first decade of the 2000s, reaching its peak in 2006 during the Álvaro Uribe administration. It also shows that, until 2015, aerial eradication was more widely used than manual eradication.

Figure 1: Crops and Eradication, 1999-2016

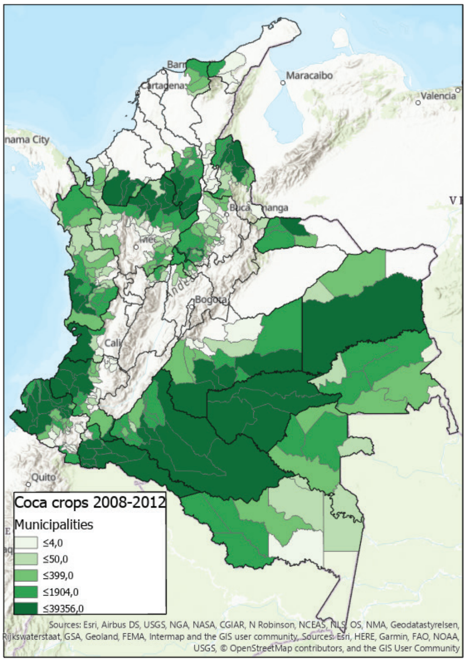


Source: Own elaboration, with data from the Colombian Drug Observatory

Map 1 shows the distribution of coca cultivation in Colombia. Between 2008 and 2012, crops were located in the east of the country, on the Pacific coast, in Catatumbo, and in western Antioquia. Map 2 shows that aerial spraying occurred in these areas. Thus, it is evident that more aerial spraying occurred in the regions with a higher concentration of coca cultivation. Social conditions in the areas where spraying took place were different from those where it did not, in that they had less access to education, health care, and state institutions such as justice or security.

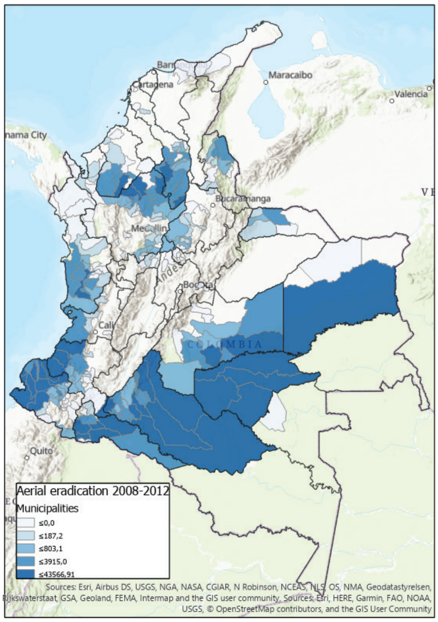
3 One hectare has approximately the same area as two American football fields. In other words, the Colombian government sprayed the equivalent of 3,400,000 football fields during implementation of the policy.

Map 1: Coca Plantations, 2008-2012



Source: Own elaboration, with data from the Colombian Drug Observatory

Map 2: Aerial Eradication, 2008-2012



Source: Own elaboration, with data from the Colombian Drug Observatory

To study child labor in coca-growing areas, it is important first to understand how the coca economy works. Coca crops are labor intensive (Riley 1993; Morales 1986), as they require plowing the land, then planting, fumigating, and harvesting the leaf. The production stage that demands the most labor is the picking or scraping of the leaf, which is demanding, unskilled labor that is both suitable for children and essential to the coca economy (Riley 1993). In Colombia, there is ethnographic evidence of child labor occurring in the villages where coca is grown. Espinosa (2009, 39) found, for example, that even if the parents of a family do not grow coca, "the children have worked with coca under contract: they scrape it, chop it, act as chemists in the artisanal laboratories and transport it to places where the guerrillas buy it."

Children who live in coca-growing regions are likely to be less educated because there is a limited state institutional presence, which contrasts with a high presence of armed forces. In these regions, which are poorly connected to big cities and have high poverty rates, education quality and access are below the national average (Zuleta 2017; Espinosa 2009). For example, a survey of 6,350 coca-growing families conducted in 2018 found an illiteracy rate of 36 percent, while the national average was 5 percent (Garzón and Gélvez 2018). Moreover, the decision to go to school becomes more complex when joining the armed forces is considered an alternative to attending school (Sviatschi 2019).

AERIAL SPRAYING AND THE CONSEQUENCES OF ECONOMIC SHOCKS FOR CHILD LABOR AND EDUCATION

Forced eradication, especially aerial spraying, has been studied in terms of how effective it is in reducing coca cultivation in specific areas of Colombia. Much of the economics literature shows that aerial spraying does not reduce the number of cultivated hectares (Moreno-Sánchez, Kraybill, and Thompson 2003; Reyes 2014). However, Mejía, Restrepo, and Rozo (2015) show that aerial spraying at best helps to reduce the number of hectares planted with coca leaf, but it is not cost-effective. A negative side effect of spraying is that glyphosate has been found in the soil, in fruit and plants, and in animals (Cox 1995; Relyea 2006). Finally, there is evidence that aerial spraying reduces coca-growing communities' confidence in the state and its institutions (Rivera 2005; García 2014), displaces farmers (Espinosa 2009), has negative effects on health (Camacho and Mejía 2017), can exacerbate poverty, and causes infant deaths (Rozo 2014). This study explores how rural families counter the negative economic impact of spraying and the consequences it has for their children's access to education and opportunities in the labor force.

The prevalence of child labor responds to incentives and opportunities (Basu and Tzannatos 2003). However, the economic literature is mixed on what happens in an economic downturn, as two effects—the income effect and the substitution effect—act simultaneously, as in the following example. A household living in a coca-growing area must decide between their children working in the drug industry and earning wages now, or sending them to school so they will be able to earn a higher salary in the future and probably do so working in legal markets.[4] When the government unexpectedly sprays the plantations the children are working in, the region's economy is negatively affected, which results in lower wages earned from the production of drugs.

The income effect refers to the fact that this economic shock reduces household income. Children then must work more hours and reduce the time they dedicate to their education in order to maintain the household's level of consumption. In contrast, the substitution effect refers to what occurs when wages fall after crop spraying and the opportunity costs of not attending school increase. In other words, a child's wage is reduced to an amount lower than what they might earn in the future by getting an education. This reduces child labor in the affected regions and increases the time children dedicate to their education. The final result will depend on which effect is stronger.

Empirical evidence supports the dominance of both effects, and this paper contributes to this discussion. Much of the literature points to the strength of the income effect in the poorest households—that is, a negative income shock leads to an increase in child labor and reduces school attendance (Beegle, Dehejia, and Gatti 2006; Thomas et al. 2004; Guarcello, Mealli, and Rosati 2010; Cogneau and Jedwab 2012). Conversely, improved socioeconomic conditions have been found to reduce child labor and increase school attendance (Edmonds 2005; Beegle, Dehejia, and Gatti 2009). This evidence, collected in Vietnam, Indonesia, Ivory Coast, and Brazil, gives reason to believe that income is the dominant effect of this issue.

4 A household can consist of a family, several families, or unrelated people who live together and share expenses.

On the other hand, in some cases the substitution effect is dominant. For example, after 2002, when gold prices increased significantly and the mining industry was paying a higher wage, Colombia's mining regions had more child laborers than those with no mines, and school attendance and school-level attainment were lower in the mining regions (Santos 2014). The substitution effect also dominated in Brazil, where child labor increased during the coffee boom (Kruger 2007). This paper aims to determine whether crop spraying generates patterns of exclusion from access to education, or if it helps guarantee children's right to education.

Previous studies have analyzed the effects of other drug policies on child labor and education. Dammert (2008) and Angrist and Kugler (2008) examined a policy in Peru, which sought to attack coca leaf trafficking between Peru and Colombia, to estimate the effects on the labor supply of children and adolescents. Dammert (2008) found that the resultant reduction of the coca leaf supply in Peru increased child labor in rural areas of the country but found no reduction in education. In contrast, Angrist and Kugler (2008) showed that coca crops in Colombia expanded after the policy was implemented, which increased adolescent labor. There is also evidence that crop spraying reduced secondary school attendance at the municipal level in Colombia (Rozo 2014). These studies had opposite results, one demonstrating the income effect and the other demonstrating the substitution effect.

This research contributes to the evaluation of forced crop eradication in Colombia, to understanding of the consequences of aerial glyphosate spraying, and to the debate in the literature on the income effect and the substitution effect on child labor in the face of household economic shock. It also contributes to the field of EiE by assessing the relationship between drug policies and the right to education by looking at school attendance, school progress at the appropriate age, and child labor.

QUALITY OF LIFE SURVEY FOR COLOMBIA

The data used in this study correspond to the QLS for Colombia from 2008 to 2012 (no QLS occurred in 2009). The QLS was conducted by DANE in accordance with the World Bank's "Living Standards Measurement Study" (Scott, Steele, and Temesgen 2005). The four resulting cross-sectional datasets are nationally representative for five regions in urban, rural, and scattered rural areas.[5]

5 In Colombia, DANE classifies rural areas into rural and scattered rural areas, the latter being the smallest and most remote towns in the country.

The study used data from 60 coca-growing municipalities in Colombia that cultivated at least one hectare of coca between 2007 and 2012. Data on coca crops were obtained from the Colombian Drug Observatory. The study sample comprised 2,859 children ages 12 to 17 who lived in rural and scattered rural areas in municipalities where coca was being cultivated.

Prioritizing this age group was important because it is the age at which children make the transition from primary school to basic secondary.[6] Education provision in Colombia is higher for primary schools than secondary schools; in 2013, primary education had 87.34 percent coverage in rural areas, middle school education 57.45 percent, and secondary education just 26 percent (DNP 2016). Consequently, the costs associated with schooling for children in this age range are higher than for younger children, and the effect of an economic shock on household income may have a greater impact on education decisions from age 12 upward.[7]

In the QLS sample, 1,226 children lived in areas where crops were not sprayed, while 1,633 lived in municipalities where spraying occurred. Table 1 presents child and household characteristics, along with the socioeconomic characteristics of the municipalities. There were no significant differences between the groups in individual variables such as age, gender, household size, or socioeconomic stratum, which is determined by the level of public services received; for example, public services for those in the lower strata were subsidized by the those in the higher strata. Heads of household in areas where crop eradication occurred had, on average, a lower level of education than heads of household in areas where there was no eradication. Municipal variables also differed between the two groups. For example, municipalities where eradication occurred received less tax revenue, had a higher homicide rate, cultivated a larger area with coca, and experienced more violent actions by armed groups. There were no significant differences in students' results on the Saber 11 standardized test, although the municipalities where crop eradication occurred had more schools per one thousand inhabitants.[8] These findings confirm that the areas where spraying took place were systematically different from those where it did not.

6 Although the theoretical age for this step is 10 or 11, according to the Ministry of National Education (Angulo, Diaz, and Pardo 2011), students in Colombia typically do so at age 11 or 12.

7 As the number of secondary schools is lower, the cost of schooling is higher; for example, students must travel a longer distance to get to school and there are fewer places available in the schools.

8 This is the Colombian standardized test for high school seniors.

Table 1: Characteristics of the Sample

	No aerial eradication (=0)	Aerial eradication (=1)	Difference of means
	(1)	(2)	(3)
A. Characteristics of the child			
Percentage of women	0.46	0.47	-0.02
Age	14.42	14.39	0.02
SES stratum	1.28	1.88	-0.60
B. Household characteristics			
Education level of the head of household	3.03	2.86	0.17***
Household size	5.69	5.56	0.13
Households in the residence	1.03	1.02	0.01**
C. Socioeconomic characteristics of the municipality			
Tax revenues (billions of pesos)	78,382	55,436	22,946**
Coca fields (ha)	74.65	980.12	-905.5***
Homicide rate per 100,000 inhabitants	40.84	66.69	-25.86***
Number of subversive actions	0.07	0.77	-0.69***
Saber 11 score	45.30	45.18	0.13
Educational establishments per 1,000 inhabitants	2.38	2.79	-0.41***
Sample size	1,226	1,633	2,859

Source: QLS (2008-2012), Colombian Drug Observatory, Municipal Panel of the Center for Economic Development Studies (CEDE). Children who were between 12 and 17 years old, living in rural and scattered rural areas in coca growing municipalities. *** p<0.01, ** p<0.05, * p<0.1

The labor variables chosen for this analysis are in keeping with the International Labor Organization definition of child labor; that is, a child is considered economically active if they worked for at least an hour in the previous week, including housework (Edmonds and Pavcnik 2005). I used the following variables: whether the child did mainly housework, whether they worked outside the home, whether they went to school, and whether they worked and attended school simultaneously.[9] While it was possible to determine whether a child was working, it was not possible to verify the sector in which they worked. In addition, to calculate educational lag, I constructed a dichotomous variable that took the value of 1 if the child had not passed the school grade stipulated for their age by the Ministry of Education and 0 if they had. The ages are shown in Table A1.

Table 2 shows the labor and education variables between municipalities with and without aerial eradication. No significant differences occurred in the labor variables between the two groups; however, most children in the coca-growing municipalities were lagging behind in school and this proportion was higher in municipalities where there was aerial spraying. About 1,700 observations are not accounted for in the measurement of lag, since many individuals did not report the grade they were in or the last grade passed.

Table 2: Labor and Education Variables for Children Ages 12-17 as Percentages of the Sample

	No aerial eradication (=0)	Aerial eradication (=1)	Difference of means
	(1)	(2)	(3)
Housework	0.12	0.12	-0.001
Work	0.07	0.08	-0.01
Study	0.76	0.75	0.01
Work and study	0.05	0.06	-0.004
Children lagging behind	0.92	0.95	-0.03
Sample size	1,226	1,633	2,859

Source: QLS (2008-2012). Children who were living in rural and scattered rural areas in coca-growing municipalities. *** p<0.01, ** p<0.05, * p<0.1

METHODOLOGY

As mentioned above, the areas where spraying took place were fundamentally different from those where it did not. This can cause endogeneity on the effect with child labor because child labor in poor areas may be influenced by socioeconomic

9 The QLS has a question about hours worked in the previous week. However, this is not used as an outcome variable, as high underreporting prevents making estimates.

conditions. To eliminate endogeneity, I propose the following model to estimate the effects of forced eradication on child labor and education:

$$Y_{ijt} = \beta_0 + \beta_1 E_{jt} + X_i \beta + X_j \alpha + \delta_j + \delta_t + \varepsilon_{ijt} \ ,$$

where Y_{ijt} are the dependent variables for child *i,* in municipality *j,* in year *t:* whether the child studies or not, whether they work or not, whether they do both simultaneously, whether their main activity is to engage in household chores, or whether they are lagging behind in school. E_{jt} is the independent variable of interest and corresponds to the number of square kilometers eradicated in municipality *j* in year *t.* Matrix $\mathcal{X}_i$ refers to child- and household-level variables. Child-related variables include age, gender, household size, number of households in the residence, stratum, and head of household education level. Age is included, as children are more likely to drop out as they get older. Household-related variables include household size, number of households in the residence, stratum, and head of household education level. These household variables are included as an approximation of the child's socioeconomic conditions.

Matrix $\mathcal{X}_j$ refers to the municipal controls: hectares cultivated with coca, tax revenues, homicide rate, subversive actions, results of the Saber 11 test, and the number of schools. The number of hectares cultivated with coca is included because the larger the area planted, the greater the amount of spraying. The rates of homicides and subversive actions are included to capture incidents of violence and the presence of armed groups in the municipality; tax revenues are a proxy for state institutional capacity; and the number of educational establishments and results of the Saber 11 test indicate the educational opportunities available and quality of education in the municipality. The coefficient δ_j corresponds to municipality fixed effects to control for variables that do not change over time, such as the size of the municipality or its altitude, and δ_t corresponds to year fixed effects to control for shocks that affect all municipalities equally. Standard errors are clustered by household.

This methodology controls for unobservable variables that are constant over time in each of the municipalities and for annual shocks that affect all municipalities equally. Therefore, the threat to the identification strategy is unobservable variables that change over time due to systematic differences between the two groups. To solve this problem, an instrumental variable strategy is adopted, which I explain in the following section.

Identification Strategy Using Instrumental Variables

High wind shocks in municipalities are used as an instrumental variable to solve endogeneity problems, since this factor is taken into account when spraying. In fact, the police information system reports climate, coca crop, and conflict variables for the entire national territory. On the day of spraying, the police decide where to spray based on variables such as wind, temperature, if the area has a mountainous terrain, and the presence of armed groups. Spraying flights require favorable conditions because pilots must descend quickly to a few meters above the ground, spray, and return to their previous height, all at a high speed. If the information system reports strong winds, they do not spray.

The more wind there is, the harder it is to spray, so the instrument meets the relevance condition. This identification strategy assumes that there is no relationship between wind and child labor or education. This is a safe assumption, as it is unlikely that households take the wind into account when making decisions about their children's work and education, or that the wind directly affects the decisions they make; therefore, the exclusion assumption is met. The wind data were obtained from the NASA GES DISC base, which contains satellite information on winds at a resolution of 1 degree or in pixels of about 60 km^2. This information was aggregated at the municipal level in order to cross it with the spraying data. The instrument is calculated as follows:

$$V_{jt} = \sum_{d=1}^{365} 1 \left\{ v(d) > v_m{}' + \sigma_m \right\} \ ;$$

that is, the number of days when the winds were one monthly standard deviation (σ_m) above the monthly average (v_m') in municipality j in year t. This way, the variable captures the number of days on which a municipality experienced abnormal wind shocks. This indicator is calculated monthly to take into account the seasonality of the winds. Table A2 shows some descriptive statistics for this variable, under which the municipalities had wind shocks for a fifth of the year on average. These shocks vary a lot between municipalities: the minimum value is 0 and the maximum is 311.

Thus, the first-stage estimation is

$$E_{jt} = \beta_0 + \beta_1 V_{jt} + X_i\beta + X_j\alpha + \delta_j + \delta_t + \varepsilon_{ijt} \ ,$$

where E_{jt} is the number of square kilometers sprayed in municipality j in year t, V_{jt} is the calculated indicator, X_j is the matrix of municipal controls, X_j is the matrix of individual controls, are δ_j municipality fixed effects, and δ_t is time fixed effects.

From this regression, an estimate of aerial eradication is recovered (E_{jt}^), and the second stage is calculated as

$$Y_{ijt} = \beta_0 + \beta_1 E_{jt}{}^{\wedge} + X_i\beta + X_j\alpha + \delta_j + \delta_t + \varepsilon_{ijt} \ ,$$

where Y_{ijt} are the variables of child labor and education, which are regressed on the eradication estimate, individual and municipal controls, and municipality and year fixed effects.

Heterogeneous Effects

I estimated additional specifications to verify if forced eradication had differentiated effects on child labor and education. I included gender differences because of the working conditions in the coca-growing areas, or for cultural reasons. Differentiated effects also were verified by birth order. I conducted this exercise to assess whether older or younger siblings within a household were affected differently. The equation to estimate these heterogeneous effects is

$$Y_{ijt} = \beta_0 + \beta_1 E_{jt}{}^{\wedge} + \beta_2 D_i + \beta_3 D_i * E_{jt}{}^{\wedge} + X_i\beta + X_j\alpha + \delta_j + \delta_t + \varepsilon_{ijt} \ ,$$

where D_i is a dummy that varies according to the differentiated effect being explored. The endogenous variables E_{jt} and $D_i * E_{jt}$ are instrumented with the indicator V_{jt} and with the interaction between the indicator and the dummy ($V_{jt} * D_i$). The dichotomous variable for gender is equal to 1 if female and 0 if male. I also ran two regressions for birth order, in which D_i is equal to 1 if the child is the youngest in the family and 0 if otherwise, and another in which D_i is 1 when the child is the oldest in the family and 0 if otherwise.

RESULTS

This section presents the results of two models: one that only includes municipality and year fixed effects, and one that includes the two-stage least squares estimate. The descriptive statistics show no significant differences in labor-related variables and, given the income and substitution effects, it is not clear what the expected bias of the regressions may be.

Table 3 summarizes the results of the model with municipality and year fixed effects. In this case, spraying an additional square kilometer is related to an increase in the probability of a child working by 0.026 percentage points, and an increase in the probability of a child working and attending school simultaneously by 0.024 percentage points. This shows that, for this particular case, the income effect dominates in labor and education decisions after an economic shock resulting from spraying. I find no effects on the probability of children doing housework, attending school, or lagging behind in school.

Table 3: Effect of Aerial Eradication on Variables of Interest, Including Fixed Effects of Municipality and Year

Variables	Housework	Work	Study	Work and study	Falling behind
	(1)	(2)	(3)	(4)	(5)
Aerial eradication (km^2)	0.00180	0.00266*	-0.00173	0.00246*	0.00236
	(0.00144)	(0.00138)	(0.00215)	(0.00131)	(0.00189)
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Instrumental variable	No	No	No	No	No
Sample size	2,251	2,251	2,251	2,251	521
R-squared	0.145	0.108	0.184	0.102	0.222

Source: QLS (2008-2012), Colombian Drug Observatory and CEDE Municipal Panel. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All regressions are controlled by age, household size, number of households in the residence, stratum, education of the head of household, gender, hectares cultivated with coca, tax income, homicide rate, subversive actions, educational establishments, and the results of the Saber 11 test. Standard errors are robust and are clustered by household.

The results of the instrumental variable estimate are presented below. Table 4 shows the coefficient of the first stage of the regression. As expected, the relationship between wind shocks and aerial eradication is negative: the more days of strong winds, the less aerial eradication in the municipality during the year. The coefficient is significant at the 1 percent level and the F statistic is equal to 17.72, so the relevance assumption is met.

Table 4: First Stage. Effect of Wind Shocks on Aerial Eradication

Variables	Aerial eradication
	(1)
Winds	-0.143***
	(0.0409)
Municipality fixed effects	Yes
Year fixed effects	Yes
Sample size	2,251
R-squared	0.945
F statistic	17.22

Source: QLS (2008-2012), Colombian Drug Observatory, CEDE Municipal Panel, and NASA. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We control for age, size of the household, number of households in the residence, stratum, education of the head of household, gender, hectares cultivated with coca, tax income, homicide rate, subversive actions, educational establishments, and the results of the Saber 11 test. Standard errors are robust and are corrected by household clusters.

The second stage is summarized in Table 5. Like the fixed effects estimate, spraying an additional square kilometer is associated with an increase in the probability of a child working by one percentage point. This estimate is significant at the 10 percent level. It is important to note that, on average, 530 square kilometers were sprayed per year during the study period. The coefficient of the fixed effects estimate is biased downward when compared to this result. This is because the two-stage model accounts for unobservable variables that can result in less child labor in these areas, such as safety conditions, health, economic dynamism, and others. No significant effects are found on a child doing housework, on working and attending school simultaneously, or on their educational lag.

Table 5: Effect of Aerial Eradication on Variables of Interest Using Two-Stage Least Squares

Variables	Housework	Work	Study	Work and study	Falling behind
	(1)	(2)	(3)	(4)	(5)
Aerial eradication (km^2)	0.00998	0.0100*	-0.00879	0.00560	0.00349
	(0.00690)	(0.00584)	(0.00949)	(0.00531)	(0.0102)
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Instrumental variable	Yes	Yes	Yes	Yes	Yes
Sample size	2,251	2,251	2,251	2,251	521
R-squared	0.131	0.091	0.178	0.098	0.214

Source: QLS (2008-2012), Colombian Drug Observatory, CEDE Municipal Panel, and NASA. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We control for age, size of the household, number of households in the residence, stratum, education of the head of household, gender, hectares cultivated with coca, tax income, homicide rate, subversive actions, educational establishments, and the results of the Saber 11 test. Standard errors are robust and are clustered by household.

Heterogeneous Effects: Gender and Birth Order

Heterogeneous Effects by Gender

Table 6 shows that, on average, girls do more housework than boys, work less, are less likely to work and attend school simultaneously, and attend school more. However, I find no gender-differentiated effects. This is because the data do not identify what the children are working on and, while it is true that men work more on the crops, women may be working in other sectors.

Table 6: Heterogeneous Effects of Aerial Eradication by Gender

Variables	Housework	Work	Study	Work and study	Falling behind
	(1)	(2)	(3)	(4)	(5)
Aerial eradication (km^2)	0.00138	0.00232	-0.000669	0.00193	0.00198
	(0.00141)	(0.00131)	(0.00212)	(0.00122)	(0.00185)
Female	0.145***	-0.0532***	0.0630***	-0.0448***	0.0287
	(0.0146)	(0.0111)	(0.0179)	(0.00976)	(0.0259)
Aerial eradication* female	3.41e-07	6.86e-06	-1.12e-05	8.95e-06	1.79e-07
	(5.66e-06)	(7.74e-06)	(8.50e-06)	(7.39e-06)	(5.51e-06)
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Instrumental variable	Yes	Yes	Yes	Yes	Yes
Sample size	2,251	2,251	2,251	2,251	521
R-squared	0.143	0.109	1.183	0.103	0.221

Source: QLS (2008-2012), Colombian Drug Observatory, CEDE Municipal Panel, and NASA. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We control for age, size of the household, number of households in the residence, stratum, education of the head of household, gender, hectares cultivated with coca, tax income, homicide rate, subversive actions, educational establishments, and the results of the Saber 11 test. Standard errors are robust and are clustered by household.

Heterogeneous Effects by Birth Order

Table 8 presents the results of the heterogeneous effects on older siblings. In this case, older siblings are more likely than younger siblings to fall behind in school. Spraying an additional square kilometer is related to an increase in the probability that the older sibling is behind in school, 0.15 percentage points more than for the rest of the children in a family. I find no effect on the other dependent variables. This shows that older children do not stop attending school, but their academic performance may be affected.

Table 8: Heterogeneous Effects of Aerial Eradication by Birth Order

Variables	Housework	Work	Study	Work and study	Falling behind
	(1)	(2)	(3)	(4)	(5)
Aerial eradication (km^2)	0.000422	0.00432***	0.000549	0.00411**	0.00405**
	(0.00146)	(0.00177)	(0.00218)	(0.00172)	(0.00199)
Oldest sibling	0.0130	0.0203	-0.0191	0.0217*	-0.0537*
	(0.0147)	(0.0135)	(0.0196)	(0.0114)	(0.0290)
Aerial eradication* oldest sibling	0.000731	0.000435	2.35e-05	0.000925	0.00150**
	(0.000526)	(0.000820)	(0.000885)	(0.000787)	(0.000644)
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Instrumental variable	Yes	Yes	Yes	Yes	Yes
Sample size	1,819	1,819	1,819	1,819	362
R-squared	0.117	0.136	0.192	0.126	0.308

Source: QLS (2008-2012), Colombian Drug Observatory, CEDE Municipal Panel, and NASA. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We control for age, size of the household, number of households in the residence, stratum, education of the head of household, gender, hectares cultivated with coca, tax income, homicide rate, subversive actions, educational establishments, and the results of the Saber 11 test. Standard errors are robust and are clustered by household.

Table 9 shows that younger siblings have a lower probability than their older siblings of being in school, and that eradicating an additional square kilometer of coca is associated with a 5.03 percentage point lower probability of a child attending school. No heterogeneous effects were found for the rest of the variables analyzed.

Table 9: Heterogeneous Effects of Aerial Eradication by Birth Order

Variables	Housework	Work	Study	Work and study	Falling behind
	(1)	(2)	(3)	(4)	(5)
Aerial eradication (km^2)	0.000646	0.00458***	0.000904	0.00388**	0.00458**
	(0.00150)	(0.00168)	(0.00216)	(0.00162)	(0.00213)
Youngest sibling	0.000507	-0.000638	-0.00186*	-0.000810	0.000668
	(0.000567)	(0.000900)	(0.00102)	(0.00799)	(0.000822)
Aerial eradication* youngest sibling	0.00619	0.00619	-0.0503**	-0.00342	0.0426
	(0.0167)	(0.0167)	(0.0236)	(0.0134)	(0.0323)
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Instrumental variable	Yes	Yes	Yes	Yes	Yes
Sample size	1,819	1,819	1,819	1,819	362
R-squared	0.117	0.136	0.192	0.126	0.308

Source: QLS (2008-2012), Colombian Drug Observatory, CEDE Municipal Panel, and NASA. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We control for age, size of the household, number of households in the residence, stratum, education of the head of household, gender, hectares cultivated with coca, tax income, homicide rate, subversive actions, educational establishments and the results of the Saber 11 test. Standard errors are robust and are clustered by household.

Summary of Main Results

The previous sections show that spraying an additional square kilometer of coca crops is associated with an increase of one percentage point in the probability that children ages 12-17 are working. However, there is no statistical evidence of effects on the probability they are attending school. For older siblings, spraying is associated with a 0.15 percentage point increase in the probability of falling behind in school, which suggests that this policy may be affecting their academic performance. Finally, for youngest siblings, aerial eradication is negatively related to the likelihood of attending school.

The results show that the income effect dominates in this case for education and labor decisions after an economic shock caused by aerial eradication. This suggests that Colombia's spraying policy may be creating barriers to education access and to regular school attendance among children in coca-growing regions.

ADDITIONAL SPECIFICATIONS

Restriction of Sample

As proposed by Imbens (2015), I removed extreme values from the sample. To do this, I built a propensity score for the probability of being in a municipality with aerial spraying. The sample was restricted to observations between 0.1 and 0.9 of that score and to those within the region of common support.[10] Thus, as outliers and atypical values were eliminated, the results were met for a comparable proportion of the sample. Table 10 shows the composition of the new sample. The differences between areas with and without crop eradication are still statistically significant for the municipal-level variables, but the observations in municipalities with high coca cultivation and in conflict-intensive regions were eliminated from the sample.

10 The variables that determine the spraying were used to calculate the propensity score: cultivated hectares, subversive actions, homicide rate, and tax revenues.

Table 10: Comparison between the Complete Sample and Sample Restricted to the Common Support and Removing the Tales of the Distribution

	Full sample			**Restricted sample**		
	No aerial eradication (=0)	Aerial eradication (=1)	Difference of means	No aerial eradication (=0)	Aerial eradication (=1)	Difference of means
A. Characteristics of the child						
Percentage of women	0.46	0.47	-0.02	0.46	0.46	0.00
Age	14.42	14.39	0.02	14.42	14.39	0.03
SES stratum	1.28	1.88	-0.60	1.28	1.22	0.06
B. Household characteristics						
Education level of the head of household	3.03	2.86	0.171***	3.04	2.90	0.14**
Household size	5.69	5.56	0.13	5.67	5.41	0.26*
Households in the residence	1.03	1.02	0.013**	1.04	1.03	0.01
C. Socioeconomic characteristics of the municipality						
Tax revenues (billions of pesos)	78,381	55,435	22,946**	45,202	37,917	7,285***
Coca fields (ha)	74.65	980.12	-905.47***	73.65	227.95	-154.3***
Homicide rate per 100,000 inhabitants	40.84	66.69	-25.857***	39.11	60.7	-21.59***
Number of subversive actions	0.07	0.77	-0.697***	0.076	0.39	-0.314***
Saber 11 score	45.30	45.18	0.127	45.3	45.91	-0.61
Educational establishments per 1,000 inhabitants	2.38	2.79	-0.411***	2.330	2.840	-0.51***
Sample size	1,226	1,633	2,859			2,390

Source: QLS (2008-2012), Colombian Drug Observatory and CEDE Municipal Panel. Children who were between 12 and 17 years old, living in rural and scattered rural areas in coca growing municipalities. *** p<0.01, ** p<0.05, * p<0.1

As shown in Table 11, the effect of eradication on the probability of a child working is positive, and is slightly lower than the one found with the complete sample (0.02 percentage points). This means that aerial spraying increases the probability of a child working, even if I do not take outliers and atypical values into account. There also are no significant effects on the other variables of interest.

Table 11: Effect of Aerial Eradication on Variables of Interest with Sample Restricted to Common Support and Removing the Tails of the Distribution

Variables	Housework	Work	Study	Work and study	Falling behind
	(1)	(2)	(3)	(4)	(5)
Aerial eradication (km^2)	0.00775	0.00840*	-0.00720	0.00494	-0.00233
	(0.00493)	(0.00419)	(0.0712)	(0.00388)	(0.00808)
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Instrumental variable	Yes	Yes	Yes	Yes	Yes
Sample size	2,084	2,084	2,084	2,084	475

Source: QLS (2008-2012), Colombian Drug Observatory, CEDE Municipal Panel, and NASA. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We control for age, size of the household, number of households in the residence, stratum, education of the head of household, gender, hectares cultivated with coca, tax income, homicide rate, subversive actions, educational establishments, and the results of the Saber 11 test. Standard errors are robust and are corrected by household clusters.

Rainfall Included as a Control

A threat to the identification strategy is the relationship between winds and rain. If it is a strong positive relationship, the previous results may not be causal because, like wind, rain makes aerial spraying impossible and is also considered a shock to agricultural productivity. Rain also can be associated with school attendance, as it makes it difficult for students and teachers to get to school and can even affect school facilities. Therefore, results could be biased by rain shocks. Tables 12 and 13 show that, on the one hand, the first stage holds when rainfall shocks in the municipality are included as a control (calculated similarly to wind shocks). On the other hand, the results of the second stage are similar to those found without controlling for precipitation, when this control is included. Therefore, rain does not affect the instrument and the identification strategy is valid.

Table 12: First-Stage Effect of Wind Shocks on Aerial Eradication, Including Rainfall as a Control

Variables	Aerial eradication
	(1)
Winds	-0.189***
	(0.0467)
Municipality fixed effects	Yes
Year fixed effects	Yes
Sample size	1,998
R-squared	0.945

Source: QLS (2008-2012), Colombian Drug Observatory, CEDE Municipal Panel, NASA, and IDEAM. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We control for age, size of the household, number of households in the residence, stratum, education of the head of household, gender, hectares cultivated with coca, tax income, homicide rate, subversive actions, educational establishments, and the results of the Saber 11 test. Standard errors are robust and are clustered by household.

Table 13: Effect of Aerial Eradication on Variables of Interest, Controlling for Rainfall

Variables	Housework	Work	Study	Work and study	Falling behind
	(1)	(2)	(3)	(4)	(5)
Aerial eradication (km^2)	0.00857	0.00960*	-0.00858	0.00477	-0.00370
	(0.00656)	(0.00544)	(0.00821)	(0.00498)	(0.0117)
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Instrumental variable	Yes	Yes	Yes	Yes	Yes
Sample size	1,819	1,819	1,819	1,819	362
R-squared	0.117	0.136	0.192	0.126	0.308

Source: QLS (2008-2012), Colombian Drug Observatory, CEDE Municipal Panel, NASA, and IDEAM. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We control for age, size of the household, number of households in the residence, stratum, education of the head of household, gender, hectares cultivated with coca, tax income, homicide rate, subversive actions, educational establishments, and the results of the Saber 11 test. Standard errors are robust and are clustered by household.

Placebo Test as a Robustness Check

The analysis carried out in this study limited the sample to the rural and scattered rural areas of coca-growing municipalities because aerial eradication did not occur in urban areas. Therefore, there should be no effect of spraying on child labor in urban areas. Table 14 shows the results of this exercise. I examined children living in urban areas only in the same municipalities as the original sample, and there was no relationship between aerial crop eradication and children's labor and education variables. Furthermore, although the coefficients were not significant, the signs of the coefficients were the opposite of those found above.

Table 14: Placebo Test in Urban Areas

Variables	Housework	Work	Study	Work and study	Falling behind
	(1)	(2)	(3)	(4)	(5)
Aerial eradication (km^2)	-0.000393	-0.00181	0.00217	1.79e-05	-0.0176
	(0.00583)	(0.00371)	(0.00504)	(0.00340)	(0.0191)
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Instrumental variable	Yes	Yes	Yes	Yes	Yes
Sample size	3,505	3,505	3,505	3,505	486
R-squared	0.099	0.059	0.128	0.062	0.234

Source: QLS (2008-2012), Colombian Drug Observatory, CEDE Municipal Panel, and NASA. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We control for age, size of the household, number of households in the residence, stratum, education of the head of household, gender, hectares cultivated with coca, tax income, homicide rate, subversive actions, educational establishments, and the results of the Saber 11 test. Standard errors are robust and are clustered by household.

CONCLUSION

This study contributes to the empirical evaluation of the aerial spraying strategy in Colombia and its consequences for rural households in areas where coca is cultivated. Forced eradication was the country's main strategy for combating coca cultivation from 1999 to 2015; however, little was known about the effects this policy had on households, how loss of the crop was counteracted, and how spraying affected rural children.

The analysis used a two-stage least squares methodology, with NASA satellite wind data as the instrumental variable. I found that spraying one additional square kilometer of coca crops was associated with a one percentage point increase in the likelihood of working for children ages 12 to 17; I found no effects on their probability of attending school. The results are relevant because an average of 530 square kilometers were sprayed per year between 2008 and 2012. The results show that the income effect dominated in the case of aerial eradication because children were more likely to work in the event of an economic shock to a household.

There also is evidence of the heterogeneous effects of aerial eradication on educational lag. On the one hand, spraying was associated with a 0.15 percentage point increase in the probability that the oldest sibling would fall behind in school. This suggests that, even if the oldest children did not stop attending school, their academic performance may have declined. On the other hand, there was a negative relationship between aerial eradication and the probability that the youngest sibling in a family would attend school, making them five percentage points less likely to attend school than the rest of the children. Thus, this study shows that aerial spraying of coca crops, a policy framed in the logic of the war on drugs, may be creating barriers to children's access to education in rural areas. If children must perform work activities in addition to attending school, their progress in school at the appropriate age will be negatively affected.

According to these results, the forced eradication of illicit crops may be generating unexpected effects in coca-growing areas, such as an increase in child labor, which translates into less time spent on education or recreation. Future investigations should explore the sectors children are working in, as this study does not do so. This is important, because many young people in the coca-growing areas start their working life in an illegal economy (Sviatschi 2019; Espinosa 2009), which could have negative consequences for their future. The number of hours dedicated to work also should be studied, since the cost to children of working while also attending school is that they have less time for studying, leisure, recreation, and rest, all of which are key to their healthy development.

REFERENCES

Angrist, Joshua D., and Adriana Kugler. 2008. "Rural Windfall or a New Resource Curse? Coca, Income, and Civil Conflict in Colombia." *The Review of Economics and Statistics* 90: 191-215. https://doi.org/10.1162/rest.90.2.191.

Angrist, Joshua D., and Jörn-Steffen Pischke. 2009. *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton, NJ: Princeton University Press.

Angulo Salazar, Roberto Carlos, Yadira Díaz Cuervo, and Renata Pardo Pinzón. 2011. *Índice de Pobreza Multidimensional para Colombia (IPM-Colombia) 1997-2010*. Bogotá: Departamento Nacional De Planeación, Archivos De Economía. https://colaboracion.dnp.gov.co/cdt/estudios%20econmicos/382.pdf.

Basu, Kaushik, and Pham Hoang Van. 1998. "The Economics of Child Labor." *American Economic Review* 88: 412-27. https://www.jstor.org/stable/116842.

Basu, Kaushik, and Zafiris Tzannatos. 2003. "The Global Child Labor Problem: What Do We Know and What Can We Do?" *World Bank Economic Review* 17: 147-73. https://doi.org/10.1093/wber/lhg021.

Beegle, Kathleen, Rajeev Dehejia, and Roberta Gatti. 2006. "Child Labor and Agricultural Shocks." *Journal of Development Economics* 81: 80-96. https://doi.org/10.1016/j.jdeveco.2005.05.003.

Beegle, Kathleen, Rajeev Dehejia, and Roberta Gatti. 2009. "Why Should We Care about Child Labor?" *Journal of Human Resources* 44: 871-89. https://doi.org/10.3368/jhr.44.4.871.

Camacho, Adriana, and Daniel Mejía. 2017. "The Health Consequences of Aerial Spraying of Illicit Crops: The Case of Colombia." *Journal of Health Economics* 54: 147-60. https://doi.org/10.1016/j.jhealeco.2017.04.005.

Cogneau, Denis, and Rémi Jedwab. 2012. "Commodity Price Shocks and Child Outcomes: The 1990 Cocoa Crisis in Côte d'Ivoire." *Economic Development and Cultural Change* 60 (3): 507-34. https://doi.org/10.1086/664017.

Consejo Nacional de Estupefacientes. 2015. *Resolución 0006. Por la cual se ordena la suspensión del uso del herbicida glifosato en las operaciones de erradicación de cultivos ilícitos mediante aspersión aérea*. http://www.suin-juriscol.gov.co/viewDocument.asp?ruta=Resolucion/30031849.

Cox, Caroline. 1995. "Glyphosate, Part 2: Human Exposure and Ecological Effects." *Journal of Pesticide Reform* 15: 14-20.

Dammert, Ana C. 2008. "Child Labor and Schooling Response to Changes in Coca Production in Rural Peru." *Journal of Development Economics* 86: 164-80. https://doi.org/10.1016/j.jdeveco.2007.06.007.

DANE. 2017. *Boletín Técnico: Gran Encuesta Integrada de Hogares (GEIH)—Trabajo Infantil*. Bogotá: Departamento Administrativo Nacional de Estadística. https://www.dane.gov.co/files/investigaciones/boletines/ech/jobinfantil/bol_trab_inf_2017.pdf.

DNP (Departamento Nacional de Planeacion). 2016. *Plan Colombia: Balance de los 15 años*. Bogotá: DNP. https://sinergia.dnp.gov.co/Documentos%20de%20Interes/PLAN_COLOMBIA_Boletin_180216.pdf.

Edmonds, Eric V. 2005. "Does Child Labor Decline with Improvements in Economic Status?" *Journal of Human Resources* 40: 77-99. https://doi.org/10.3368/jhr.XL.1.77.

Edmonds, Eric V., and Nina Pavcnik. 2005. "Child Labor in the Global Economy." *Journal of Economic Perspectives* 19: 199-220. https://doi.org/10.1257/0895330053147895.

Espinosa, Nicolás. 2009. *Politica de Vida y Muerte: Etnografia de la Violencia Diaria en la Sierra de la Macarena*. Medellín: Universidad de Antioquia, Instituto de Estudios Regionales.

García Sánchez, Miguel. 2014. "Cultivos Ilícitos y Confianza Institucional en Colombia." *Política y Gobierno* 11: 95-126. https://www.scielo.org.mx/pdf/pyg/v21n1/v21n1a4.pdf.

Garzón Vergara, Juan Carlos, and Juan David Gélvez. 2018. *¿Quiénes Son las Familias que Viven en Zonas con Cultivos de Coca?* Bogotá: Fundación Ideas para la Paz. https://www.ideaspaz.org/publications/posts/1690.

Garzón Vergara, Juan Carlos, and María Victoria Llorente. 2018. *¿Por Qué Siguen Aumentando los Cultivos de Coca en Colombia? Los Desafíos para el Proximo Gobierno.* Bogotá: Fundación Ideas para la Paz. http://cdn.ideaspaz.org/media/website/document/5b33d29448b3b.pdf.

Guarcello, Lorenzo, Fabrizia Mealli, and Furio Camillo Rosati. 2010. "Household Vulnerability and Child Labor: The Effect of Shocks, Credit Rationing and Insurance." *Journal of Population Economics* 23: 169-98. https://doi.org/10.1007/s00148-008-0233-4.

Imbens, Guido W. 2015. "Matching Methods in Practice: Three Examples." *Journal of Human Resources* 50: 373-419. https://doi.org/10.3368/jhr.50.2.373.

Kruger, Diana. 2007. "Coffee Production Effects on Child Labor and Schooling in Rural Brazil." *Journal of Development Economics* 82 (2): 448-63. https://doi.org/10.1016/j.jdeveco.2006.04.003.

Lewin, Keith M. 2009. "Access to Education in Sub-Saharan Africa: Patterns, Problems and Possibilities." *Comparative Education* 45 (2): 151-74. https://doi.org/10.1080/03050060902920518.

Mejía, Daniel, and Pascual Restrepo. 2013. "Bushes and Bullets: Illegal Cocaine Markets and Violence in Colombia." Documento CEDE No. 011934. Bogotá: Universidad de los Andes, CEDE. https://economia.uniandes.edu.co/components/com_booklibrary/ebooks/dcede2013-53.pdf.

Mejía, Daniel, Pascual Restrepo, and Sandra V. Rozo. 2015. *On the Effects of Enforcement on Illegal Markets: Evidence from a Quasi-Experiment in Colombia.* Policy Research Working Paper. Washington, DC: World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/517811468189273130/on-the-effects-of-enforcement-on-illegal-markets-evidence-from-a-quasi-experiment-in-colombia.

Morales, Edmundo. 1986. "Coca and Cocaine Economy and Social Change in the Andes of Peru." *Economic Development and Cultural Change* 35: 143-61. https://doi.org/10.1086/451575.

Moreno-Sanchez, Rocio, David S. Kraybill, and Stanley R. Thompson. 2003. "An Econometric Analysis of Coca Eradication Policy in Colombia." *World Development* 31 (2): 375-83. https://doi.org/10.1016/S0305-750X(02)00192-4.

Osorio, Ana Rocío. 2003. "Aproximaciones a los efectos ambientales, sociales y económicos de la erradicación aérea en Colombia." *Agroalimentaria* 17: 61-72. http://ve.scielo.org/scielo.php?script=sci_arttext&pid=S1316-03542003000200005.

Ray, Ranjan. 2000. "Child Labor, Child Schooling, and Their Interaction with Adult Labor: Empirical Evidence for Peru and Pakistan." *The World Bank Economic Review* 14 (2): 347-67. https://doi.org/10.1093/wber/14.2.347.

Relyea, Rick A. 2006. "The Impact of Insecticides and Herbicides on the Biodiversity and Productivity of Aquatic Communities: Response." *Ecological Applications* 16: 2027-32. https://doi.org/10.1890/03-5342.

Reyes, Luis Carlos. 2014. "Estimating the Causal Effect of Forced Eradication on Coca Cultivation in Colombian Municipalities." *World Development* 61: 70-84. https://doi.org/10.1016/j.worlddev.2014.03.024.

Riley, K. Jack. 1993. *Snow Job? The Efficacy of Source Country Cocaine Policies*. Santa Monica, CA: RAND. https://www.rand.org/pubs/rgs_dissertations/RGSD102.html.

Rivera, Guillermo. 2005. *Cultivos de Coca, Conflicto y Deslegitimación del Estado en el Putumayo*. Bogotá: Universidad Externado de Colombia.

Rozo, Sandra V. 2014. "The Unintended Consequences of Anti-Drug Programs in Producing Countries." *SSRN Electronic Journal*. http://www.sandravrozo.com/uploads/2/9/3/0/29306259/spraying_rozo_mar_2016.pdf.

Santos, Rafael. 2014. "Not All That Glitters Is Gold: Gold Boom, Child Labor and Schooling in Colombia." Documento CEDE No. 2014-31. Bogotá: Universidad de los Andes, CEDE. https://doi.org/10.2139/ssrn.2489203.

Scott, Kinnon, Diane Steele, and Tilahun Temesgen. 2005. "Chapter XXIII: Living Standards Measurement Study Surveys." New York: United Nations Statistics Division. https://unstats.un.org/unsd/hhsurveys/pdf/Chapter_23.pdf.

Sviatschi, Maria Micaela. 2019. "Making a Narco: Childhood Exposure to Illegal Labor Markets and Criminal Life Paths." Unpublished manuscript. https://www.micaelasviatschi.com/wp-content/uploads/2016/05/jmpMMSviatschi.pdf.

Thomas, Duncan, Kathleen Beegle, Elizabeth Frankenberg, Bondan Sikoki, John Strauss, and Graciela Teruel. 2004. "Education in a Crisis." *Journal of Development Economics* 74: 53-85. https://doi.org/10.1016/j.jdeveco.2003.12.004.

Tobón, Gabriel John, and Gloria Inés Restrepo. 2011. "Erradicación de Cultivos Ilícitos y Desplazamiento Forzado en el Parque Natural Sierra de la Macarena." *Cuadernos de Desarrollo Rural* 63: 31. https://revistas.javeriana.edu.co/index.php/desarrolloRural/article/view/1185.

UNODC (UN Office on Drugs and Crime). 2018. *Colombia. Monitoreo de Territorios Afectados por Cultivos Ilícitos 2017.* Bogotá: UNODC. https://www.unodc.org/documents/crop-monitoring/Colombia/Colombia_Monitoreo_territorios_afectados_cultivos_ilicitos_2017_Resumen.pdf.

Zuleta, Hernando. 2017. "Coca, Cocaína y Narcotráfico." Documento CEDE No. 42. Bogotá: Universidad de los Andes, CEDE. http://doi.org/10.2139/ssrn.2987333.

APPENDIX

Table A1: Number of Normative Approved Years of Education by Age

Age	Number of normative years approved
7	1
8	2
9	3
10	4
11	5
12	6
13	7
14	8
15	9
16	10
17	11

Source: Angulo, Diaz, and Pardo (2011)

Table A2: Descriptive Statistics of Wind Shocks

	Wind shocks
Mean	77.61
Standard deviation	97.29
Maximum	311
Minimum	0
Sample size	2,859

Source: Own construction from NASA's GES DISC base