STRATEGIES, INCENTIVES, AND DECISIONS: ILLICIT CROP CONTROL IN COLOMBIA

by

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ABSTRACT

ELEONORA DAVALOS ALVAREZ. Strategies, incentives, and decisions: illicit crop control in Colombia. (Under the direction of Dr. JENNIFER TROYER)

This dissertation examines three aspects of coca cultivation in Colombia. Fist, I evaluate how social investment in conjunction with eradication affects new coca crops. The results suggest that aerial spraying is effective in deterring farmers from increasing the size of their new coca fields, but this effect is small. Social investment, in addition to generating social welfare, has a significant negative relationship with new coca crops. Second, I analyze the motivations of coca growers by estimating a discrete choice model including head of household characteristics, household variables, and agricultural unit attributes. I find that poverty motivates farmers to grow coca crops. Specifically, extremely poor farmers are more likely to grow coca crops compared to non-poor farmers in the same area. Basic household and agricultural unit characteristics also influence farmer decisions to grow coca crops. Households connected to the energy grid, with access to credit, and receiving cash payments for their licit crops, are less likely to grow coca crops. Finally, I use georeferenced agricultural data to test the hypothesis that forced eradication generates spillover effects. Based on the results, there are strong negative spillover effects from aerial eradication, but spillover effects are positive and stronger for aerial eradication inside natural parks.

DEDICATION

To the memory of my classmate and friend—Jose Ignacio Salazar Arenas—one of the many victims of the armed conflict in Colombia, may the peace agreement last and bring relief to the surviving victims of atrocious war crimes.

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CHAPTER 1: INTRODUCTION

This dissertation aims to determine how the strategies used to control illicit crops interact with individual level motivations to cultivate coca. To answer this question, I evaluate illicit crop control strategies from three different perspectives. The first essay approaches this question at the aggregate level. I evaluate the effectiveness of traditional strategies used to control illicit crops in municipalities, and propose a complementary strategy to boost compliance and promote deterrence. In the second essay, I approach the same question at the individual level. I analyze the motivations of smallholder households to grow an illicit crop. In the third essay, I test the hypothesis that forced eradication generates spillover effects. Evaluating illicit crop control strategies from these three different and interrelated perspectives provides a better understanding of the decision process behind illicit crop cultivation and may enlighten policy makers to better tailor strategies to control this illegal activity.

The aggregate municipal level analysis explores a complementary approach to control coca cultivation (Chapter 2). This analysis includes social investment as a complementary strategy to control crime. Following the framework of the economic theory of crime (Becker, 1968), individuals involved in criminal activities are those with the lowest market income. Hence, increasing their return from legal activities may be an effective crime-regulatory strategy. The model is tested using a dataset consisting of annual data for 440 contiguous municipalities that had coca during the period of study, from 2001 to 2010. The analysis includes the two main techniques used to control illicit crops—manual and aerial eradication. The results reveal a significant negative relationship between the level of social investment and new coca crops. Social investment (expenditures in human capital and infrastructure) emerges as an effective complementary strategy to control illicit crops.

The individual level analysis aims to understand the motivations of smallholder households to grow coca crops (Chapter 3). Based on the assumption that individuals distribute time between legitimate market opportunities and criminal activities depending on the expected return from each occupation and the probability and severity of the punishment (Becker, 1968; Block & Heineke, 1975; Ehrlich, 1973; Stigler, 1970), crime control strategies need to increase the punishment for performing criminal activities or increase the reward for conforming to a set of standards accepted by society, or both. The model is tested using a random sample of 440 smallholder households—coca growing and non-coca growing farms— representative of agricultural units located in the Northeast and South Bolivar regions of Colombia. The results suggest poverty motivates farmers to grow coca crops. Specifically, extremely poor farmers are more likely to grow coca crops compared to non-poor farmers in the same area. Basic household and agricultural unit characteristics also influence farmer decisions to grow coca crops. Households connected to the energy grid, with access to credit, and receiving cash payments for their licit crops, are less likely to grow coca crops.

Finally, to test the hypothesis that forced eradication generates spillover effects, I use georeferenced agricultural annual data for 1,116 contiguous municipalities in

Colombia between 2001 and 2010 (Chapter 4). The results suggest that manual eradication does not affect new coca crops. Aerial eradication, in contrast to manual eradication, reduces new coca crops and generates negative spillover effects over neighboring municipalities. Implementing aerial eradication inside natural parks also generates spillovers. This policy change imposes great burden on municipalities located beside natural parks because when aerial eradication is implemented inside natural parks, new coca crops increase in the municipality with natural parks and its neighboring municipalities.

The findings of these analyses illuminate conflicting previous results while enhancing the capacity to inform policy. All the findings in this study support that traditional strategies used to control illicit crops have nil or low impact on coca cultivation, because most of the factors that motivate farmers to grow coca crops are linked to social development needs. As a result, social investment emerges as a relevant complementary factor that can better address the underlying causes of illicit crop growing.

CHAPTER 2: NEW ANSWERS TO AN OLD PROBLEM: SOCIAL INVESTMENT AND COCA CROPS IN COLOMBIA

2.1 Introduction

Forced eradication is the main strategy to control illicit crops (Reuter, 2010). This coercive tactic is implemented worldwide to control cannabis, coca leaf, and opium poppy (UNODC, 2014c).[1] Billions of dollars have been poured into this task. Since 1999, the United States spent nearly USD 5 billion in Colombia trying to control cocaine production and USD 7 billion in Afghanistan trying to control opium poppy (GAO, 2008; Oehme, 2010; SIGAR, 2014b).[2] Despite these investments, as of 2013, opium production in Afghanistan reached the highest area under cultivation since 1993 (SIGAR, 2014a), and the area affected by coca crops in Colombia dropped just 17 percent over the 2001-2010 period (UNODC, 2014b). Despite the importance of assessing the effectiveness of illicit crop eradication, there has been no systematic evaluation of the strategy in either country.

Existing research assessing the effectiveness of illicit crop eradication on coca cultivation yields contradictory conclusions. Results vary depending on the period of time evaluated and the unit of analysis. Studies based on data from 1988 to 2008 reported that

[1] Forced eradication of cannabis occurs in Italy, the United States, Ukraine, Tajikistan, and the Philippines. Forced eradication of coca occurs in Colombia, Peru, and Bolivia. Forced eradication of opium poppy occurs in Afghanistan, Myanmar, and Mexico (UNODC, 2014c).
[2] According to GAO (2008), 80 percent of the U.S. funding to Plan Colombia from 2000 to 2008 were spent on counternarcotic and security activities. From 2002 to 2013, the United States spent USD 6.9 billion on counternarcotic activities in Afghanistan (SIGAR, 2013).

aerial spraying—one of the methods used to eradicate crops—has little impact on illicit crops, or increases the area under coca cultivation (Bogliacino & Naranjo, 2012; Diaz & Sánchez, 2004; Moreno-Sanchez, Kraybill, & Thompson, 2003; Moya, 2005; Reyes, 2011; Tabares & Rosales, 2005). These striking results question the effectiveness of aerial spraying, and imply that there are unintended consequences from the control strategy. Conversely, analyses based on theoretical models calibrated using data from 2000 to 2003 and survey-based experiments using data from 2005 concluded that aerial spraying was effective on reducing the area on illicit crops (Grossman & Mejia, 2008; Marcela Ibañez & Carlsson, 2010). Therefore, the debate on the effectiveness of eradication on illicit crop cultivation remains unresolved.

The main limitations of previous studies lie on the use of country-level aggregate data (Moreno-Sanchez et al., 2003), the lack of comparability between surveys used in the analysis (Moya, 2005; Tabares & Rosales, 2005),[3] and the fact that farmers often locate in areas historically affected by illicit crops (Marcela Ibañez & Carlsson, 2010).[4] In this study, I aim to overcome those limitations by: 1) analyzing a period of 10 years under a single regime to control illicit crops and based on comparable survey data (UNODC, 2011c), 2) incorporating social expenditure as a complementary strategy to control illicit crops, and 3) controlling for unobservable factors that may vary across municipalities but do not vary in time. In particular, my analyses simultaneously test the

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[3] Moya (2005), and Tabares and Rosales (2005) analyzed 1999-2002 data. However, data after 2000 cannot be compared with data from previous years due to change of methodology to estimate the number of hectares under cultivation (UNODC, 2003b). Coca surveys in 1999 and 2000 did not cover the entire country (UNODC, 2009). Coca survey conducted in 1999 covered 12 percent of the country while coca survey conducted in 2000 covered 41 percent; limiting the sample to areas where the UNODC suspected that coca was present (UNOCD, 2001). Starting in 2001, coca surveys cover the whole country.

[4] Marcela Ibañez and Carlsson (2010) used a survey-based experiment of 293 self-selected coca and non-coca farmers from Putumayo, a state in which 80 percent of its municipalities have areas under coca cultivation (UNODC, 2010). Therefore, it is an extreme case that could not be generalizable.

effectiveness of *ex ante* regulations (structural laws and market incentives) and *ex post* penalties (statutory commands) to control coca crops.

Ex ante regulations are more preventive than reactive (Bright, 1992); they control behavior indirectly by influencing the physical and social arrangements that facilitate the behavior to occur (Cheng, 2006). *Ex post* penalties, in contrast, regulate behavior directly by setting specific prohibitions or standards of conduct. Here, *ex ante* regulations are operationalized as social investment in infrastructure, human capital, and alternative development programs, while *ex post* penalties are operationalized using manual and aerial spraying.

To determine if *ex ante* regulations contribute to controlling illicit crops, I use annual data for 440 contiguous municipalities that had coca in any year between 2001 and 2010. I estimate a panel data regression model to assess the effect of investments in infrastructure and human capital on new area of coca. The results suggest that aerial spraying is effective in deterring farmers from increasing the size of their new coca fields, but this effect is small. Social investment, in addition to generating social welfare, emerges as an effective complementary factor to control illicit crops. Additional USD 5.55 spent in social investment (human capital and infrastructure) per inhabitant prevents the appearance of a whole new hectare, which saves around USD 1,954 that would have been spent on aerial spraying to reduce cultivation by the same area.

The paper is organized as follows. Section two encompasses historical background of illicit cultivation in Colombia with the theoretical approach to control illicit crops. Section three describes the strategies to control illicit crops. Section four and five introduce the data and analytical strategy. Section six presents the results of the panel data regression with municipality and year fixed effects, and section seven closes with a discussion of the results, highlighting the some of the limitations of this analysis.

2.2 Background and theoretical approach

2.2.1 Old problem, old approach

In Colombia, as 2013, growing illicit crops is regulated mainly by statutory commands, specific prohibitions or standards of conduct that are enforced by police and prosecutors. Growing illicit crops is a felony; crops are destroyed using forced eradication; and in theory, illicit crop growers could face up to 12 years in prison and 400 monthly minimum wages in fines, or around USD 110,000 ("Ley 30 de 1986," 1986).[5] In practice, however, there are municipalities in which the probability of crop eradication is close to zero;[6] there are large numbers of violators; and few are prosecuted.[7] As a result, in illicit crop growing areas, growing illicit crops is socially accepted and noncompliance is rampant.

Statutory commands, such as forced eradication, rely on deterrence to regulate behavior (Cheng, 2006), but deterrence is difficult to attain with widespread noncompliance, as is the case in illicit crop growing areas of Colombia. To improve deterrence it would be necessary to increase the probability of being caught or implement more severe punishments if caught, or both (Becker, 1968). In the case of coca growing, improving deterrence involves increasing the number of coca growers caught, the number of years in prison, and the number of hectares eradicated. However, given the large

[5] In 2012, the monthly minimum wage in Colombia was COP 566,700, and the exchange rate COP to USD was around two thousand pesos per dollar.
[6] Author's estimations based on 2001-2010 coca surveys.
[7] It is estimated that in 2009 about 300,000 people were involved in coca cultivation. However, Colombian police reports 855 felonies (Colombia, 2010) and only 162 people were prosecuted for this crime. The unusual prosecution made national news (Tiempo, 2009).

number of people involved in growing illicit crops, the few prosecuted, and the large number of hectares already eradicated,[8] increasing the penalties is unlikely to change the supply of coca.

Following the framework of the economic theory of crime (Becker, 1968), farmers weigh the best legitimate work opportunity against the payoff of growing illicit crops. If the payoff of growing coca exceeds the best legitimate opportunity, then crime is committed. Therefore, aggregate stable or increasing area implies that forced eradication (other things being equal) does not generate enough incentives to reduce the area under cultivation. If farmers, on average, are keeping or increasing the size of their fields, their decision must be related to the benefit associated to growing coca, the cost of committing crime, and the best legitimate productive alternative available. Since coca leaf prices have decreased consistently,[9] eradication actions have increased steadily (see Figure 2.1), and the punishment if caught is constant (years in prison and fines), then legitimate productive alternatives must help explain why coca cultivation has not declined.

2.2.2 Areas where coca is grown

Coca crops in Colombia are located in remote regions of the country that are isolated by geographic barriers and inclement weather. Most of the municipalities in Colombia do not have coca crops (61 percent), but those that do, are on average six times larger than municipalities lacking coca crops. Only six percent of all municipalities in Colombia are located in the Amazon region of the country. However, 15 percent of the

[8] In 2012 a vast portion of the area of coca identified was eradicated; 131,035 hectares were eradicated out of 135,000 hectares affected by coca crops (UNODC, 2014a). However, at the end of the year 48,000 hectares of coca remained. Please note that the UNODC estimates the area affected with coca crops by a geographical sum of the coca crop area from aerial spraying, manual eradication, and the annual coca survey. This method does not take into account that the same hectare could be eradicated more than once.

[9] Coca leaf prices decreased from COP 3,300/kg in 2004 to COP 2,465/kg in 2010 (UNODC, 2011a).

municipalities with coca crops are in the Amazon region, and about 59 percent of the area affected with coca crops in Colombia is located in this region. These municipalities are covered with thick rainforest and receive, on average, 900 mm more rainfall per year compared to municipalities without coca crops (see Table 2.1 and 2.2).

TABLE 2.1: Municipalities and area, Colombia 2001-2010

Place	Municipalities	Area (sq km)
Colombia	1,118	1,140,618
Municipalities with coca	440	887,789
Municipalities in Amazon Region	72	533,556
Municipalities in Amazon Region with coca	65	521,860

Source: Compiled by the author based on the CEPAL (2013) report for the Amazon region classification, and UNODC annual surveys for municipalities affected by coca cultivation from 2001 to 2010.

Due to their geographic location and historical neglect, municipalities with coca crops also have poor infrastructure. On average, their road density is 40 percent lower than municipalities without coca crops, and their Unsatisfied Basic Needs index (UBN) is 14 percentage points higher.[10] Indeed, previous studies on illicit crops in Colombia concur that poverty and isolation from legal markets influence the area under coca cultivation (Dávalos et al., 2011; Dion & Russler, 2008; Marcela Ibañez & Carlsson, 2010; Moreno-Sanchez et al., 2003). It seems that the lack of legitimate opportunities in those isolated areas prevent coca growers from getting involved in legal activities.

In addition to geographic isolation and poor infrastructure, Andean and Amazonian forests that have been cleared to make way for illicit crops are rich in native

[10] UBN index ranges from zero to 100 depending on the percentage of households with one or more unsatisfied basic needs. Higher UBN values indicate the presence of more households with unsatisfied needs. This indicator captures four different factors associated with poverty: inadequate housing materials (e.g. paper, wood, cement), inadequate access to running water and sewage, overcrowding, school-age children not enrolled in school, and economic dependence.

species but require careful management to maintain crop productivity (Dávalos, Bejarano, & Correa, 2009).[11] These environmental characteristics make ecosystems in these regions particularly vulnerable to erosion and soil exhaustion under intensive agriculture. Farmers in those areas require high capital investment to make them as productive as areas in the country close to developed markets.

2.2.3.Old problem, new approach

Given the characteristics of the areas where coca is grown, structural laws and market incentives can better address the underlying causes of illicit crop growing. Geographically isolated areas could be interconnected with developed markets by investing in infrastructure: paving roads, increasing flight frequency, and developing supply chains. Reducing travel time will, in turn, expand the market and facilitate distribution of local goods; products that otherwise will not be marketable. Investments on infrastructure revitalize the local economy, increasing legitimate opportunities in isolated areas (Aschauer, 1989; Munnell & Cook, 1990). Therefore, providing basic infrastructure gives local communities the means to join legal markets.

Investments in infrastructure and human capital could push farmers towards compliance by making legitimate opportunities more profitable and less burdensome. Agricultural subsidies for crops or fertilizers, or both, may ease the costs pressing on farmers and make alternative crops more attractive. In addition, training in environmental management, instructing local communities on how to cope with vulnerable ecosystems could greatly prevent flooding, droughts, and landslides (López-Rodríguez & Blanco-Libreros, 2008). Better infrastructure coupled with agricultural subsidies and training

[11] The soil, climate, and slopes in those areas facilitate leaching of nutrients.

increases the benefits of alternative crops and thus increases the opportunity cost of incarceration. Since those who commit crime are individuals with the lowest market income (Becker, 1968; Kelly, 2000), increasing their return from legal activities may be an effective strategy to regulate crime.

Despite the importance of social investment in poor areas and the persistent poverty in areas where coca is cultivated (Bedi & de Jong, 2011; Laterveer, Niessen, & Yazbeck, 2003; McIlwaine & Moser, 2003), scholars have devoted limited attention to the effect of social expenditure on preventing and reducing illicit crop expansion. Redistributive transfers could reduce and prevent illicit crop expansion as they expand and increase legitimate productive opportunities. In addition to conventional strategies to control illicit crops (forced eradication), government investments in infrastructure, agricultural subsidies, and human capital in these areas are an option that could provide income stability and become an alternative to achieve a lasting decline in coca cultivation. As compliance rates increase, noncompliance behavior breaks down because of new production opportunities, and a set of new social norms takes its place, creating a virtuous cycle that reinforces lawful conduct (Smith, 2000).

2.3 Strategies to control illicit crops

Illicit crop control aims to reduce the amount of drugs entering consuming countries and raise the cost of drug production (Reuter, 2010). The main strategy to control illicit crops is forced eradication. This strategy is implemented in two different ways: manual eradication and aerial spraying. The government of Colombia has used both types of eradication to control illicit crops.

Aerial spraying was first implemented in 1978 to eradicate marijuana crops with *N*,*N*′-dimethyl-4,4′-bipyridinium dichloride, known commercially as Paraquat (R. Vargas, 2002). Because of ecological risks associated with the herbicide, Paraquat was replaced with glyphosate (commercially known as Roundup) in the mid 1980's, and the latter has been constantly sprayed in Colombia ever since. Conversely, manual eradication does not generate health or environmental risks, but it is labor intensive and thus expensive. Therefore, manual eradication is implemented sporadically in easy-access areas lacking armed conflict, and in areas where spraying was restricted: natural parks and indigenous reservations. It was only in 2004 that manual eradication became a national program, with a budget allocated specifically to this activity (DNP, 2010). Following this change, spraying was allowed inside natural parks in 2005 (Council, 2005) and indigenous reservations in 2007 (Council, 2007).

Manual eradication activities in Colombia were less than 10 percent of total eradication actions until 2004 (Figure 2.1). Manual eradication activities then grew steadily until 2008, just after spraying was allowed in indigenous reservations (October 2007), and decreased substantially from 2008 to 2009. In contrast, spraying has always dominated the eradication strategy, with more than 50 percent of the total activities, even though spraying effectiveness decreases substantially with heavy rain, or if growers wash the crop immediately after spraying (UNODC, 2005a).

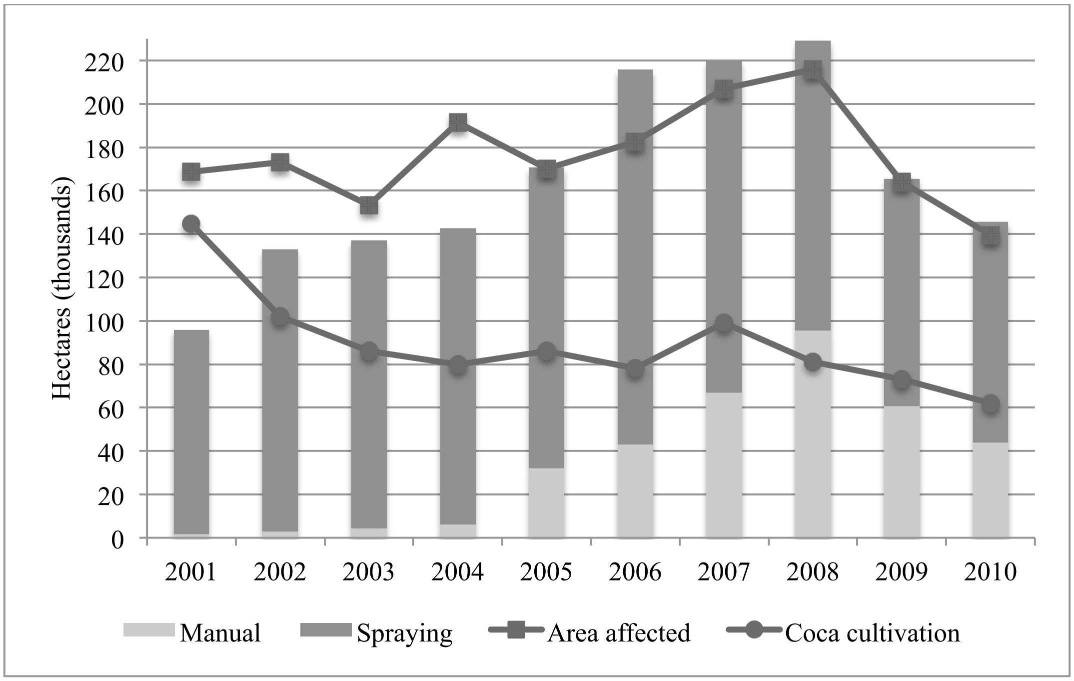

FIGURE 2.1: Manual eradication, aerial spraying, area affected by coca crops, and coca cultivation. Colombia 2001-2010 Notes: Done by the author based on the UNODC (2005b, 2011d, 2014b) reports. The area affected by coca crops is the geographical area that had coca cultivation, manual eradication, or aerial spraying at some point during the year. The UNODC estimates this area by a geographical sum of coca crop area from aerial spraying, manual eradication, and the annual coca survey. Coca cultivation is the area under coca cultivation at the cut-off date of the annual coca survey, December 31.

2.4 Data

This paper analyzes annual data for all the municipalities in Colombia that had coca crops in any year between 2001 and 2010. The outcome variable used in this analysis—new coca crops each year—is relevant only for 440 municipalities. New coca crop area was calculated using data on net area under coca cultivation from the *Annual Coca Survey* collected by the UNODC. Since 2001, the Illicit Crop Monitoring Global Program of the UNODC captures a set of satellite images that cover the entire continental Colombian territory. The area under coca cultivation identified in the images is adjusted for areas manually eradicated and sprayed during the same period.[12] The area after the adjustments is the net area under coca cultivation on December 31 (see Appendix A for detailed process). Equation 2.1 describes the dependent variable used in this analysis.

Equation 2.1: Outcome variable used in the econometric analysis

$$Y_t = X_t - X_{t-1}$$

Equation 2.1 describes the annual change on the area under coca cultivation at the cut-off date of the annual coca survey. Y_t is the new area on coca crops in period t. X_t is the net area under coca cultivation at the cut-off date of the annual coca survey in period t, and X_{t-1} is the net area under coca cultivation at the cut-off date of the annual coca survey in period $t-1$.

Figure 2.2 shows the area of study throughout the period analyzed. Darker areas illustrate larger number of hectares per municipality at the end of the year after eradication activities took place. Data on the primary independent variables, manual and aerial eradication, come the Colombian Antinarcotics Police (DIRAN for its Spanish acronym). These three variables were reported in annual hectares.[13]

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[12] For more details about the collection process and methodology, visit: http://www.biesimci.org/SIMCI/metodologia.html, and http://www.biesimci.org/Documentos/archivos/Accuracy-Colombia_field_mission_04_final.pdf
[13] One hectare is equivalent to 2.5 acres.

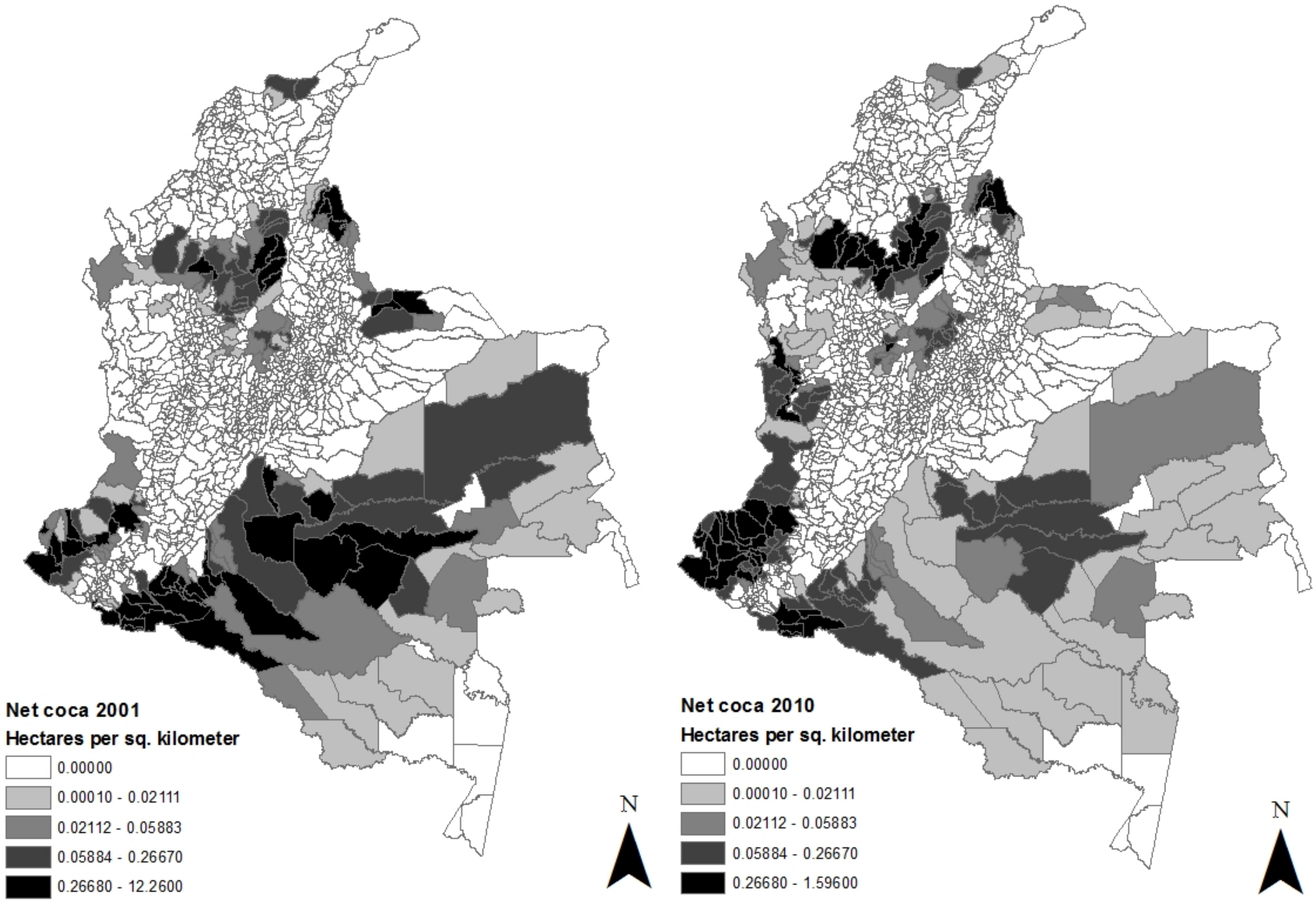

FIGURE 2.2: Hectares of coca per municipality, Colombia 2001 and 2010

Alternative development accounts for the number of families joining alternative development projects that require voluntary eradication. These data are collected by the Colombian Agency for Social Action and International Cooperation. Social investment, the proposed complementary strategy to control illicit crops, is the annual budget spent on infrastructure and human capital in each municipality. Infrastructure refers to expenditures on fixed capital, such as: land, roads, buildings, and equipment. Human capital includes: teacher salaries, training, school feeding programs, and education material. These definitions follow the International Monetary Fund (IMF) guidelines (IMF, 2001). Expenditures are measured in nominal thousand pesos and come from the Colombian National Planning Department (DNP for its Spanish language acronym). Annually each municipality reports to the DNP their income and expenditures desegregated by activity. To standardize these measures and make them comparable across municipalities and over time, I use per capita values and the consumer price index (CPI) to adjust for inflation. Table 2.2 provides a summary of the main variables used in this analysis for municipalities with and without coca.

This analysis also includes main covariates to control for other municipal-level characteristics. Data on government financing sources, such as property tax, industry and commerce tax, gasoline tax, natural resources royalties, and cofinancing, come from the DNP. They are reported annually in nominal thousand pesos. I use the CPI to adjust for inflation and per capita measures to make investments comparable over time and across municipalities. The DNP also ranks municipalities based on their fiscal performance. DNP follows the IMF guidelines to generate a rank that ranges from zero to 100, in which values over 80 mean that the municipality is solvent and values below 40 that has low savings capacity, difficulties covering its operation expenses, and relies on national transfers (DNP, 2012). Finally to measure armed conflict, I use the number of victims of all kind of human rights violations perpetrated by any kind of armed group (guerrilla, paramilitary, or national army). Human rights violations occurred daily in each municipality and are collected and reported by the Centre for Research and Popular Education/Peace Program—Cinep—a non-profit foundation that promotes social change in Colombia.

TABLE 2.2: Descriptive statistics municipalities with and without coca crops and data sources, Colombia 2001-2010

					Municipalities with Coca N=440		Municipalities without Coca N=678	
Type	Short name	Units	Description	Source(s)	Mean	Std.	Mean	Std.
Crops	Coca (net of eradication)	Hectare	Area under coca cultivation at the cut-off date of the annual coca survey: December 31	UNODC annual coca survey	201.56	748.62		
	New area coca	Hectare	Annual change on the area under coca cultivation at the cut-off date of the annual coca survey	Calculated from UNODC annual coca survey	-20.96	428.21		
Policy variables of interest	Manual eradication	Hectare	Number of hectares manually eradicated throughout the year in each municipality	UNODC	78.03	522.15		
	Spraying	Hectare	Number of hectares sprayed throughout the year in each municipality	DIRAN from UNODC	294.99	1,353.18		
	Social investment	Constant 2008 COP	Thousands pesos spent annually, per inhabitant, in each municipality on infrastructure and human capital	DNP	517.82	441.41	555.86	515.13
	Infrastructure	Constant 2008 COP	Thousands pesos spent annually, per inhabitant, in each municipality on land, roads, buildings, and equipment	DNP	224.46	318.42	259.93	370.85
	Human capital	Constant 2008 COP	Thousands pesos spent annually, per inhabitant, in each municipality on teacher salaries, training, school feeding programs, and education material	DNP	293.37	163.66	295.93	198.09
Demographic measures	Total population	Number	Total number of inhabitants	DANE	29,975	60,516	44,132	297,579
	Urban population	Percentage	Percentage of urban population	Calculated from DANE	35.99	22.90	44.60	24.22
	Rural population	Percentage	Percentage of rural population	Calculated from DANE	64.01	22.90	55.40	24.22
Geographic characteristics	Area	Sq. kilometer	Total municipal area	SIGOT-IGAC	2,017.70	4,865.89	372.90	716.58
	Elevation	Meter	Altitude above sea level	IGAC 2005 from Armenteras, Cabrera, Rodríguez, and Retana (2013)	1,004.96	862.90	1,247.90	1,086.38
	Precipitation	Milimeter	Total annual precipitation in 2005	Worldclim 2005 from Armenteras et al. (2013)	2,606.22	935.56	1,733.28	643.24

TABLE 2.2 (continued)

Type	Short name	Units	Description	Source(s)	Municipalities with Coca N=440		Municipalities without Coca N=678	
					Mean	Std.	Mean	Std.
Source of income	Property tax	Constant 2008 COP	Thousands pesos collected annually, per inhabitant, in each municipality from property taxes	DNP	16.90	25.60	28.27	33.56
	Industry and commerce tax	Constant 2008 COP	Thousands pesos collected annually, per inhabitant, in each municipality from industry and commerce taxes	DNP	13.99	41.99	18.50	48.01
	Gasoline tax	Constant 2008 COP	Thousands pesos collected annually, per inhabitant, in each municipality from gasoline taxes	DNP	13.69	15.96	14.65	19.85
	Non tax income	Constant 2008 COP	Thousands pesos received annually, per inhabitant, in each municipality from other sources of income different from taxes	DNP	19.90	44.99	23.15	33.65
	Natural resources royalties	Constant 2008 COP	Thousands pesos received annually, per inhabitant, in each municipality from natural resources	DNP	51.03	219.74	47.69	279.97
	Cofinancing	Constant 2008 COP	Thousands pesos received annually, per inhabitant, in each municipality from cofinancing projects	DNP	19.22	65.97	23.33	77.27
Other characteristics	Fiscal performance	Rank from 0 to 100	Municipal fiscal performance, where values over 80 mean that the municipality is solvent and values below 40 that has low savings capacity, difficulties to cover its operation expenses, and relies on national transfers	DNP	58.48	8.84	59.52	9.00
	Human rights violations	Number	Victims of all kind of human rights violations per 1,000 inhabitants	CINEP	1.95	51.69	0.20	2.67
	Road density	Km of road per 100 sq. km of land	Density of road in each municipality in 2005	Calculated from IGAC 2005 by Armenteras et al. (2013)	1.88	1.25	3.02	1.50
	Unsatisfied basic needs	Percentage	Percentage of population with unsatisfied basic needs in 2005	DANE 2005	53.60	21.57	39.96	18.97

2.5 Empirical model

To determine if social investment contributes to controlling illicit crops, I use a panel data regression model with municipal and year fixed effects. This approach controls for unobservable heterogeneity, for instance cultural attitudes towards crime. The model is estimated using Huber-White standard errors clustered by municipality to control for arbitrary correlation within a municipality. The basic econometric model is presented in equation 2.2.

Equation 2.2: Panel data model assessing the effect of social investment on new area of coca

$$Y_{it} = \beta_0 + \beta_1 W_{it-1} + \beta_2 S_{it} + \beta_3 Z_{it} + \alpha_i + \lambda_t + e_{it}$$

where $i = 1, \dots, 440$, and $t = 1, \dots, 10$

Equation 2 describes the relationship between the new area of coca and the strategies used to control illicit crops. The outcome variable is the new hectares of coca in municipality i in period t, Y_{it}, previously defined in equation 2.1. New coca crops are a function of the traditional strategies used to control illicit crops, W_{it}, alternative strategies to control coca crops, S_{it}, and a set of control variables, Z_{it}. In addition to the basic factors related to new coca crops, this analysis controls for policy implementation changes related to eradication activities affecting coca growing. Z_{it} includes dummy variables capturing the difference between allowing aerial spraying inside natural parks and indigenous reservations. These dummies are coded zero before aerial spraying was implemented and one once it was implemented in municipalities with natural parks (after 2005) and indigenous reservations (after 2007).

Equation 2.2 includes a vector of regressors with lags of the variables mentioned before (W_{it-1}) to conform a dynamically complete model. I tested different model specifications including several lag periods. I include and report lag periods that are significant; thus relevant to this analysis. The model also includes municipal fixed effects (α_i) to capture time-invariant municipal-specific characteristics that may confound the estimate of interest, and time fixed effects (λ_t) to control for variables that are constant across municipalities but evolve over time. The term e_{it} is a stochastic error term.

Identification occurs from changes in coca cultivation as they relate to changes in eradication activities and social investment. The key to this strategy is that eradication activities and social investment have idiosyncratic variation conditional on the attributes of a municipality and existing hectares of coca. The main mechanism of influence is through the ability of eradication to increase costs associated with coca cultivation and thus limits its benefits, discouraging farmers from growing coca and leading them to adopt other income producing activities. Likewise, changes in social investment expand or restrict access to health care, opportunities of education, job training openings, and the infrastructure needed to develop healthy licit markets. Social investment stimulates legitimate production opportunities as it increases the return from legal activities.

In general, it is expected that coefficients on infrastructure and human capital to be negative. In other words, the new area of coca will decrease as isolated areas, where coca is cultivated, are integrated to licit markets. As for the traditional strategies used to control illicit crops, coefficients on manual eradication and aerial spraying are expected to be negative. Negative coefficients illustrate deterrence. The lower the coefficient, the more effective the strategy is in discouraging new coca crops.

2.6 Results

To test the hypothesis that social investment is a complementary strategy to control coca crops, I regress the size of new coca crops on per capita budget spent on social investment. Table 2.3, columns (1) through (3), presents panel data estimates of equation 2 with different measures of social investment. Column (1) reports coefficients on statutory commands to control coca crops. Columns (2) and (3) show results on structural laws and market incentives, including control variables. Numbers in parentheses are Huber-White standard errors clustered by municipality.

Results are consistent throughout the three models. Coefficients on aerial spraying, one of the traditional strategies to control illicit crops, are significant and negative. The long-term effect of aerial spraying is associated with a reduction of 0.11 hectare of new coca crops. In other words, on average, one hectare of coca sprayed last year deters coca growers from increasing their fields by about 11 percent.

Focusing on column (2), the area with new coca crops decreases as social investment increases. Increasing the budget allocated to social investment by one thousand pesos per inhabitant is associated with a reduction of 0.09 hectare of new coca crops. This effect is equivalent to a 50-cent increase in social expenditure per inhabitant to reduce nine percent of a new hectare of coca crops.[14] This result is consistent with previous research on the effects of redistributive transfers on crime rates (Zhang, 1997). I

[14] One dollar is equivalent to two thousand Colombian pesos, and one hectare is equivalent to 10,000 squared meters; thus, a reduction of 0.09 hectares equals a reduction of 900 squared meters or 9 percent of a hectare.

also disaggregate the effect of social investment in the two different types of investment: infrastructure and human capital. Results in column (3) show that the effect of social investment on new coca crops comes from expenditures in infrastructure as well as human capital.

TABLE 2.3: Regression analysis of the effect of statutory commands, structural laws, and market incentives on new coca cultivation, Colombia 2001-2010

	New Area on Coca Crops					
	(1)		(2)		(3)	
Statutory commands						
L1. Manual eradication	0.01	(0.04)	0.01	(0.04)	0.01	(0.04)
L1. Spraying	-0.11***	(0.04)	-0.11***	(0.04)	-0.11***	(0.04)
Structural laws and market incentives						
Social investment			-0.09**	(0.04)		
Infrastructure					-0.06**	(0.03)
Human capital					-0.18**	(0.09)
Alternative development			0.10	(0.09)	0.10	(0.09)
Control variables						
Conflict			1.17***	(0.15)	1.17***	(0.15)
Property tax			-0.92*	(0.47)	-0.91*	(0.47)
Industry and commerce tax			0.23	(0.15)	0.22	(0.14)
Gasoline tax			1.80**	(0.81)	1.82**	(0.82)
Non tax income			0.19**	(0.09)	0.20**	(0.09)
Natural resources royalties			0.05	(0.05)	0.04	(0.05)
Cofinancing			0.13**	(0.06)	0.11**	(0.05)
Fiscal performance			-1.33	(0.84)	-1.20	(0.85)
Natural parks			-30.46	(39.13)	-28.71	(39.06)
Indigenous reservations			30.70	(22.77)	32.07	(22.92)
Observations	3699		3699		3699	
Within R-squared	0.06		0.08		0.08	
Clusters	424		424		424	

Notes: This table presents the results of the specification established in equation 2.2 by panel data regression. The outcome variable used in this analysis is new area on coca crops. The estimates correspond to micro data set by municipality. The sample includes all Colombian municipalities that had coca crops at some point between 2001 and 2010. State and year fixed effects regressors not shown. L1 represents one-year lag. Huber-White standard errors clustered by municipality in parentheses. See table 2.2 for description, units, and source for all the variables. *** p<0.01, ** p<0.05, * p<0.10

Considering that variations in coca leaf, coca paste, cocaine base, and cocaine price also affect coca cultivation; year and municipal fixed effects included in equation 2.2 control for annual national and municipal fluctuations. I ran a different model specification including four quantile categories based on annual regional coca paste price for five different regions to control for specific farm-gate price variations. Results are substantively similar to those with year and municipal fixed effects only (see Appendix B).

In addition to the effect of the strategies used to control coca cultivation on new coca crops, the coefficient on armed conflict is always positive and close to one (columns 2 and 3). One additional victim of a human right violation per thousand inhabitants is associated with an increase of more than one hectare of new coca crops. This effect is substantial considering that eradication efforts deter coca cultivation by much less than one hectare. This result is not surprising since most of the human rights violations in these rural areas include mass executions that generate massive displacement (Bureau of Democracy, 2011; Watch, 2013). Indeed, previous studies have established a link between illicit crop cultivation and guerrilla and paramilitary groups throughout different channels: direct control of production, crop protection, production taxation, and civilian displacement (Angrist & Kugler, 2008; Camacho G. & López R., 2000; Diaz & Sánchez, 2004; Holmes, Gutierrez de Pineres, & Curtin, 2006). This study does not identify the channels through which human rights violations stimulate coca cultivation, but one can expect that places with weak rule of the law and scarce state presence are prone to human rights violations and criminal activities including illicit crop cultivation (K., 2003; Rotberg, 2002; F. E. Thoumi, 2002).

Finally, changes in the method to implement forced eradication in natural parks and indigenous reservations have no effect on new coca crops. In terms of new coca crops, on average, there is no difference between implementing manual or aerial spraying inside natural parks or indigenous reservations. The coefficient on spraying inside natural parks and spraying inside indigenous reservations is not statistically significant in any of the models estimated. Given that aerial spraying activities generate great environmental damage, finding that spraying in natural parks does not increase deterrence is a surprising result.

2.7 Conclusions

After more than two decades of implementing forced eradication strategies in earnest, the net area under coca cultivation has decreased from its peak by more than 50 percent, but the area affected by coca crops has decreased just 17 percent over the 2001-2010 period (UNODC, 2014b).[15] Eradication paralleled and even surpassed coca cultivation, and yet eradication has not succeeded in changing Colombia's status as the producer of roughly half the world's coca leaf (UNODC, 2013b). Despite great advances in surveillance, monitoring, and even the implementation of manual eradication in many regions, as of 2010, 23 out of 32 *departamentos* (political units roughly equivalent to states or provinces) reported coca plantations totaling 62,000 hectares (UNODC, 2011a).

Two decades of illicit crops attest that eradication alone does not consolidate areas free of illicit crops. Eradication is effective in deterring farmers from increasing the

[15] The net are on coca cultivation is the area under coca cultivation at the cut-off date of the annual coca survey, December 31.The area affected by coca crops is the geographical area that had coca cultivation, manual eradication, or aerial spraying at some point during the year. The UNODC estimates this area by a geographical sum of coca crop area from aerial spraying, manual eradication, and the annual coca survey.

size of their new coca fields, but this effect is small. Social investment, in addition to generating social welfare, emerges as a complementary answer to control illicit crops. Increasing social investment by about USD 5.55 per inhabitant is associated with the reduction of a whole hectare of new coca crops. In an average municipality with 30,000 inhabitants that is equivalent to increasing social investments by USD 166,500. Preventing the appearance of a whole new hectare saves around USD 1,954 that would have been otherwise spent on aerial spraying to control that same area. These estimates are based on conservative measures of USD 1,768 per hectare spent to support spraying operations and a survival rate of coca crops of 10.5 percent.[16]

Increasing the expected punishment for growing coca crops does not offset the benefits obtained out of this criminal activity at this level on the drug trafficking chain (Kilmer & Reuter, 2009; Reuter, 2010). However, increasing the benefits out of a legitimate productive opportunity increases the opportunity cost of committing crime and thus reduces the size of coca fields. In sum, based on these results, controlling illicit crops requires a comprehensive approach involving both *ex ante* regulations (structural laws and market incentives) and *ex post* penalties (statutory commands) to control coca crops. Strategies that include the cost of committing crime (years in prison, monetary fines, and eradication) as well as the social benefits of refraining from it (e.g. investments on infrastructure and human capital) may be more effective in reducing the market for illicit crops.

[16] During the period of study the DIRAN estimated that, on average, there is a survival rate of 10.5 percent of the area of coca sprayed with glyphosate (see Appendix C). During the same period, GAO (2008) estimated that between 2002 and 2008 the United States provided around USD 1,765 million to the Colombian military and national police to support spraying operations (see Appendix D). Hence, to eradicate a whole hectare of coca we need USD 1,954.

When interpreting these results, there are some methodological limitations to consider. First, data on illicit crops have an accuracy of 89 percent. The UNODC conducts ground truthing to calculate the extension of the area under coca cultivation with gaps or covered by clouds.[17] Lack of visibility and gaps in the images may generate some measurement error on the estimation of the area under coca cultivation. However, measurement error in the dependent variable does not necessarily imply bias in the estimates if the error is nonsystematic (Wooldridge, 2010). In this case, bad weather and satellite location are exogenous to the decisions of coca growers. Hence, measurement error arising from these issues is considered random. Second, data on social investment might also have measurement error due to corruption practices. Municipalities could report social investment expenditures that are higher than the actual amount spent. If this is the case, the coefficient on social investment will be attenuated due to measurement error. Third, because coca growers often locate in areas historically affected by illicit crops, there might be some spatial dependence on the illicit crop growing activities. This analysis focuses on the influence of the explanatory variables from the same geographic unit on the dependent variable, but it does not consider spillover effects. To control for the influence of explanatory variables that come from different geographic units on the dependent variable, it is necessary to perform a spatial econometric analysis that is material for future research.

Finally, I acknowledge that social investment is a means for social development. Its main purpose is increasing labor market participation, promoting human capital accumulation, mobilizing resources into poor communities, and fostering enterprise (Midgley, 1999). Crime control through social investment is therefore a by-product; a

[17] http://www.biesimci.org/SIMCI/metodologia.html

positive externality generated in addition to other social benefits that a community could enjoy. Public investments in infrastructure, human capital, and agricultural subsidies are an effective complementary strategy to illicit crop eradication, but not a substitute. Public investments target individuals that will refrain from crime when given a profitable legitimate alternative. Remaining offenders, for whom the benefits of crime are greater than its cost, require the use of traditional coercive tactics.

CHAPTER 3: SOCIAL DEVELOPMENT DETERS SMALLHOLDER COCA CULTIVATION

3.1 Introduction

Coca cultivation is one of the main challenges to economic, social, and environmental stability in the Andean region. Smallholder households plant most of these crops (UNODC, 2009),[18] and the cumulative effects of their benefit-maximizing decisions have made Colombia, Peru, and Bolivia the only three global producers of illegal coca (UNODC, 2016b). While most coca cultivation remains linked to colonization fronts in western Amazonia (Dávalos, Sanchez, & Armenteras, 2016), nowhere in the Andean region is coca more widely dispersed than in Colombia, where it is found in 21 out of 32 *departamentos* or political units roughly equivalent to states (UNODC, 2016a). Despite theoretical models demonstrating the economic advantages of coca cultivation in the Andean Region (Kennedy, Reuter, & Riley, 1993), not all the households with the potential to produce coca adopt its cultivation (M. Ibañez, 2007). Hence why some households grow coca, while others do not, remains an outstanding question.

Colombia, in cooperation with the international community, has implemented two strategies to control coca cultivation: forced eradication including manual eradication and aerial spraying, and alternative development programs based on voluntary eradication.

[18] Smallholder households are family farms that practice subsistence agriculture in which most of the labor comes from the household (Arias, Hallam, Krivonos, & Morrison, 2013; Netting, 1993).

Despite local gains in reducing coca cultivation,[19] coca persists, and Colombia remains the top global producer with more than 90,000 hectares in cultivation (UNODC, 2016a). To date, only three out of the 24 states that have ever had coca bushes have been completely cleared from coca crops in Colombia (UNODC, 2016a).

As of 2013, small coca fields—plots less than one hectare in size—accounted for more than 60 percent of the total area under coca cultivation (UNODC, 2014b). Hence, the strategies used to control coca crops target smallholder crops. Researchers have used theoretical modeling to understand the growth of illicit crops (Kennedy et al., 1993; Whynes, 1991). Most of those analyses explained the aggregate growth of drug trafficking in Colombia (Chumacero, 2008; Grossman & Mejia, 2008; Ortiz, 2002; Rocha, Thoumi, & Uribe, 1997), but did not analyze individual household incentives. As a result, there are few insights into what motivates smallholder households to cultivate coca, despite the obvious relevance of motivation to illicit crop control strategies.

Models to approximate household decision-making in the presence of armed conflict and illicit crop eradication were slowly introduced in the 2000s (Gorbaneff & Jácome, 2000; C. Vargas, 2004). The closest approximation to decision-making in coca-growing households is a survey-based choice experiment analyzing responses by 293 coca and non-coca farmers from four municipalities in one state in Colombia (M. Ibañez, 2007). This analysis succeeded in highlighting the impact of non-economic factors (e.g. religion and awareness campaigns on negative effects of coca) on cultivation, but the data collection approach used may have introduced bias, undermining the general conclusions. First, coca growers answering the survey were self-selected, reporting productive

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[19] The area under coca cultivation declined by 52 percent since 2001, from 144,800 to 69,000 hectares in 2014, (author's estimates based on UNODC (2008) and UNODC (2016b)).

activities on their farms for the past three years. Thus, these data do not necessarily represent average farmers, and could contain measurement error induced by the social desirability of not being cataloged as a criminal. Second, the sample size was relatively small and limited. It accounted for only one out of 24 states where coca is grown. Finally, the state selected—Putumayo—has been historically affected by illicit crops, with about 80 percent of its municipalities having coca cultivation (UNODC, 2010). Thus, it is an extreme case that might not be generalizable.

Here, I seek to close the gap left by previous analyses by estimating a discrete choice model that reflects the decision-making process of smallholder households. The model is tested using a random sample of 440 smallholder households—coca growing and non-coca growing farms— representative of agricultural units located in the Northeast and South Bolivar regions of Colombia. The area of study encompasses nine states, including 601 municipalities. The results suggest poverty motivates farmers to grow coca crops. Specifically, extremely poor farmers are more likely to grow coca crops compared to non-poor farmers in the same area. Basic household and agricultural unit characteristics also influence farmer decisions to grow coca crops. Households connected to the energy grid, with access to credit, and receiving cash payments for their licit crops, are less likely to grow coca crops. Therefore, strategies aiming to discourage farmers from growing coca crops should be tailored to answer their basic social development needs.

3.2 The Economics of crime control strategies and social investment

The economic theory of crime suggests that individuals distribute time between legitimate market opportunities and criminal activities depending on the expected return from each occupation and the probability and severity of the punishment (Becker, 1968; Block & Heineke, 1975; Ehrlich, 1973; Stigler, 1970). Following this framework, crime control strategies need to generate the right incentives to regulate human behavior, either increase the punishment for performing criminal activities or increase the reward for conforming to a set of standards accepted by society, or both. The government, as central agent, could encourage individuals to behave according to social norms using law enforcement. But increasing the returns from legal market options also increases the opportunity cost of committing crime. Therefore, there is another useful public policy approach to control crime: social investment.

Social expenditures are redistributive transfers that increase the opportunity cost of incarceration (Benoit & Osborne, 1995). Their main goal is improving quality of life. Public investments in infrastructure revitalize local economies, expand markets, and increase job opportunities. Public investments in human capital are long-term investments to build skills, increase productivity, and boost future earning power. Public expenditures in health programs, for example, work as subsidies that increase available income. These are redistributive transfers that allow families to consume other goods that would have not been consumed if they had to spend part of its income in medical bills (e.g. recreation activities). As a result, redistribution reduces the inequality between criminals and potential victims and gives criminals more to lose (Eaton & White, 1991).

Criminal activities are linked to many social variables. In general, income inequality and poverty are positively related with property crime (Ehrlich, 1973; İmrohoroğlu, Merlo, & Rupert, 2000; Kelly, 2000), whereas unemployment and market wages have a negative relationship with crime rates (Huang, Laing, & Wang, 2004; Mauro & Carmeci, 2007). There are, then, many mechanisms through which public spending could prevent and deter crime. In particular, social investments in infrastructure and human capital in coca-growing areas prevent new coca crops (Davalos, 2016). To date, however, most of the strategies used to control this criminal activity focus on law enforcement. Thus, the potential for social investment to shape decision-making by farmers remains unexplored.

3.2.1 Current strategies to control coca crops in Colombia

Controlling coca cultivation seeks to disrupt the productive process of cocaine by targeting the first link on the drug trafficking structure. Controlling the crops is, at least in theory, the easiest way to tackle drug trafficking because cultivation is relatively fixed (Felbab-Brown, 2009). Coca crops are controlled using eradication. Forced eradication includes manual eradication and aerial fumigation. Manual eradication implies uprooting, and sometimes burning, coca bushes. This is a labor-intensive method performed in easily accessible areas without armed conflict. Aerial fumigation is accomplished by spraying herbicide over coca plantations larger than two hectares, located in difficult-access areas with active armed conflict (Council, 1994; DNE, 2003). Fumigation using the herbicide glyphosate mixed with a variety of surfactants and adjuvants was conducted in Colombia until September 2015 (ANLA, 2015).

In addition to forced eradication, alternative development programs aim to control illicit crops by promoting productive projects. In Colombia, as 2013, this strategy included two main programs, *Proyectos Productivos* (productive projects) and *Familias Guardabosques* (ranger families). To be eligible, both programs require families to voluntarily eradicate their coca crops. *Proyectos Productivos* aims to establish agro-forestry and agricultural projects to provide stable and licit employment and income. *Familias Guardabosques* aims to generate self-management capabilities to improve the living conditions of the rural population, and strengthen the culture of legality in areas with or at risk of growing illicit crops and drug trafficking drugs (Acción Social, 2011).

3.3 Smallholder households

The criterion used by the government to differentiate between coca cultivation by smallholders and commercial coca crops is plantation size. Plantations larger than three hectares are classified as commercial, while smaller ones are attributed to smallholders (PLANTE, 2002). At the peak of coca production in Colombia—2000, 40 percent of the area planted fit the definition of smallholder cultivation (UNODC, 2003a), but as a consequence of enhanced surveillance and monitoring, by 2010 coca production in smallholder plots rose to almost 76 percent of the area (UNODC, 2011b). By 2013, small coca fields accounted for more than 60 percent of the total area under coca cultivation, providing a focus for coca control strategies (UNODC, 2014b).

Smallholder households are family farms practicing subsistence agriculture in which most of the labor comes from the household. Smallholder households that undertake illicit cultivation are motivated by the stability and security of income from illicit crops, not necessarily by undue profits. The estimated annual gross income for a coca-growing family of four people in 2010 was $6,950 USD (UNODC, 2011c), while the gross domestic product per capita in the same period was $5,630 USD. According to both the United Nations Office of Drug Control and the Colombian government, the higher income of coca growing families does not imply a higher standard of living, as cost of living is higher and infrastructure poorer in coca-growing regions (UNODC, 2006, 2011c; UNODC & DNE, 2010).

Most coca growers are migrants attracted to the agricultural frontier by the promise of land ownership, productive booms in rubber, timber, gold, oil or illicit crops, or displaced by armed conflict from their area of origin (Dávalos et al., 2016; Ramírez & Molano, 1998). The earliest of these mass migrations to the frontier took place in the 1960s and 1970s under a policy authorized by the government through the "Directed Colonization Project" law of 1961. By opening the forested frontier this policy relieved political pressure to break the large landholdings or *latifundia* in the Andes and northern lowlands. By the 1980s, productive booms at the frontier were as attractive to the rural and urban unemployed as the promise of landholding (Zornoza, 1998). Finally, a floating population of coca leaf collectors (*raspachines*) emerged in the 1990s, and has become a regular feature of the rural economy in coca-growing regions (García, 2006).

3.3.1 Choice or fate?

Smallholder households where coca is grown face two alternatives; 1) they can plant a legal crop in untreated soil without technical assistance or assured buyers knowing that transportation and commercialization will be costly in time and resources, or 2) they can plant coca from seeds provided by the trafficker, applying multiple herbicides, chemical fertilizers and pesticides afforded by the high value of the crop, and knowing with complete certainty that there will be a buyer (UNODC, 2013a; UNODC & Social, 2008, 2010). Additionally, the coca species and varieties cultivated in Colombia are native to the Andes or Amazonian lowlands; they are adapted to many local conditions and produce an average of 4.3 annual harvests (range: 2.5–6.0) (UNODC, 2007). As a result, illicit crops provide smallholder families with access the cash economy, but do not resolve the lack of basic infrastructure, education, health care, justice, or environmental management.

3.4 Data

This paper analyzes agricultural units located in the Northeast and South Bolivar, Colombia. This analysis uses the 2008 version of the *Encuesta de Costos de las Unidades de Producción Agropecuaria* survey conducted during the second half of 2008 by the Illicit Crops Monitoring Global Program of the United Nations Office of Drugs and Crime in Colombia. The random sample was selected using the area sampling frame technique. First, based on the 2007 Coca Survey, the Northeast and South Bolivar regions of Colombia were divided into one-kilometer square grids. Then, the area in the grids was classified into different strata; areas with the same land use formed a stratum. Following this procedure, the grids were numbered in a serpentine order, starting in the northeast of the region. Finally, 110 grids were selected using a systematic selection process after a random start.

A survey team visited each of the 110 grids, located in 25 municipalities, and selected a coca field in each of them. The survey team searched for two agricultural units growing coca crops and two agricultural units without coca crops around each selected field inside the grid. In total, the survey team conducted 220 interviews with coca farmers and 220 interviews with non-coca farmers. The final dataset consist of a random sample of 440 cross-sectional units—coca growing and non-coca growing farms—representative of the agricultural units located in Northeast and South Bolivar, Colombia. The area of study encompasses nine states, including 601 municipalities. Figure 3.1 illustrates the geographic location of the area of study.

The survey asked questions related to the characteristics of the head of the household, the household, and the agricultural unit. This analysis includes those three types of variables. The main characteristics of the head of the household are captured in five variables. Sex is a dichotomous variable coded one if female, zero otherwise. Age is a continuous variable describing how old the head of the household is. Literacy is a dichotomous variable coded one if the head of the household knows how to read and write, and zero otherwise. Education is a continuous variable describing the number of years of education completed by the head of the household. Poverty is a set of dichotomous variables, not poor, poor, or extremely poor, coded 1 if the head of the household is not poor, poor, or extremely poor, zero otherwise. In the analysis the excluded category is not poor. The poverty variable was created based on the Colombian system of identification of potential beneficiaries of social programs (SISBEN for its Spanish-language acronym). This classification considers socioeconomic characteristics of the individual, of his/her home, the size of the household, education, health, employment, etc. Level I groups people with the worst socioeconomic conditions.

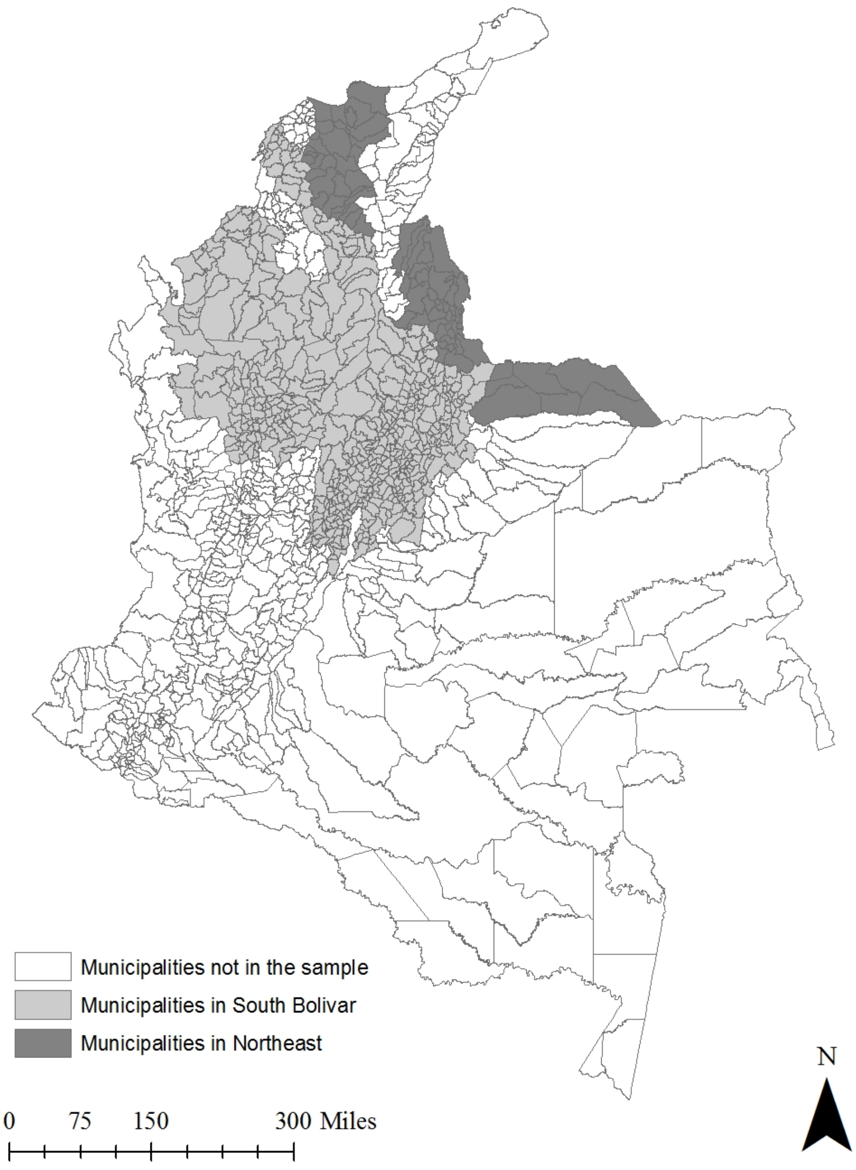

FIGURE 3.1: Smallholder households survey Northeast and South Bolivar, Colombia 2007

The household is characterized through six variables. The size of the household is the number of people in the household. Work force is the percentage of people in the household who are old enough to work, older than ten years old. The variable males is the percentage of males in the household, and children is the percentage of people in the household who are 5 years old or younger. Read and write is the percentage of people in the household who know how to read and write. Electricity is a dichotomous variable coded one if the household has electricity, zero otherwise. The size of the agricultural unit is measured in hectares.[20] The variable cattle is the number of cows in the agricultural unit. Crop lost includes the lost of seasonal and perennial crops because of fumigation, pests, bad weather, or other reasons. The area planted in seasonal crops is a continuous variable measured in hectares. Access to credit is a dichotomous variable coded one if the agricultural unit has some sort of credit to support agricultural production, zero otherwise. Cash payment for licit crops, cattle and non-cattle animals are dummy variables coded one if the payment was made in cash, zero otherwise; other forms of payment include credit, barter, etc. Table 3. 1 shows descriptive statistics of the variables included in the analysis

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[20] One hectare is equivalent to 2.5 acres.

TABLE 3.1: Descriptive statistics agricultural units with and without coca crops, Northeast and South Bolivar, Colombia 2007

	Agricultural unit with coca crops N=220				Agricultural unit without coca crops N=220			
	Mean	Std.	Min	Max	Mean	Std.	Min	Max
Head of household characteristics								
Female	0.04	0.20	0	1	0.05	0.21	0	1
Age	41.59	12.54	20	92	43.66	11.69	22	78
Literacy	0.89	0.32	0	1	0.85	0.35	0	1
Years of education	4.18	2.98	0	12	3.63	2.95	0	11
Poor	0.08	0.27	0	1	0.09	0.28	0	1
Extremly poor	0.85	0.35	0	1	0.81	0.39	0	1
Household characteristics								
Size household	4.44	2.13	1	14	4.67	1.77	1	10
Work force	80.37	19.91	29	100	81.79	19.25	40	100
Percentage males	57.65	20.69	0	100	56.96	17.62	0	100
Percentage children 5 years old or younger	10.79	15.41	0	60	10.15	14.15	0	50
Percentage people who read and write	79.75	23.64	0	100	79.74	21.53	0	100
Electricity	0.38	0.49	0	1	0.45	0.50	0	1
Agricultural unit characteristics								
Size agricultural unit	25.01	26.92	0.5	200	28.79	37.70	0.5	300
Access to credit	0.02	0.13	0	1	0.08	0.27	0	1
Cattle	4.24	10.26	0	66	12.56	33.28	0	247
Crop lost	0.11	0.32	0	1	0.12	0.33	0	1
Area planted seasonal crops	1.02	1.69	0	12	1.66	3.29	0	30
Cash payment licit crops	0.16	0.37	0	1	0.25	0.44	0	1
Cash payment cattle	0.10	0.29	0	1	0.21	0.41	0	1
Cash payment non-cattle	0.01	0.10	0	1	0.05	0.22	0	1

Notes: This table presents descriptive statistics for 440 agricultural units representative of agricultural units located in Northeast and South Bolivar, Colombia. The survey was conducted in the second half of 2008.

3.5 Empirical model

To establish the main factors that motivate smallholder households to grow coca crops, I use a logit regression model. The dependent variable has a binary distribution, and the residuals have a standard logistic distribution. The regression model includes municipal fixed effects to control for unobservable cross-municipal differences, for instance, cultural attitudes towards crime. The basic econometric model is presented in Equation 3.1. The model is estimated using Huber-White standard errors clustered by municipality to control for arbitrary correlation within a municipality.

Equation 3.1: Logit model assessing the probability of growing coca crops

$$\Pr(y_i = 1|x_i, w_i, z_i) = \mathrm{F}(\gamma_0 + \gamma_1 x_i + \gamma_2 w_i + \gamma_3 z_i + \alpha_j)$$

where $i = 1, \dots, 440$ and $j = 1, \dots, 25$

The outcome variable is the chance of growing coca crops for agricultural unit i. F is the cumulative standard logistic distribution function, and x, w, and z are vectors of regressors. An agricultural unit's chance of growing coca crops is a function of head of household individual characteristics, x, household variables, w, and different agricultural unit attributes, z. The model also includes municipal fixed effects (α_j) to capture time-invariant municipal-specific characteristics that may confound the estimate of interest.

This model assumes the household is aware of the actions of the Colombia government to forcibly eradicate and substitute illicit crops, and soil quality is homogenous based on the high adaptability of coca bushes. The probability of forced eradication for a single smallholder household is exogenous, as individual smallholders cannot affect decisions by policymakers. In general, coefficients on human capital accumulation (literacy, years of education) are expected to be negative. I.e., the probability of growing coca crops will decrease, as the head of household and/or the members of the household are more educated. As for household variables, coefficients on size of the household and the percentage of children five years old and younger are expected to be positive, since their economic burden is greater. In contrast, agricultural unit attributes, like access to credit and cash payments, are expected to be negative, as resources to invest on the farm are likely to increase legal productivity and reduce the attractiveness of coca cultivation.

3.6 Results

To determine what motivates smallholders to cultivate coca, I regress the decision of growing or not growing coca crops on head of household individual characteristics, household variables, and agricultural unit attributes. Table 3.2, columns (1) through (4), presents logit estimates of equation 3.1. Column (1) reports coefficients on head of household characteristics. Column (2) presents results including household variables. Columns (3) and (4) show estimates on agricultural unit attributes. Results in column (4) include municipal fixed effects regressors not shown. Numbers shown without parentheses are logit coefficients. Numbers in parentheses are Huber-White standard errors clustered by municipality.

Results are consistent throughout the four models. Coefficients on age are significant and display a negative relationship. The probability of growing coca crops decreases, at a decreasing rate, as the head of household ages. The older the head of household, the less likely the household is to grow coca. Based on the sample, this relationship reverses around 48 years of age. This result differs from the traditional aggregate age crime curve or inverted U curve, in which the peak of crime ranges from 18 to 24 years old (Donohue & Levitt, 2001). Here, the chances of growing coca crops decline until 48 years of age, and then start increasing as farmers get older (see Appendix E). It might be that older farmers have more experience avoiding forced eradication, and thus are less risk averse. Another relevant characteristic of the head of household is poverty. Extreme poverty is always positive and statistically significant. The poorer the head of the household, the more likely the household is to grow coca. This result, at the individual level, supports several previous studies of aggregate data in which poverty measures displayed a significant relationship with coca crops (Dávalos et al., 2011; Dion & Russler, 2008; Moreno-Sanchez et al., 2003; Rincón Ruiz, Pascual, & Romero, 2013).

Among the household characteristics analyzed, the coefficient on electricity is consistently negative and significant. Households connected to the grid are less likely to grow coca. This result connects the *energy poverty* to the discussion on coca cultivation. Indeed, previous studies in developing countries have established the nexus between electricity, poverty, income, academic achievement, and agricultural productivity (Bridge, Adhikari, & Fontenla, 2016; Ingwe, 2014; Ringel, 2004). All these variables are relate to coca cultivation, as poverty appears to be one of the main motivations to grow coca, and low agricultural productivity is one of the reasons why licit crops fail to compete with illicit ones.

TABLE 3.2: Logit regression determining the probability of growing coca

	Agricultural unit growing coca crops							
	(1)		(2)		(3)		(4)	
Head of household characteristics								
Female	-0.09	(0.48)	-0.11	(0.50)	-0.03	(0.53)	-0.04	(0.54)
Age	-0.09**	(0.04)	-0.09*	(0.04)	-0.09*	(0.05)	-0.08*	(0.05)
Age squared	0.00*	(0.00)	0.00*	(0.00)	0.00*	(0.00)	0.00*	(0.00)
Literacy	0.00	(0.38)	0.07	(0.47)	0.19	(0.49)	0.22	(0.54)
Years of education	0.04	(0.04)	0.05	(0.04)	0.06	(0.05)	0.05	(0.06)
Poor	0.27	(0.39)	0.39	(0.35)	0.18	(0.38)	0.37	(0.39)
Extremly poor	0.46	(0.31)	0.49*	(0.27)	0.54*	(0.31)	0.71**	(0.30)
Household characteristics								
Size household			-0.05	(0.07)	-0.04	(0.07)	-0.03	(0.08)
Work force			-0.01	(0.01)	-0.01	(0.01)	-0.02	(0.01)
Percentage males			0.00	(0.01)	0.00	(0.01)	-0.00	(0.01)
Percentage children 5 years old or younger			-0.01	(0.01)	-0.01	(0.01)	-0.02	(0.01)
Percentage people who read and write			0.00	(0.01)	-0.00	(0.01)	-0.00	(0.01)
Electricity			-0.45***	(0.17)	-0.48*	(0.25)	-0.80**	(0.39)
Agricultural unit characteristics								
Size agricultural unit					0.01**	(0.01)	0.01**	(0.01)
Access to credit					-1.03*	(0.57)	-1.38*	(0.72)
Cattle					-0.02**	(0.01)	-0.03**	(0.01)
Crop lost					0.19	(0.24)	0.48*	(0.28)
Area planted seasonal crops					-0.13**	(0.06)	-0.16*	(0.08)
Cash payment licit crops					-0.58*	(0.30)	-0.94**	(0.44)
Cash payment cattle					-0.58*	(0.35)	-0.82**	(0.39)
Cash payment non-cattle					-1.27	(1.08)	-1.57	(1.21)
Intercept	1.50	(1.25)	2.40	(1.55)	2.66	(1.74)	3.00	(2.20)
Observations	440		440		440		440	
Clusters	25		25		25		25	

Notes: This table presents the results of the specification established in Equation 3.1 by Logit regression. The outcome variable used in this analysis is defined as: agricultural unit growing coca crops=1, 0 otherwise. The sample includes 440 agricultural units located in Northeast and South Bolivar, Colombia. Huber–White standard errors clustered by municipality in parentheses. Municipal fixed effects regressors not shown in column 4. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

As expected, the availability of land has a positive relationship with growing coca crops. More land available makes the agricultural unit more likely to grow coca. Losing a crop, either a seasonal or permanent crop, because of fumigation, pests, or bad weather also increases the probability of growing coca crops. In contrast, all the other attributes of the agricultural unit have a negative relationship with growing coca. Having more cattle, planting more seasonal crops, having access to credit, and cash payments for licit crops decrease the likelihood of growing coca. These last two attributes are key to design strategies appealing to farmer needs in coca-growing areas. As previous studies suggested, access to credit is a successful means to overcome poverty (Yunus, 1998; Yunus & Jolis, 1999). Therefore, banking alternatives for farmers in coca-growing areas might be a way to promote legal crops.

3.7 Conclusions

The household survey analyzed here, encompassing a greater diversity of households and regions than any previous survey of coca growers, provides hitherto inaccessible insights into smallholder decision-making and illuminates efforts to control coca cultivation. Although municipal-level analyses had already identified poverty and underdevelopment as important covariates of coca cultivation (Dávalos et al., 2011; Dion & Russler, 2008; Marcela Ibañez & Carlsson, 2010; Moreno-Sanchez et al., 2003), individual households in coca-growing areas are not uniformly prone to coca cultivation. First, poorer households within already poor and underserved areas are more likely to grow coca than others. Second, the negative relationship between connection to the electric grid and coca cultivation suggests rural electrification is a key intervention to boost legal productivity. Third, boosters of legal productivity, from credit assistance to enhancing legal crop management may play a key role in steering growers away from coca. In contrast, and as observed at wider geographic scales, crop loss including loss from aerial fumigation instigates further coca production. Finally, the relationship between coca cultivation and the age of the head of the household is U-shaped, suggesting a peak in risk-aversion, the importance of experience to successfully growing coca, and/or difficulties in switching away from coca for older households.

If the main goal of all the eradication efforts is to reduce the area under coca cultivation (DNP & DJS, 2006; USAID, 2009), the strategies used to deter farmers from growing coca crops should be tailored to answer their needs. In general, the strategies should aim to reduce poverty and promote social development. In particular, households in coca growing areas should have access to electricity. They should be connected either to the energy grid or linked to off-grid solutions. There are multiple options to electrification in remote areas, for instance micro hydro electricity generators, biomass gasifier systems, small wind electric generators, or solar power systems (El Bassam, Maegaard, & Schlichting, 2013; Kanase-Patil, Saini, & Sharma, 2010; Nouni, Mullick, & Kandpal, 2008). In addition to provide licit market options, alternative development programs should ensure cash payments for their products and access to credit, since previous program failures and partial or in kind payments tend to discourage farmers from joining new projects.[21] Finally, the strategies to approach farmers (e.g. communication strategies, productive projects, and training programs) should factor the age of the head of the household. Farmers in their mid twenties to mid forties are less likely to grow coca crops. People in this age range can easily be retrained and shift production activities, but their older counterparts find these changes more challenging (Bailey Iii & Hansson, 1995; Hendricks, 1984; Super, 1990). As a result, policy makers need to better understand the contextual factors that make some crops or career changes especially problematic for each target population in order to design more effective policies.

[21] In 1996, for example, the crop substitution program in the Orinoco basin received almost 5,000 requests for credit to improve irrigation, crop processing, and other activities related to legal crop production, only 127 were funded during the first semester because of insufficient resources (Ramírez & Molano, 1998).

CHAPTER 4: DOES FORCED ERADICATION SPREAD COCA CULTIVATION?

4.1 Introduction

As dozens of press headlines have announced, the War on Drugs has failed to curb cocaine production, consumption, and trafficking (Chalabi, 2016; Doward, 2016; Pardo Veiras, 2016). Therefore, presidents of the countries involved, public figures, and researchers have called for a new public policy approach to control drugs (LSE, 2014; Mulholland, 2016; Policy, 2011; Post, 2016). On the supply side, the failure has been attributed to the strategies used to control illicit crops, as coca crops shift from one area to another but do not disappear (Bertram, Blachman, Sharp, & Andreas, 1996; Nadelmann, 1989; Stares, 1996; Zepeda Martínez & Rosen, 2015). In the drug policy literature, this dynamic shifting is commonly known as the *balloon effect*. Cultivation is squeezed in one side; then it emerges in another.

Even though balloon effect dynamics of coca cultivation are popular with the public and some researchers, its empirical testing has been limited (Basov, Miron, & Jacobson, 2001; Reuter, 2014; Reuter et al., 2009; Francisco E. Thoumi, 2003). Previous studies evaluating the effectiveness of the strategies used to control illicit crops (Marcela Ibañez & Carlsson, 2010; Moreno-Sanchez et al., 2003; Moya, 2005; Reyes, 2014; Tabares & Rosales, 2005), and specifically testing the balloon effect (Raffo Lopez, Castro, & Diaz España, 2016; Rouse & Arce, 2006), did not account for the spatial dependence of coca cultivation and forced eradication. However, an increase in coca cultivation in one region can be caused by the reduction in forced eradication in its own region or by the increase in forced eradication in neighboring regions. As a result, the broad impacts—including local and spillover effects—on coca crops may lead to biased policy conclusions if the spatial dependence of forced eradication is not factored in the analyses.

A recent study, acknowledging the spatial dynamics of coca crops, established a positive relationship between aerial fumigation in a municipality and coca cultivation in neighboring municipalities the following year (Rincón-Ruiz & Kallis, 2013). However, the analysis used an indicator of spatial correlation (Moran's I) that suggests association but does not imply causation (Anselin, Sridharan, & Gholston, 2007). Hence, the spillover effect of the strategies used to control illicit crops on coca cultivation is still unknown. In contrast to previous research, this study implements a spatial econometric technique to address spatial dependence and estimates the spillover effects of forced eradication activities.

To assess the spillover effects of the strategies used to control illicit crops, I use annual data for 1,116 contiguous municipalities in Colombia between 2001 and 2010. I estimate a spatial Durbin model (SDM) with municipal and time fixed effects. The results suggest that manual eradication does not affect new coca crops. Aerial eradication, in contrast, reduces new coca crops and generates negative spillover effects. Aerial eradication activities in a municipality reduce, on average, the new area under coca cultivation by 8 percent in that municipality and by 3 percent in neighboring municipalities. In addition, implementing aerial eradication inside natural parks generates great spillovers or indirect effects. The change in neighboring municipalities to the change in the municipality itself is in the proportion of 6.25 to 1. Therefore, neighboring municipalities bear much of the impact of this policy change.

The paper is organized as follows. Section two describes the municipalities where coca cultivation takes place, explains the strategies used to control illicit crops in Colombia, and performs a descriptive analysis to illustrate spatial clustering in the area of study. Section three describes data used in the econometric analysis, and section four explains the econometric methodology used. Section five presents the results of the spatial panel data model, and section six closes with a discussion of the results.

4.2. Coca crops, forced eradication, and spatial dependence

In Colombia, most coca cultivation takes place in remote areas of the country isolated by the Andes mountain range and the characteristic Amazon inclement weather. More than 50 percent of the area affected with coca crops in Colombia lies in the Amazon region (see Table 4.1). Municipalities with coca cultivation are on average six times larger that those without coca crops. These municipalities are covered with thick rainforest and receive on average 50 percent more annual rainfall compared to municipalities without coca crops (Davalos, 2016). This geographic location produces a pattern of spatial aggregation of lowland forests and of coca cultivation that econometric analyses must account for.

Forced eradication follows coca cultivation. Eradication activities take place in municipalities with coca crops, 440 municipalities out of 1,116 contiguous municipalities in Colombia as of 2010 (see Table 4.1). Forced eradication is implemented using manual eradication and aerial fumigation. Manual eradication is a labor-intensive activity to uproot coca bushes. This was the only method of eradication used inside natural parks and indigenous reserves before aerial eradication was permitted inside natural parks in 2005 (Council, 2005) and indigenous reserves in 2007 (Council, 2007). Aerial eradication is accomplished by using airplanes to spray herbicide over coca plantations located in difficult-access areas with active armed conflict (Council, 1994; DNE, 2003). Aerial eradication with glyphosate was conducted in Colombia until September 2015 when it was suspended because of the health and environmental risks associated with the herbicide (ANLA, 2015).

TABLE 4.1: Municipalities and area, Colombia 2001-2010

	Municipalities			Area (sq km)		
	Without coca	With coca	Total	Without coca	Affected by coca crops	Total
Amazon region	7	65	72	11,696	521,860	533,556
Rest country	669	375	1,044	241,089	365,929	607,018
Colombia	676	440	1,116	252,785	887,789	1,140,574

Source: Compiled by the author based on the CEPAL (2013) report for the Amazon region classification, and UNODC annual surveys for municipalities affected by coca cultivation from 2001 to 2010. The area affected by coca crops is the total area of the municipality that had coca cultivation, manual eradication, or aerial eradication at some point during the year.

Analyzing the same geographic area using a local indicator of spatial association, there is a notable positive spatial clustering of coca crops in the Amazon region of Colombia in 2001. Figure 4.1 illustrates clusters of high-high hectares of coca. Hence, municipalities with high amounts of coca crops surround municipalities with high amounts of coca crops. By 2010, positive spatial clustering also appears in the Pacific and Northern region of the country.

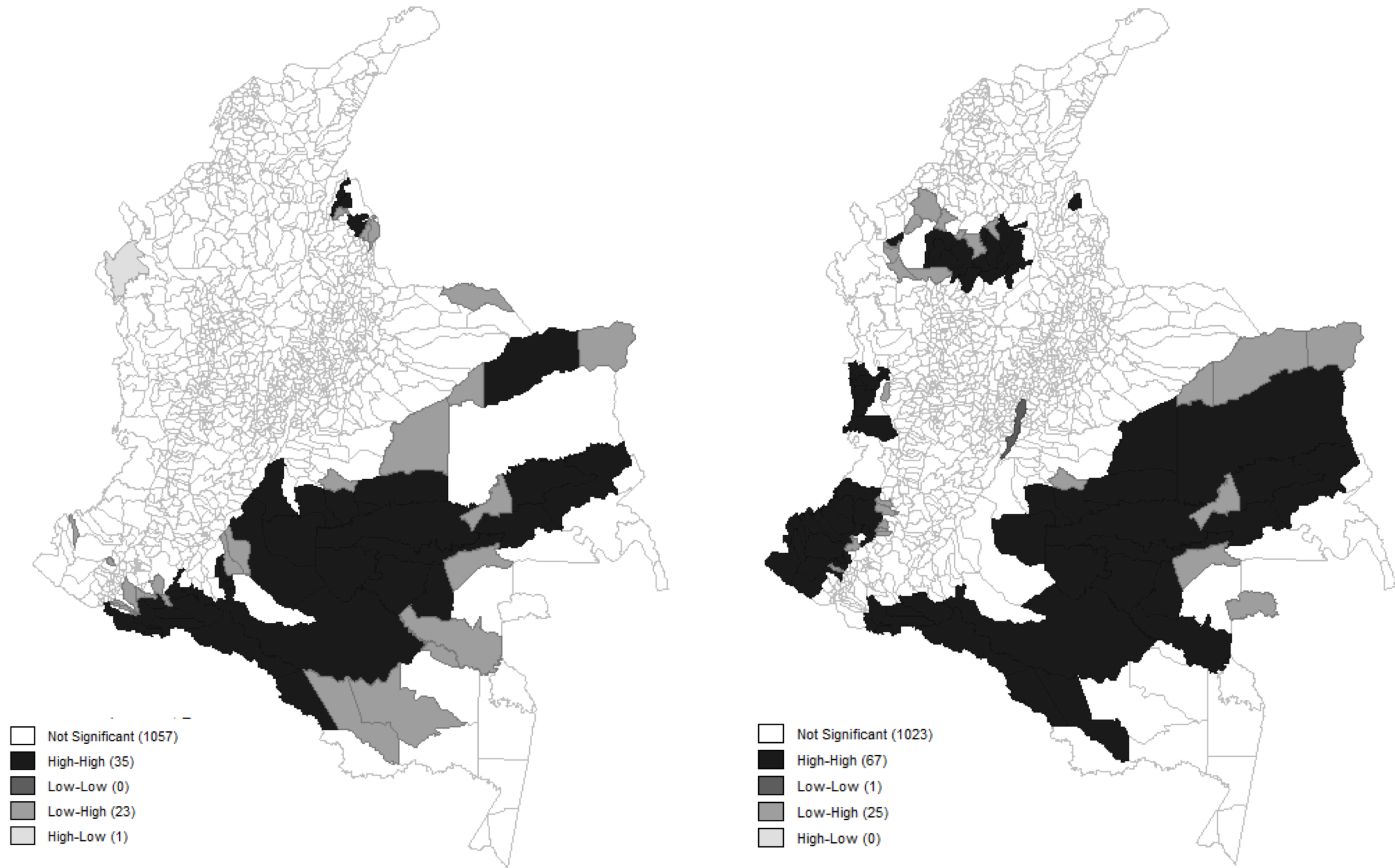
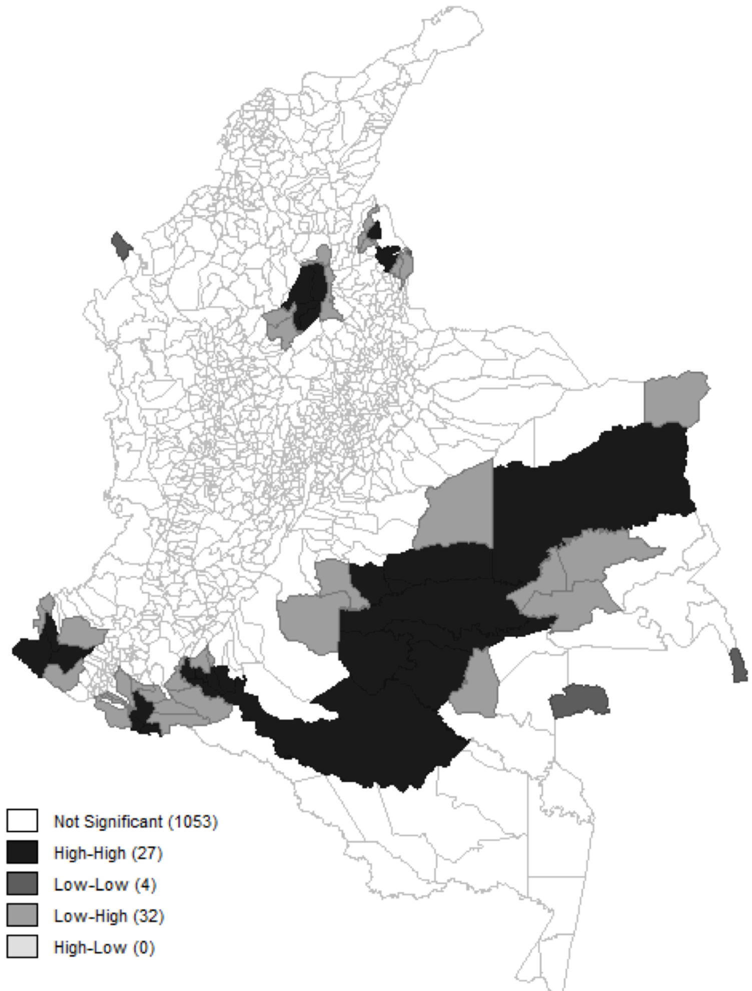


FIGURE 4.1: Local indicator of spatial association cluster map of coca cultivation per municipality, Colombia 2001 and 2010



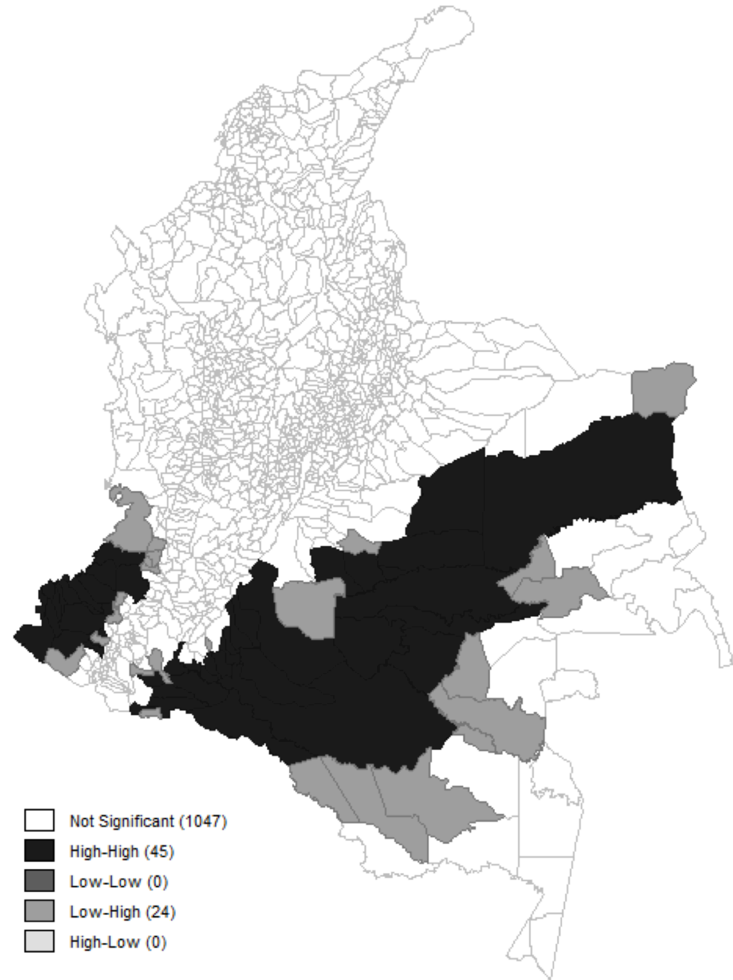


FIGURE 4.2: Local indicator of spatial association cluster map of aerial eradication per municipality, Colombia 2001 and 2010

Simultaneously, Figure 4.2 shows positive spatial clustering for aerial eradication in the Amazon region of Colombia in 2001. Eradication activities are concentrated in areas where coca cultivation is high. Therefore, there is also a positive spatial clustering for aerial eradication in the Pacific region in 2010. For this descriptive analysis, spatial weights for both Figures were created using a Queen contiguity method, first-order neighbors. The statistical significance of the correlations was calculated using 10,000 permutations. White areas in Figure 4.1 and 4.2 showed no statistically significant spatial clustering.

4.3. Data

This paper analyzes annual data for 1,116 contiguous municipalities in Colombia from 2001 to 2010. The outcome variable used in the econometric analysis is the change in the net area under coca cultivation at the cut-off date of the annual coca survey—December 31. The dependent variable was calculated using data on net area under coca cultivation from the *Annual Coca Survey* collected by United Nations Office of Drugs and Crime (UNODC). The Illicit Crops Monitoring Global Program of the UNODC captures satellite images that cover the entire continental Colombian territory (1,142,000 Km^2). The land cover accuracy is 89 percent. Therefore, the UNODC conducts field verification to calculate the extension of the area under coca cultivation with gaps or covered by clouds.[22]

Equation 4.1 describes the dependent variable. y_t is the new area on coca crops in period t. x_t is the net area under coca cultivation at the cut-off date of the annual coca

[22] For more details about the collection process and methodology, visit: http://www.biesimci.org/SIMCI/metodologia.html, and http://www.biesimci.org/Documentos/archivos/Accuracy-Colombia_field_mission_04_final.pdf

survey in period t, and x_{t-1} is the net area under coca cultivation at the cut-off date of the annual coca survey in period $t-1$. This variable was reported in annual hectares.[23]

Equation 4.1: Outcome variable used in the econometric analysis

$$y_t = x_t - x_{t-1}$$

Data on the strategies used to control coca crops, manual and aerial eradication, come the Colombian Antinarcotics Police (DIRAN for its Spanish-language acronym). These variables were also reported in annual hectares. Alternative development is the number of families joining *Familias Guardabosques* (ranger families), an alternative development program implemented in coca growing areas. These data were collected by the Colombian Agency for Social Action and International Cooperation, currently known as the *Departamento para la Prosperidad Social*.

In addition to the basic factors related to new coca crops, this analysis controls for policy implementation changes related to eradication activities affecting coca cultivation. The model estimated includes dummy variables capturing the difference between allowing aerial spraying inside natural parks and indigenous reservations. These dummies were coded zero before aerial eradication was implemented and one once it was implemented in municipalities with natural parks (after 2005) and indigenous reservations (after 2007).

This analysis also controls for other municipal-level characteristics. Data on public spending, government financing sources, for instance: property tax, industry and commerce tax, gasoline tax, natural resources royalties, and cofinancing, come from the

[23] One hectare is equivalent to 2.5 acres.

Colombian National Planning Department (DNP). They are reported annually in nominal thousand pesos. I use the CPI to adjust for inflation and per capita measures to make expenditures comparable over time and across municipalities. The DNP also ranks municipalities based on their fiscal performance. DNP follows the IMF guidelines to generate a rank that ranges from zero to 100, in which values over 80 mean that the municipality is solvent and values below 40 that has low savings capacity, difficulties covering its operation expenses, and relies on national transfers (DNP, 2012). Finally to measure armed conflict, I use the number of victims of all kind of human rights violations perpetrated by any kind of armed group (guerrilla, paramilitary, or national army). Human rights violations occurred daily in each municipality and are collected and reported by the Centre for Research and Popular Education/Peace Program—Cinep—a non-profit foundation that promotes social change in Colombia. Table 4.2 provides a summary of the variables included in the spatial econometric analysis.

TABLE 4.2: Descriptive statistics contiguous municipalities and data sources, Colombia 2001-2010

Type	Short name	Units	Description	Source(s)	Municipalities N=1,116	
					Mean	Std.
Crops	Coca (net of eradication)	Hectare	Area under coca cultivation at the cut-off date of the annual coca survey: December 31	UNODC annual coca survey	73.88	418.60
	New area coca	Hectare	Annual change on the area under coca cultivation at the cut-off date of the annual coca survey	Calculated from UNODC annual coca survey	-8.26	269.05
Estrategies to control illicit crops	Manual eradication	Hectare	Number of hectares manually eradicated throughout the year in each municipality	UNODC	34.18	347.74
	Fumigation	Hectare	Number of hectares fumigated throughout the year in each municipality	DIRAN from UNODC	119.85	871.42
	Voluntary eradication	Families	Number of families that joined alternative development program implemented in coca growing areas	Acción Social	12.03	118.05
Control variables	Conflict	Number	Victims of all kind of human rights violations per 1,000 inhabitants	CINEP	0.53	14.39
	Infrastructure	Constant 2008 COP	Thousands pesos spent annually, per inhabitant, in each municipality on land, roads, buildings, and equipment	DNP	245.84	344.47
	Human capital	Constant 2008 COP	Thousands pesos spent annually, per inhabitant, in each municipality on teacher salaries, training, school feeding programs, and education material	DNP	291.44	173.02
	Industry and commerce tax	Constant 2008 COP	Thousands pesos collected annually, per inhabitant, in each municipality from industry and commerce taxes	DNP	17.47	46.76
	Gasoline tax	Constant 2008 COP	Thousands pesos collected annually, per inhabitant, in each municipality from gasoline taxes	DNP	14.56	18.24
	Non tax income	Constant 2008 COP	Thousands pesos received annually, per inhabitant, in each municipality from other sources of income different from taxes	DNP	21.78	38.40
	Natural resources royalties	Constant 2008 COP	Thousands pesos received annually, per inhabitant, in each municipality from natural resources	DNP	50.35	265.17
	Fiscal performance	Rank from 0 to 100	Municipal fiscal performance, where values over 80 mean that the municipality is solvent and values below 40 that has low savings capacity, difficulties to cover its operation expenses, and relies on national transfers	DNP	59.52	8.96

4.4. Methods

The estimation is carried out using two sequential steps:

4.4.1 Spatial autocorrelation test

To measure spatial autocorrelation, I calculated Moran's I for the area under coca cultivation and the area fumigated with glyphosate using *GeoDa* (Anselin, Syabri, & Kho, 2006). The global Moran's I is defined in Equation 4.2 (Moran, 1950):

Equation 4.2: Global Moran's I

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} * \frac{\sum_{i=1}^{n} w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{\sum_{i=1}^{n} w_{ij}(x_i-\bar{x})^2}$$

Where n denotes the number of municipalities, 1,116 for the national level assessment, x and $\bar{x}$ denote the specific region and its mean, and w_{ij} is the spatial weight matrix, representing the spatial relationship between municipality i and j. The spatial region in this study is contiguous, and the spatial weight matrix was generated using the Queen Contiguity method.

I tested for spatial autocorrelation for new coca crops and aerial fumigation for each year from 2001 to 2010. Table 4.3 reports the results by year and scale of analysis. The global Moran's I for new coca crops and area fumigated are significant for all years for the national level data. This result indicates that spatial autocorrelation persists across years, and positive values indicate spatial clustering. The spatial dependence in the dependent and key independent variable implies that previous analyses that did not account for clustering are statistically biased.

TABLE 4.3: Moran's I value of new area coca and area fumigated

Scale	Municipal Level (1,116 municipalities)			
Year	New area coca		Area fumigated	
2001			0.255	***
2002	0.519	***	0.332	***
2003	0.059	***	0.284	***
2004	0.056	***	0.334	***
2005	0.102	***	0.262	***
2006	0.037	**	0.479	***
2007	0.133	***	0.346	***
2008	0.218	***	0.482	***
2009	0.183	***	0.416	***
2010	0.238	***	0.425	***

Note: ** p<0.05, *** p<0.01.

4.4.2 Spatial econometric analysis

To assess the spillover effects of forced eradication, I use a spatial panel data model (Elhorst, 2014b). The model includes a spatially lagged dependent variable and spatially lagged independent variables to specify spatial dependence among the observations (Anselin, Gallo, & Jayet, 2008; LeSage & Pace, 2009). Following the strategy described in LeSage and Pace (2009), Elhorst (2010), and Elhorst (2014a), I start with a spatial Durbin model (SDM) as a general specification and test for alternative models. The formal structure of the SDM is explained below.

Equation 4.3: Spatial Durbin model that contains a spatially lagged dependent variable and spatially lagged independent variables

$$y_{it} = \lambda \sum_{j=1}^{N} w_{ij}\, y_{jt} + \phi + x_{it}\beta + \sum_{j=1}^{N} w_{ij}\, x_{ijt}\theta + c_i + \alpha_t + v_{it}$$

where $i = 1, \ldots, 1116$, and $t = 1, \ldots, 10$

y_{it} is the dependent variable for cross-sectional unit i at period t. The variable $\sum_j w_{ij} y_{jt}$ is the interaction effect of the dependent variable y_{it} with the dependent variables y_{jt} in the neighboring units, w_{ij} is the i, jth element of a prespecified nonnegative $N \times N$ spatial weights matrix W describing the arrangement of the spatial units in the sample, ϕ is the constant term parameter, x_{it} is a $1 \times K$ vector of exogenous variables, and β is a matching $K \times 1$ vector of fixed but unknown parameters. To capture time-invariant municipal-specific characteristics that may confound the estimate of interest, the model also includes municipal fixed effects, c_i, and to control for variables that are constant across municipalities but change over time, it has time-period specific effects, α_t. Finally, θ is a $K \times 1$ vector of parameters, and v_{it} is the stochastic error term.

Using a general-to-specific approach, I estimate a spatial Durbin model to test whether it can be simplified to the spatial lag (SAR) or the spatial error model (SEM) (Burridge 1981). Table 4.4 summarizes the results of the Hausman test to determine if the spatial panel model should include fix or random effects, and the Wald test for special model selection. The Hausman test favors fixed-effects estimations over random-effects estimations. The Wald test (243.52, p=0.000) indicates that the hypothesis whether the spatial Durbin model can be simplified to the spatial lag model, $H_0\colon \theta = 0$, must be rejected. In contrast to the previous result, the hypothesis that the spatial Durbin model can be simplified to the spatial error model, $H_0: \theta + \lambda\beta = 0$, cannot be rejected (17.37, p=0.183). These results imply that the SAR must be rejected in favor of the SDM, but the SEM is preferred over SDM. However, the SEM is a special case of a SDM for which $\theta + \lambda\beta = 0$ (Appendix F). This kind of model is not suitable for a spillover effects analysis as the indirect effects are zero by construction (Elhorst, 2014b). As a result, the spatial econometric analysis is performed using a SDM.

TABLE 4.4: Specific tests for spatial dependence

Tests	Test statistics	Prob>chi2
Hausman test Ho: difference in coefficients not systematic	267.72	0
Wald test Ho: SDM can be simplified to SAR	243.52	0
Wald test Ho: SDM can be simplified to SEM	17.37	0.183

4.5. Results

To assess the spillover effects of forced eradication, I regress the size of new coca crops on the area manually eradicated and fumigated with glyphosate. Table 4.5, columns (1) to (3), reports coefficients on three different spatial panel models. Column (1) presents results of a spatial autoregressive model (SAR). Column (2) shows estimates of a spatial error model (SEM), and column (3) reports coefficients of a spatial Durbin model (SDM). The three sets of results include spatial and time fixed effects regressors not shown. Numbers shown without parentheses are spatial panel coefficients. Numbers in parentheses are standard errors.

TABLE 4.5: Model comparison of the estimation results explaining new coca crops

	New Area on Coca Crops					
	SAR		SEM		SDM	
Strategies to control illicit crops						
L1. Manual eradication	0.00	(0.01)	0.02*	(0.01)	0.01	(0.01)
L1. Aerial fumigation	-0.07***	(0.01)	-0.08***	(0.00)	-0.08***	(0.01)
L1. Alternative development	0.02	(0.03)	0.02	(0.02)	0.02	(0.03)
Control variables						
Conflict	0.83***	(0.22)	1.00***	(0.18)	0.84***	(0.21)
Natural parks	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
Indigenous reservations	28.22*	(15.61)	12.04	(13.41)	34.22**	(15.81)
Expenditures infrastructure	-0.01	(0.02)	-0.01	(0.02)	-0.01	(0.02)
Expenditures human capital	-0.04	(0.03)	-0.02	(0.02)	-0.04	(0.03)
Industry and commerce tax	-0.04	(0.16)	-0.02	(0.13)	-0.07	(0.16)
Gasoline tax	1.10***	(0.40)	0.95***	(0.33)	1.11***	(0.39)
Non tax income	0.07	(0.10)	0.06	(0.08)	0.06	(0.10)
Natural resources royalties	0.03	(0.03)	0.02	(0.02)	0.03	(0.03)
Fiscal performance	-0.09	(0.53)	-0.50	(0.45)	-0.28	(0.53)
W*L1. Manual eradication					-0.00	(0.00)
W*L1. Aerial fumigation					0.03***	(0.00)
W*L1. Alternative development					-0.01	(0.01)
W*Conflict					-0.28***	(0.10)
W*Natural parks					-5.66*	(3.25)
W*Indigenous reservations					-6.09	(5.22)
W*Infrastructure					0.00	(0.01)
W*Human capital					0.01	(0.01)
W*Industry and commerce tax					-0.01	(0.06)
W*Gasoline tax					-0.10	(0.15)
W*Non tax income					0.01	(0.04)
W*natural resources royalties					0.01	(0.01)
W*Fiscal performance					0.32	(0.20)
Rho	0.30***	(0.00)			0.30***	(0.00)
Lambda			0.03***	(0.00)		
Observations	10,044		10,044		10,044	
R-squared	0.00		0.00		0.00	
Municipalities	1,116		1,116		1,116	

Notes: This table presents the results of the specification established in Equation 4.2 by spatial panel data regression. The outcome variable used in this analysis is new area on coca crops. The estimates correspond to micro data set by municipality. The sample includes all Colombian contiguous municipalities from 2001 and 2010. Municipal and year fixed effects regressors not shown. L1 represents one-year lag. See Table 4.2 for description, units, and source for all the variables. ** p<0.05, *** p<0.01.

Results are consistent throughout the three models. The spatial lag of the dependent variable, *rho*, is positive and significant in the SAR and the SDM. As a result, there are spatial effects, clustering of similar municipalities and similar reactions. A significant and positive spatial error term, *lambda*, has an equivalent interpretation for a SEM. Coefficients on aerial fumigation are also pretty consistent in the three models, negative and statistically significant. Specifically in the SDM, coefficients on spatially lagged explanatory variables, aerial fumigation, conflict, indigenous reservations, and gasoline tax, are significant.

Table 4.6 reports direct, indirect, and total effects from the SDM estimation. The direct effect of an additional hectare of coca fumigated a year ago in municipality i reduces, on average, new coca crops by 0.08 hectares in municipality i. The direct effect of expenditures in human capital is also negative and significant. Increasing expenditures in human capital by one thousand pesos per inhabitant in municipality i is associated with a reduction of 0.04 hectare of new coca crops in the same municipality. This result is consistent with previous findings on the effects of social investment on new coca crops (Davalos, 2016). Armed conflict also has a direct effect on new coca crops. One additional victim of a human right violation per thousand inhabitants in municipality i is associated with an increase of 0.84 hectares of new coca crops in municipality i, on average. This result supports previous findings establishing associations between coca cultivation and armed conflict (Angrist & Kugler, 2008; Camacho G. & López R., 2000; Carvajal Contreras & Sánchez Torres, 2002; Diaz & Sanchez, 2004; Holmes et al., 2006). There is no feedback effect. Coefficients on aerial eradication, conflict, and expenditures in human capital (SDM results in Table 4.5) are very close to the direct effect of aerial eradication, conflict, and expenditures in human capital (Table 4.6).

The indirect effect of aerial eradication is negative and statistically significant. Therefore, if aerial eradication increases in municipality i during year t, new coca crops decrease in municipality i and its neighboring municipalities in year $t + 1$. The change in neighboring municipalities to the change in the municipality itself is in the proportion of 1 to -2.7. The indirect effect of spraying an additional hectare of coca in municipality i on the new coca crops in neighboring municipalities is a reduction of 0.03 hectares. There are no indirect effects for expenditures on infrastructure or human capital. However, policy changes of implementing aerial eradication inside natural parks generate great spillovers or indirect effects. When aerial eradication was implemented inside natural parks, new coca crops increase its neighboring municipalities. The ratio of the change in neighboring municipalities to the change in the municipality itself is in the proportion of 6.25 to 1. Therefore, neighboring municipalities bear much of the impact of this policy change.

TABLE 4.6: Direct and indirect effects estimates based on the coefficients estimates of the spatial Durbin model reported in Table 4.5

	Direct effect		Indirect effect		Total effect	
Strategies to control illicit crops						
L1. Manual eradication	0.01	(0.01)	0.00	(0.04)	0.02	(0.04)
L1. Aerial fumigation	-0.08***	(0.01)	-0.03***	(0.01)	-0.12***	(0.01)
L1. Alternative development	0.03	(0.02)	0.02	(0.09)	0.05	(0.09)
Control variables						
Conflict	0.84***	(0.21)	0.10	(0.98)	0.94	(1.03)
Natural parks	6.80	(6.81)	42.98***	(16.27)	49.78**	(21.29)
Indigenous reservations	32.61*	(17.95)	-26.12	(42.13)	6.50	(41.66)
Expenditures infrastructure	-0.01	(0.02)	0.02	(0.05)	0.01	(0.05)
Expenditures human capital	-0.04*	(0.02)	-0.00	(0.08)	-0.04	(0.08)
Industry and commerce tax	-0.07	(0.15)	0.22	-0.54	0.15	(0.53)
Gasoline tax	0.80**	(0.32)	-1.17	(0.97)	-0.37	(0.91)
Non tax income	0.04	(0.09)	-0.22	(0.29)	-0.18	(0.32)
Natural resources royalties	0.01	(0.03)	-0.15	(0.10)	-0.14	(0.10)
Fiscal performance	-0.36	(0.53)	-1.53	(1.30)	-1.89	(1.24)

Notes: This table presents the results of the specification established in Equation 4.2 by Spatial Durbin Model. The outcome variable used in this analysis is new area on coca crops. The estimates correspond to micro data set by municipality. The sample includes all Colombian contiguous municipalities from 2001 and 2010. Municipal and year fixed effects regressors not shown. L1 represents one-year lag. See Table 4.2 for description, units, and source for all the variables. * p<0.10, ** p<0.05, *** p<0.01.

Finally, the total effect of aerial eradication is the sum of its direct and indirect effect. If all municipalities increase aerial eradication by one hectare in period t, new coca crops will decrease by 12 percent in period $t + 1$ in the typical municipality.[24] Implementing aerial eradication inside natural parks also reports total effects. If all municipalities had natural parks and implemented aerial eradication inside them, new coca crops would increase, on average, by 49.8 hectares. There are no statistically significant total effects for expenditures on infrastructure or human capital.

4.6. Conclusions

If the War on Drugs failed to achieve the goals set 40 years ago, coca crop shifting because of forced eradication is not to blame, at least not at the municipal level. Based on the results, new coca cultivation increases because armed conflict intensifies. New coca crops extend, move to other municipalities, after aerial eradication starts inside natural parks. Therefore, the two variables exacerbating coca cultivation are not part of the strategies used to control illicit crops.

Aerial eradication does affect negatively coca crops intensity and expansion. New coca crops decrease as aerial eradication activities increase in its municipality. Aerial eradication also deters new coca crops expansion to neighboring municipalities as exercises pressure to reduce the extension of new coca crops. In both cases, the effect is small. Aerial eradication reduces by 8 percent the area in new coca crops in its municipality and by 3 percent in neighboring municipalities. Yet, until 2015, aerial

[24] One hectare is equivalent to 10,000 squared meters; thus, a reduction of 0.12 hectares equals a reduction of 1,200 squared meters or 12 percent of a hectare.

eradication was the only credible threat to coca cultivation because out of many coca growers only few are prosecuted.[25]

As of 2016, aerial fumigation is suspended in Colombia and coca crops went up 27,000 hectares (UNODC, 2016a). As a consequence, manual eradication emerges as the strategy to follow (Semana, 2016). This labor-intensive strategy requires the work of 20 people during one day to eradicate just one hectare of coca (Mansfield, 2011). Manual eradication is an arduous and dangerous activity for those performing the task.[26] Based on the results manual eradication has no impact on coca cultivation, so spending time and resources implementing a strategy that does not generate an impact on the area under coca cultivation is a risky move.

[25] It is estimated that in 2009 about 300,000 people were involved in coca cultivation. However, Colombian police reports 855 felonies (Colombia, 2010) and only 162 people were prosecuted for this crime. The unusual prosecution made national news (El Tiempo, 2009).

[26] According to Mansfield (2011): "In Peru, thirty eradication staff were killed in the Upper Huallaga Valley between 1986 and 1988. In the Macarena National Park in Colombia there were twenty-nine fatalities during a single day of eradication in December 2005 and a total of one hundred and eighteen were killed between 2005 and 2008. A further forty soldiers and police were killed during manual eradication efforts in Colombia in 2009."

CHAPTER 5: CONCLUSIONS

The area under coca cultivation in Colombia, 96,000 hectares as of 2015, illustrates that forced eradication alone does not consolidate areas free of illicit crops (UNODC, 2016a). Based on the results from this research, there are four explanations for this outcome. First, manual eradication does not affect coca cultivation. Second, aerial eradication deters farmers from increasing the size of their new coca fields, but the effect is small. Third, farmers are motivated to cultivate coca because they have unresolved social development needs. Finally, implementing aerial eradication inside natural parks spread coca cultivation.

The main strategy used to control illicit crops in Colombia—forced eradication—is partially effective. Coefficients on manual eradication are not statistically significant (Chapter 2 and 4). Hence, manual eradication does not affect coca cultivation. Aerial eradication, however, has a negative effect on new coca crops. Its impact varies between 8 and 11 percent; an additional hectare of coca eradicated reduces the area on new coca crops by 8 percent based on the analysis performed in Chapter2 and 11 percent based on the results from Chapter 4. These effects are small considering the amount of resources required to eradicated one hectare.

The strategies used to deter farmers from growing coca crops should be tailored to answer their social development needs. Poorer households within already poor and underserved areas are more likely to grow coca than others. The key interventions to boost legal productivity identified in this study are: connection to the energy grid, access to credit, and receiving cash payments for licit crops (Chapter 3). In general, addressing social development issues increases the opportunity cost of committing crime, but social investment in coca-growing areas increases the opportunity cost of growing coca crops specifically.

Implementing aerial eradication in some areas displace coca crops to other municipalities. Aerial eradication inside natural parks spread coca cultivation to neighboring municipalities in a very high ratio, 6.25 hectares in neighboring municipalities to 1 hectare in the municipality that implemented aerial eradication inside natural parks (Chapter 4). This policy change generates positive spillover effects that expand coca cultivation.

In sum, crime prevention can be achieved through many different crime control strategies. Law enforcement is just one means to prevent crime (Sherman et al., 1998). All the results presented in this study support public policy approaches to prevent crime as options besides law enforcement. Most of the statistically significant variables address social development issues: poverty, electrification, and access to banking services. These results could guide new public policies that integrate social development programs as apart of crime prevention strategies to control illicit crops. The results suggest social investment offers a range of public policy interventions to discourage farmers from growing coca. However, since raising the cost of crime is also necessary, social investment is a complement, not a substitute, to traditional coercive tactics.

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APPENDIX A: ESTIMATION PROCESS OF THE AREA UNDER COCA CULTIVATION IN COLOMBIA

1. Identification and acquisition of satellite images	LansSat 7 ETM+ LandSat 5 TM SPOT 4 and 5	ALOS ASTER IRS6-LISS III
2. Pre-processing of the images	Geo-reference: The satellite images are georeferenced by means of mosaics built with the images from previous surveys that are less cloudy. Minimization of areas without information: Gaps in the LandSat 7 ETM data are adjusted overlapping clear and cloudy images taken in different dates. Radiometric and spatial enhancements. Color composition.	
3. Visual interpretation of coca fields	Preliminary interpretation of coca cultivation. Verification of over flights: Direct visual inspection of the field from an aircraft. Edition: The information collected by over flights verification is used to adjust the preliminary interpretation of the images.	
4. Digital classification of the covers of land use and vegetation	There are 12 classes of land use and vegetation: primary forest and rain forest, secondary forest, grass and low stubble, high stubble, naked land, rocky outcrops, sandbanks, flooding zones, other crops, clouds, and gaps.	
5. Corrections	Correction for forced manual eradication: The information is corrected depending on the image and the eradication date. If the eradication took place before the image was taken and before the survey cut-off date, the eradicated field is not considered. Corrections for aerial spraying: Coca fields interpreted based on images taken before spraying are deleted from the interpretation and the estimate survival percentage of the sprayed cultivation is added to the final statistics. Corrections for cloudiness and gaps in LandSat 7 images. Corrections of different images acquisition dates.	

Source: Compiled by the author based on UNODC (2010)

APPENDIX B: REGRESSION ANALYSIS OF THE EFFECT OF STATUTORY COMMANDS, STRUCTURAL LAWS, AND MARKET INCENTIVES ON NEW COCA CULTIVATION, INCLUDING QUANTILE CATEGORIES BASED ON ANNUAL REGIONAL COCA PASTE PRICE FOR FIVE DIFFERENT REGIONS, COLOMBIA 2001-2010

	New Area on Coca Crops					
	(1)		(2)		(3)	
Statutory commands						
L1. Manual eradication	0.01	(0.04)	0.01	(0.04)	0.01	(0.04)
L1. Spraying	-0.11***	(0.04)	-0.11***	(0.04)	-0.11***	(0.04)
Structural laws and market incentives						
Social investment			-0.08**	(0.04)		
Infrastructure					-0.06**	(0.03)
Human capital					-0.17*	(0.09)
Alternative development			0.10	(0.09)	0.10	(0.09)
Control variables						
Conflict			1.18***	(0.15)	1.18***	(0.15)
Property tax			-0.91*	(0.47)	-0.90*	(0.46)
Industry and commerce tax			0.21	(0.14)	0.20	(0.13)
Gasoline tax			1.83**	(0.81)	1.84**	(0.82)
Non tax income			0.18**	(0.09)	0.18**	(0.09)
Natural resources royalties			0.05	(0.05)	0.04	(0.05)
Cofinancing			0.15**	(0.06)	0.13**	(0.05)
Fiscal performance			-1.30	(0.84)	-1.19	(0.85)
Natural parks			-31.72	(39.55)	-30.10	(39.51)
Indigenous reservations			34.15	(25.42)	35.39	(25.59)
Coca paste price						
Quantile 2	-2.04	(19.94)	-2.36	(21.20)	-2.06	(21.25)
Quantile 3	-44.01**	(18.50)	-40.45*	(21.02)	-39.81*	(20.95)
Quantile 4	-84.14**	(35.22)	-83.42**	(35.85)	-82.21**	(35.80)
Missing	-64.60**	(29.44)	-63.93**	(30.99)	-62.97**	(30.51)
Observations	3699		3699		3699	
Within R-squared	0.07		0.08		0.08	
Clusters	424		424		424	

Notes: This table presents the results of the specification established in equation 2 by panel data regression including quantile categories based on annual regional coca paste price for five different regions. The outcome variable used in this analysis is new area on coca crops. The estimates correspond to micro data set by municipality. The sample includes all Colombian municipalities that had coca crops at some point between 2001 and 2010. State and year fixed effects regressors not shown. L1 represents one-year lag. Huber-White standard errors clustered by municipality in parentheses. See table 2 for description, units, and source for all the variables *** p<0.01, ** p<0.05, * p<0.10

APPENDIX C: DIRAN ESTIMATED SURVIVAL RATE OF COCA CROPS 2002-2010

Year	Percentage
2002	17
2003	8.5
2004	10
2005	10
2006	12
2007	12
2008	9.0
2009	10
2010	5.9
Average survival rate	10.5

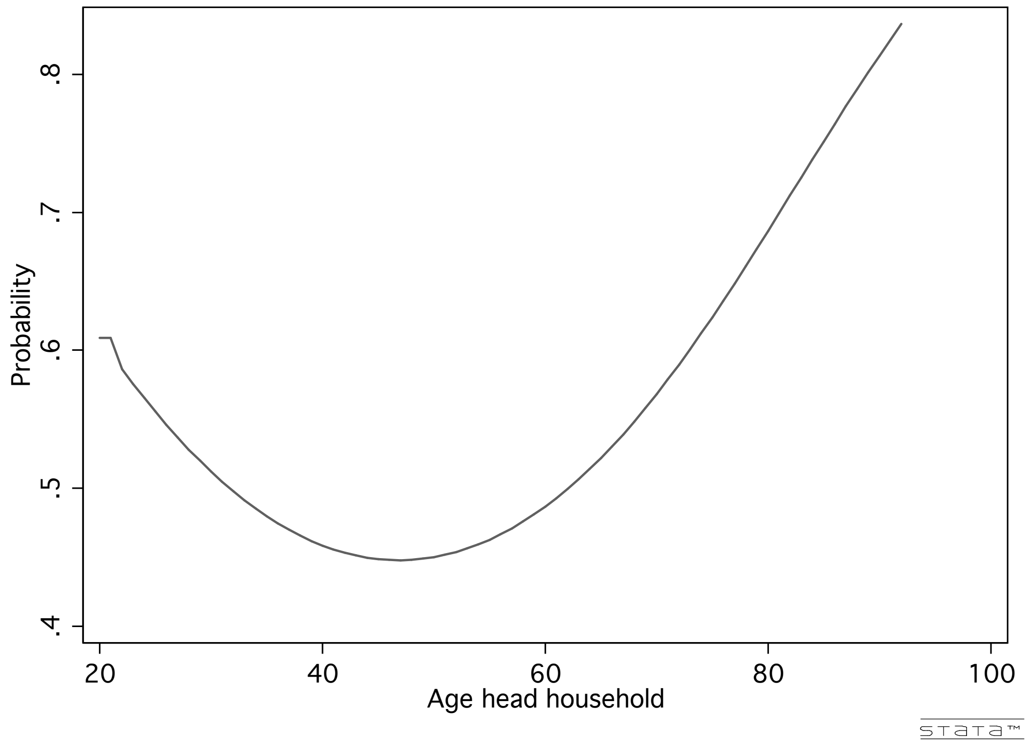
Source: Compiled by the author based on annual coca surveys 2002-2010.

APPENDIX D: ASSISTANCE PROVIDED TO THE COLOMBIAN MILITARY AND NATIONAL POLICE 2002-2008

		Dollars in millions		
Year	Hectares coca sprayed	Army aviation brigade	National police aerial eradication program	National police air service
2002	130,364	78	37.4	67.5
2003	132,817	140.8	63.7	62.3
2004	136,552	155.2	44.2	71.2
2005	138,775	127.5	82.5	70
2006	172,926	143.2	81.7	70.5
2007	153,134	129.6	82	69
2008	133,496	69.7	66.5	52.5
Total	998,064	844	458	463

Source: Compiled by the author based on the UNODC (2011d) report for the number of hectares of coca sprayed, and the GAO (2008) report for the amount of money spent on spraying related activities.

APPENDIX E: CHANCES OF GROWING COCA AS HEAD OF HOUSEHOLD GET OLDER, RESULTS MODEL (4) TABLE 3.2



Notes: Based on estimations model (4), Table 3.2. Chances of growing coca crops decline until 48 years of age, and then start increasing as farmers get older.

APPENDIX F: SPATIAL ERROR MODEL (SEM) IS A SPECIAL CASE OF A SPATIAL DURBIN MODEL (SDM)

Starting from a SDM:

$$y_{it} = \lambda \sum_{j=1}^{N} w_{ij}\, y_{jt} + \phi + x_{it}\beta + \sum_{j=1}^{N} w_{ij}\, x_{ijt}\theta + c_i + \alpha_t + v_{it}$$

If $\theta + \lambda\beta = 0 \Rightarrow \theta = -\lambda\beta$

$$y_{it} = \lambda \sum_{j=1}^{N} w_{ij}\, y_{jt} + \phi + x_{it}\beta - \lambda\beta \sum_{j=1}^{N} w_{ij}\, x_{ijt} + c_i + \alpha_t + v_{it}$$

$$y_{it} = \lambda \left[\sum_{j=1}^{N} w_{ij}\, y_{jt} - \beta \sum_{j=1}^{N} w_{ij}\, x_{ijt} \right] + \phi + x_{it}\beta + c_i + \alpha_t + v_{it}$$

$$y_{it} = \lambda \left[\sum_{j=1}^{N} w_{ij} \left(y_{jt} - \beta x_{ijt} \right) \right] + \phi + x_{it}\beta + c_i + \alpha_t + v_{it}$$

$$y_{it} = \lambda \sum_{j=1}^{N} w_{ij} \left(u_{jt} \right) + \phi + x_{it}\beta + c_i + \alpha_t + v_{it}$$

$\Rightarrow$ SEM $y_{it} = \phi + x_{it}\beta + c_i + \alpha_t + u_{it}$

where $u_{it} = \lambda \sum_{j=1}^{N} w_{ij}\, u_{jt} + v_{it}$