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ABSTRACT

ESSAYS ON THE ECONOMICS OF COCAINE PRODUCTION IN COLOMBIA

By

Luis Carlos Reyes-Hernández

The United Nations estimate that there are 16 to 21 million cocaine users in the world, and the majority of the production of this illegal drug takes place in Colombia. This dissertation explores different drug control policies in the Andean country, in two chapters.

In the first one I tackle the question of how drug control policies affect the production of coca at the municipality level. I use a five year panel that includes observations on aggregate coca production for every Colombian municipality. I consider the effects of two drug control policies: eradication of coca crops, and alternative development programs. I take an Instrumental Variable (IV) approach to estimate the change in land allocated to coca by farmers as a consequence of eradication and alternative development programs.

I use instruments that enter the expected cost function of the government as it implements eradication and alternative development programs, yet affect farmers' land allocation decisions through no channel other than their effect on drug policy. The instruments are derived from increases in the expected cost of coca eradication as crews get far from the zone where Antinarcotics Police helicopters can protect them from illegal armed groups that try to shoot them down. I find that there is a strong negative relationship between distance from this zone and the level of eradication that takes place.

Moreover, eradication decreases at a higher rate where the presence of illegal armed group combatants is greater. Because of analogous safety limitations in getting alternative development program administrators to their destination in coca growing regions, the same correlation exists between distance from the safety zone and government spending on alternative development programs. IV estimation of the effect of eradication shows that a one percent increase in eradication results in a 0.3 percent increase in coca cultivation. A one percent increase and alternative development program spending results in coca cultivation increases of up to 0.5 percent.

In the second chapter I use a cross section of household level survey data collected by the United Nations Office on Drug and Crime to analyze the impact of crop eradication through fumigation in coca farms. I use once again IV estimation to deal with policy endogeneity. The estimates suggest that, conditional on being a coca producer, a one percent increase in eradication can result in a decrease of up to 0.2 percent in the share of land that is devoted to coca.

To the memory of my grandfather, Álvaro Vicente Hernández-Rojas

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Doing research on cocaine production is at times a peculiar task. I am grateful to the people and the institutions who kindly shared their data with me, and in particular to Martha Paredes, the United Nations Office on Drug and Crime, and the Colombian Antinarcotics Police. I am also thankful to my advisor, Stacy Dickert-Conlin, my parents, my friends from the Graduate Intervarsity Christian Fellowship at Michigan State University, and Christopher and Priscilla Smith for their support and their encouragement throughout my time in East Lansing; and to the customs officers at Miami International Airport who inquired about my doctoral research on my way back from Colombia, for eventually coming around to believing that my interest in cocaine was merely academic and not personal.

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CHAPTER 1: DO ERADICATION AND ALTERNATIVE CROP PROGRAMS REDUCE COCA CULTIVATION IN COLOMBIA?

I. INTRODUCTION

Colombia is the main supplier of cocaine to the United States. Because of the social costs resulting from production and consumption of the drug, both countries have made it a priority to put an end to illegal drug manufacturing and trafficking. In order to disrupt the flow of drugs, the governments of the two nations have targeted every step of this process, allocating billions of dollars to antinarcotics military units, border controls, interdiction of drug shipments, and the destruction of laboratories and the precursor chemicals used in the production of cocaine.

However, little applied work has been done to assess the efficacy of drug control policies. This is particularly true in the case of coca eradication and alternative development programs, which target the farmers that produce coca leaf, the primary input of cocaine. Only Moreno et al. (2003) and Dion and Russler (2008) have attempted to estimate the effectiveness of coca eradication, and to date there are no econometric evaluations of whether increased spending on alternative development programs leads to a reduction in coca cultivation.

It is widely acknowledged in the economic literature on crime that empirical estimation of the effects of law enforcement and other government programs on illegal behavior is a task complicated by severe endogeneity of the policy variable (Johnson, R. S., S. Kantor and P. V. Fishback 2007, Levitt, S. D. 1997). Yet the available studies of the effect of eradication on coca cultivation do not address this issue. This is surprising, because endogeneity in this setting is a serious concern. The Colombian government has a clear incentive to concentrate its antinarcotics efforts on those regions of the country where the production of coca is most pervasive.

In this paper I use an Instrumental Variable (IV) approach to account for drug policy endogeneity. I choose instruments that enter the expected cost function of the government as it implements eradication and alternative development programs, yet affect farmers' land allocation decisions through no channel other than their effect on drug policy. The instruments are derived from variations in the expected cost of coca eradication as crews get far from the zone where Antinarcotics Police helicopters can protect them from illegal armed groups on the ground that try to shoot them down. I find that there is a strong negative relationship between distance from this zone and the level of eradication that takes place. Because of similar safety limitations in getting alternative development program administrators to their destination in coca growing regions, the same correlation exists between distance from the safety zone and government spending on alternative development. The location of coca eradication bases is not determined by coca production levels in the vicinity, but by the presence of pre-existing commercial and military airports, which makes instruments derived from the distance to the safety zone surrounding the bases ideal to estimate the causal effect of eradication and alternative development programs on coca production.

By evaluating the effectiveness of eradication and alternative development programs in reducing the cultivation of coca, I contribute to answering the wider question of whether the current approaches to drug policy are succeeding. Eradication and alternative development are a particularly good place to start because the outcome of these programs - coca cultivation per municipality - can be observed directly. Six years of municipality level data on coca cultivation for the entire country are available from Project SIMCI II, a satellite survey of coca crops conducted by the United Nations Office on Drug and Crime (UNODC). I construct a panel that combines SIMCI II data with municipality level measures of eradication, alternative development, and the presence of illegal armed groups, as collected by entities such as the Antinarcotics Police and the Presidency of the Republic.

This paper is divided in six sections. In Section II, I provide a comprehensive review of the relevant literature on crop choice, coca farming, and crime. In the third section I describe the data. Section IV describes the instrument and its correlation with Colombian antinarcotics policies. The estimates of the causal effects of eradication and alternative development on coca cultivation are presented in section V. Section VI concludes.

II. LITERATURE REVIEW

Coca eradication and alternative development programs seek to reduce illegal crop cultivation by modifying the economic incentives faced by farmers, and there is evidence that coca farming households respond to such changes. In particular, studies of coca farmers demonstrate that they respond to fluctuations in the profitability of their crops. Angrist and Kugler (2008), for example, analyze the impact of an exogenous rise in the price of coca resulting from the sudden interruption of coca imports from Bolivia and Peru, a consequence of heightened enforcement at the border in 1994. Using data from an annual survey of rural households, they find that after 1994 there was higher self employment income in regions where coca was traditionally grown. They attribute the rise in self employment to an increase in illegal crop farming. Furthermore, they were able to link higher coca prices to an increase in child labor. Additionally, they found a rise in violent deaths per capita in coca growing areas. This suggests that the traditional assumption that illegal crop farming results in conflict over coca profits is true. Using the same shift in coca production from Peru and Bolivia to Colombia, but focusing on its consequences for Peruvian farmers, Dammert (2008) finds that reduced coca earnings led to an increase in child labor. Her findings further demonstrate that coca farmers respond to economic incentives and that altering them is a viable approach to drug policy.

Whether eradication and alternative development change incentives in a way that will lead to a reduction in coca farming is a complex question. At issue is the mechanism through which policy intervention can reduce or eliminate production of illegal crops. One way eradication can make farmers switch from coca to other crops is by increasing the variability of coca yields. Agricultural households in the developing world have been observed to forego profitable economic activities when they have highly variable returns (Morduch, J. 1995). This stems from the households' inability to buy insurance against annual fluctuations in harvest yields and the associated difficulty in smoothing consumption across years. Rosenzweig and Binswanger (1993) conclude that Indian farmers in environments with more weather variability choose less profitable but less risky crop portfolios. Kurosaki and Fafchamps' (2002) study of crop choices in Pakistan finds that agricultural production choices are similarly affected by price and yield risk. Yield variations in this literature are due to weather shocks, but the threat of government sponsored eradication in Colombia acts in the same way, making the returns from coca farming more uncertain. It is reasonable to assume that, just like their counterparts in other developing countries, coca farmers in Colombia cannot fully insure against harvest losses, thereby smoothing consumption across years. Consequently, they may diversify their crop portfolio and replace some coca with other crops.

While eradication can increase income variability, a serious problem with government attempts to force a change in the farmers' crop portfolio is that coca offers the highest expected profit, approximately double that of the next best legal crop (Peterson, S. 2002, Thoumi, F. E. 2002). Some authors have explored the mechanisms through which eradication and alternative development can overcome this obstacle. In a study of opium production in Afghanistan, Clemens (2008) sketches a theoretical model of illegal crop farming in which farmers face the possibility of eradication and/or receive some kind of alternative development support. The farming household maximizes expected utility from consumption, which depends positively on the returns of a crop portfolio, and negatively on moral aversion to poppy cultivation. Each crop has returns that vary across different states of nature. By increasing the returns to legal crops through price support, cost reduction, or higher yields, or by using eradication to raise the probability that returns from illegal crop cultivation will be zero, and perhaps by finding ways to increase moral aversion to coca farming, resources would be reallocated from illegal crops to legal ones.

It is clear that illegal crop eradication lowers yields and may cause a reallocation of land away from coca. But it is possible that an inelastic demand causes prices to increase with eradication, as Vargas-Manrique (2004) notes. This would keep profits high and minimize the effect of eradication. Inelastic demand would result in farmers responding to eradication programs which reduce expected yield by increasing land used. The incentive to do this would be provided by higher prices, resulting in minimal changes in the quantity of coca harvested.

Because land allocated to coca can conceivably increase or decrease as a result of eradication, the question of whether drug control policies lead to a reduction in coca cultivation is ultimately empirical. Yet few empirical analyses of the effect of eradication and alternative development spending on coca cultivation exist.

An early study of the effect of eradication is Moreno-Sanchez et al. (2003). It uses national level data. Regressing hectares of coca cultivated in Colombia on hectares of coca eradicated, they find that eradication does not effectively control the supply of coca. Rather, it is associated with greater levels of cultivation. They attribute this outcome to farmers compensating for the destruction of their crops by cultivating greater extensions of land. Their specification accounts for the effects of coca cultivation in Bolivia and Peru and the prices of coca and plantain. Coca cultivation in Colombia is found to be unitary elastic to production in Bolivia and Peru, inelastic to its own price, and elastic to plantain price. Moreno-Sanchez et al. conclude that unilateral enforcement by one country does not work because the unitary elasticity of coca production in Colombia to production in Bolivia and Peru suggests that production will simply move from country to country as levels of enforcement vary. Because they find that the elasticity of coca cultivation to the price of other crops seems to be higher than that to the price of coca, they take it as evidence that alternative development efforts may be more successful than eradication.

More recently, Dion and Russler (2008) have used panel data on Colombian departments (administratively equivalent to US states) to examine the effect of fumigation and other variables on coca cultivation. The dependent variable in their study is hectares cultivated per capita. The main independent variable is the percentage of department land area fumigated by the government. They find that aerial eradication, the size of the incoming population of displaced persons, department Gross Domestic Product, and corruption indicators do not have an effect on the level of coca cultivation. Government spending per capita, the number of outgoing persons displaced by violence and market access are associated with lower levels of coca cultivation. Poverty and legal agricultural output are associated with increased coca production. While the results are interesting, a weakness of these studies is that they do not try to account for the endogeneity of eradication policy.

Yet there is a substantial literature on crime that has better addressed the endogeneity of enforcement, whose approach I incorporate to the analysis of the relationship between drug policy and coca cultivation. By finding exogenous shocks to enforcement, the economic literature on crime has been able to address issues of causality. A seminal paper is Levitt (1997), which measures the effect of the size of police departments on crime in the United States. It reviews several previous studies which found a counterintuitive positive relation between police and crime. It also documents a previously unknown relationship between mayoral and gubernatorial elections and changes in the size of police departments. Levitt constructs a panel of US city level data and regresses changes in violent crime on changes in police size, using election cycles as an instrument for police officers. He finds a negative relation between the number of police officers and crime.

In the same vein, Klick and Tabarrok (2005) use terror alert levels as a source of exogenous variation in police levels in Washington D.C. They claim that more police are deployed when terror alert levels – which are considered exogenous to local crime - are high, therefore having a deterrent effect on crime. Regressing the daily number of crimes on terror alert levels, they find that a high terror alert level has a negative effect on crime, which they attribute to the additional numbers of police officers on the streets. A final example is Johnson et al. (2007), which evaluates the effect of welfare spending per capita on crime rates during the Great Depression, using panel data on major US cities. Because welfare spending was allocated in part with the goal to reduce the criminality that could spring from widespread unemployment, the government targeted federal aid to cities that were considered more likely to harbor crime. As a result of the endogeneity of the allocation, OLS estimates are likely to be biased. The authors therefore use an IV approach, instrumenting spending with variables based on state size and federal land ownership.

I apply the insights of the crime literature to the problem of estimating the effect of drug policy on coca cultivation. An IV approach that accounts for the endogeneity of coca eradication and alternative development spending allows me to estimate the causal relationship between enforcement and coca cultivation.

III. DATA

The data I use are a six year panel of the 257 Colombian municipalities that grew coca at some point between 2001 and 2006. The United Nations Office on Drug and Crime in Bogota conducts satellite surveys of coca crops in every municipality of the country since 2001[1]. The surveys use satellite photography and are designed to measure the number of hectares of coca in a given municipality on December 31st of each year. These measures are reasonably accurate, and the methodology behind them is discussed in the data appendix.

Figure 1 shows a map of the average annual level of coca cultivation per municipality for the period 2001-2006. 57 percent of cultivation took place in the Colombian Amazon rainforest, 17 percent in the Pacific coast, 15 percent in the Andes Mountains, 8 percent in the eastern plains bordering Venezuela, and the remaining 3 percent in the Caribbean region[2]. Entire municipalities entered and left the market: in 2001, there were 164 coca producing municipalities, and by 2006 they are 199. Moreover, 257 municipalities cultivated coca at least once, implying that some entered and left the market over this period. This suggests that coca production can shift across

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[1] Cultivation data per municipality are publicly available at http://www.biesimci.org/Ilicitos/cultivosilicitos/cocampios.html

[2] Colombia is divided into five natural regions: Amazonian, Andean, Caribbean, Eastern Plains, and Pacific. These regions vary in socioeconomic conditions, climate, soil, flora, and fauna, and they provide different conditions for the cultivation of coca. When analyzing regional differences in coca cultivation, UNODC further subdivides the Amazonian region into Meta-Guaviare and Putumayo-Caquetá, and the Andean region into Catatumbo and Sur de Bolívar.

municipalities, in a local version of the "balloon effect" sometimes mentioned in the literature on drug production (Rouse, S. M. and M. Arce 2006).

National and regional levels of cultivation by year can be found in Table 1. Cultivation across the country fell by 46 percent, from 144,808 hectares in 2001 to 77,870 in 2006, and the reduction came mainly from lower cultivation in the Amazonian and Andean regions. But in every region there were municipalities where coca cultivation went up, increasing or staying constant in 157 municipalities and falling in 100. A map showing these changes in coca production is given in Figure 2.

A reduction in coca cultivation need not result in lower cocaine production. Recent estimates of productivity per hectare[3] are higher than those obtained by previous studies, and indicate that cocaine production in Colombia fell by only 1 percent, from 617 to 610 metric tons (UNODC 2006). Furthermore, because coca leaf yields vary across regions as shown by the map in Figure 3, production could have migrated from low to high yield locations. However, this does not seem to be the case, as cultivation has fallen in the regions with the highest yields.

The Colombian Antinarcotics Police maintain a national database of eradication and provided their data for this study. The data are automatically recorded by GPS units on board of the fumigation planes, or by the agents conducting manual eradication. Table 2 gives national and regional annual eradication levels, and the map in Figure 4 shows average annual eradication per municipality. Eradication increased dramatically between 2001 and 2006: it more than doubled, going from roughly 94,000 hectares to 210,000. The number of hectares eradicated at the national level exceeded the number of hectares

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[3] Cocaine production per coca hectare is not estimated by UNODC on an annual basis, and methodologies vary across studies, which limits the usefulness of comparing total cocaine production estimates over time.

at the end of every year. The reason is that the coca bush can regenerate in 6 to 8 months, so that the same area of coca may be eradicated more than once per year.

The police locate coca crops using data from SIMCI II as well as less thorough aerial surveys conducted every six months. Early in the period under consideration there was a marked emphasis on eradication in the areas with the highest levels of production. From 2001 to 2003, for example, not a single hectare of coca was eradicated in the Caribbean region. Yet between 2001 and 2006 there was a uniform trend toward higher levels of eradication in every region of the country. Moreover, eradication increased or stayed at 2001 levels in 239 out of 257 municipalities.

The methods of eradication also changed slightly over time. The government has used fumigation with glyphosate throughout the period covered by the data, and this continues to be the most widely used technique. Glyphosate kills coca leafs and keeps the bush from producing another harvest for around six months. From 2005 onwards, manual destruction of coca bushes replaced fumigation in areas near the border with Ecuador and in national parks. The primary reason was political pressure resulting from environmental concerns. As I describe below, the pattern of application of both methods is essentially the same, so I have added the number of hectares aerially sprayed to the number of hectares eradicated manually to obtain a single eradication variable.

Countrywide data on spending in alternative development programs are collected by the Presidency of the Republic, and were provided by UNODC. Table 3 shows spending data at the national and regional level and the map in Figure 5 shows average annual spending per municipality.

The funding for alternative development programs fell by 81 percent between 2001 and 2006, increasing only in 6 out of 257 municipalities. The secular decline in alternative development spending probably resulted from a change in government. 93 percent of the programs were started before or during 2001, roughly coinciding with the presidency of Andrés Pastrana. There was a sharp increase in spending toward the end of his government, and a gradual decline after he was succeeded by Álvaro Uribe in 2002.

The diversity of alternative development programs is remarkable, and it limits somewhat our ability to measure their effectiveness. Over the period of interest, there were 1379 different types of crop substitution programs, many of which provided training or subsidized inputs for the production of alternative crops. But they also included the introduction of new agricultural techniques, help to commercialize farm products, technical assistance, and construction of processing facilities and various types of infrastructure. By considering spending on alternative development as a single policy variable I am able to evaluate the effects of the average program, but I cannot determine the performance of individual ones.

Aside from the data on coca cultivation, eradication, and alternative development spending, I obtained data on other variables that are likely to affect coca cultivation levels. Population data come from the 2005 census and are available from the National Administrative Department of Statistics (DANE). To control for the varying availability of land across municipalities, I used data on municipality areas from the Agustín Codazzi Geographical Institute in Bogota. Finally, data on the presence of illegal armed groups per municipality for the year 2005 were provided by UNODC.

IV. DISTANCE TO A FUMIGATION BASE AND ANTINARCOTICS POLICY

According to the Colombian Antinarcotics Police, there is a strong link between distance from a fumigation base and the amount of coca eradication that goes on in a municipality. Fumigation of coca crops with glyphosate, the primary method of eradication, is conducted by police personnel flying various types of unarmed aircraft. They include OV-10 Bronco military planes, modified so that they have no weapons. Instead, they carry modern fumigation equipment. There are also Air Tractor AT-802 and Turbo Thrush spraying planes, which are small aircraft widely used in agriculture that have no artillery (Luna, A. O. 2007). While the planes can fly to every region of the country, security as they perform their task is often at stake.

Armed attacks from the ground against fumigation planes are common. Police protect from the attacks by escorting the planes with armed helicopters like the Huey II and the UH-60 Black Hawk. According to Antinarcotics officers, the range of the helicopters is 80 miles from the base, a point after which they must return to the base they departed from. The map in Figure 6 shows which coca municipalities are within reach of a base. Beyond the 80 mile range, fumigation planes must go unprotected, greatly increasing the expected cost of eradication missions. Being vulnerable to attack by disgruntled coca producers (or by the armed groups acting on their behalf), the planes are liable to being shot down, resulting in losses of lives and equipment.

The observed patterns of coca cultivation, eradication, and alternative development efforts across Colombian municipalities suggest that the lack of protection of fumigation planes results in major shifts in drug policy. A comparison of the mean number of hectares of coca grown per municipality for the years 2001 through 2006 shows that cultivation is roughly equal across locations within 80 miles of a base and outside of this range. The mean for the first group is 397.7 hectares, and 328 for the second group. Instead, fumigation within 80 miles of a base is significantly higher than beyond this distance. Mean fumigation per municipality within the safety zone is 681.7 hectares, but only 208.2 hectares outside of it. The trend of more intensive eradication in areas closer to the fumigation bases remains unaltered when manual eradication is included into the eradication calculations (see Table 4). Figure 7 shows the relationship between distance from a fumigation base, coca cultivation, and eradication per municipality. The number of hectares of coca fumigated is greater than the number of hectares allocated to coca cultivation for the first 80 miles. At that point the relationship is turned around, with cultivation surpassing fumigation thereafter.

Another noticeable difference between the two zones emerges when mean alternative development spending per municipality is calculated: average funding for these programs is far greater in municipalities within the 80 mile range of a base than in the rest, by a ratio of 5 to 1. This results from the same security issues as in the case of fumigation, and from the government's preference to concentrate alternative development efforts in areas where a greater rate of eradication makes alternative crops more attractive to farmers. Figure 8 shows the relationship between alternative development spending and distance from a fumigation base.

Naturally, the relationships I have presented do not take into consideration other factors that may affect eradication and alternative development levels, such as the presence of illegal armed groups. For example, the police may want to pursue different levels of eradication in municipalities with left wing militias that seek to overthrow the government, such as the Revolutionary Armed Forces of Colombia (FARC) and the National Liberation Army (ELN), or where the right wing United Self-Defense Forces of Colombia (AUC) are present. A more thorough model of the effect of distance from a fumigation base on drug policy is given in Equation 1.1, which is the first stage equation for IV estimation of the effects of drug policy on coca cultivation:

$$(1.1) \quad F_{it} = \alpha + \mathbf{D}_i'\beta + \mathbf{X}_i'\gamma + a_r + e_t + u_{it}$$

F_{it} is the policy in question, which can be either eradication or alternative development spending in municipality i in period t. $\mathbf{D}_i$ is a vector of variables that reflect cost variations in drug policy, $\mathbf{X}_i$ is a vector of control variables, and a_r and e_t stand for regional and year fixed effects. Finally, u_{it} is an error term with zero mean.

Table 6 shows OLS estimates of three different specifications of Equation 1.1. The dependent variable is hectares of coca eradicated per municipality per year. All regressions control for the number of illegal armed combatants belonging to FARC, ELN, and AUC, as well as for municipality area and population. Indicators for year and regional fixed effects are also included.

Specification (1) includes two variables that proxy for the expected cost of drug policy. The first is an indicator for whether a municipality is within the safety zone surrounding a fumigation base. As a result of the lower cost of drug policy implementation in this area, the coefficient on the indicator should take a positive value. This would indicate that drug policies are implemented more intensively where they are cheaper. The second variable is distance from the safety zone. The longer an eradication plane stays away from the safety zone, the more likely it is to get shot. Because unprotected exposure to potential attacks will last longer as distance to a destination increases, I take the probability of an attack on a fumigation plane to be increasing on distance from the safety zone. Therefore, the coefficient on distance to the safety zone should take a negative value, reflecting lower levels of drug policy implementation as costs increase. The estimated coefficients on the drug policy cost proxy variables are statistically significant and take on the predicted signs.

Specification (2) adds interactions between distance from the safety zone and the number of combatants in illegal left wing (FARC and ELN) and right wing (AUC) armed organizations. These interactions exploit variation in the expected cost of drug policy implementation across municipalities that are equidistant from a base. Because the likelihood of an attack (and therefore the expected cost of drug policy) is increasing on the number of illegal group members at the destination, the sign of the coefficients on the interactions should be negative. The coefficients are indeed negative, and the one on the distance and left wing combatant interaction statistically significant.

Finally, specification (3) includes three more regressors, intended to capture variation in expected drug policy costs within the safety zone. One is the interaction of the safety zone indicator with distance from the fumigation base, and the other two are interactions of this variable with the number of left and right wing combatants. For reasons analogous to those given above, the coefficients on these interactions should be negative. The estimates of two of these additional interaction terms are, indeed, negative and statistically significant.

Table 7 presents estimates of Equation 1.1 where the dependent variable is changed from coca eradication to alternative development spending. Otherwise, the specifications are the same as in Table 6. The estimated coefficients take values that are generally consistent with the predicted variation in the cost of drug policy implementation, and several of them are statistically significant. However, the variation in the number of illegal armed combatants across municipalities located at the same distance from a base seems to have less influence on alternative development spending than on coca eradication.

To verify that these correlations do not arise randomly or because of unaccounted factors related to a municipality's distance from a major urban area, I estimate Equation 1.1 again, replacing the location of the ten fumigation bases with the location of the ten largest Colombian cities without a fumigation base. Predicted eradication is shown in Table 8. The coefficients on the instruments are generally statistically insignificant, and in the few instances where they are significant they have the "wrong" sign. Table 9 shows predicted alternative development spending. All but one of the coefficients on the instruments turns out to be statistically insignificant. The weakness of these alternative specifications is reassuring, demonstrating that the measures of drug policy implementation that I use are actually picking up the effect of expected cost variations.

V. THE EFFECT OF ERADICATION AND ALTERNATIVE DEVELOPMENT ON COCA CULTIVATION

The previous section documents the negative relationship between Colombian drug policy and the ability of the Antinarcotics Police to protect its coca eradication crews. I now take advantage of the exogenous variation in drug policy costs demonstrated by this correlation to estimate the causal effect of eradication and alternative development on coca production in Colombian municipalities.

If distance from the zone where eradication aircraft can fly safely is to be used as an instrument for drug policy, distance from this zone cannot itself be related to a municipality's propensity to produce coca. The exclusion restriction is not satisfied if the second stage regression does not account for variables that are correlated with distance to this zone and with coca production levels. The most obvious violation of this condition would occur if the bases had been intentionally located in areas with high levels of production of coca. However, the bases were not built with this criterion. Rather, they made use of preexisting structures such as airports in large cities that made them suitable to host a fleet of airplanes and helicopters.[4]

The location of the bases being exogenous, the issue becomes whether there are systematic differences between the more urban areas where the bases are located and the rural regions out of their reach. To account for this I control for a number of variables. More rural areas have lower population densities, so I control for population and municipality area. I also include in the regressions the number of FARC, ELN, and AUC combatants present in each municipality, because they concentrate in rural areas and benefit from the drug trade. Furthermore, regional fixed effects control for the impact of variations in climate, local institutions, and history, on coca cultivation decisions. For example, regional variations in growing conditions result in significant differences in annual yields per hectare that could affect land allocation decisions. Moreover, the

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[4] Because it is possible that unobserved characteristics of rural areas may have prompted the construction of military bases and created a predisposition to grow coca, I have excluded from the calculations the only fumigation base not located in an urban area, the Larandia military fort in rural Caquetá. The results do not change significantly when it is included.

existence of trading routes, markets, and experience in coca cultivation and processing may also be better developed in parts of the country like the Amazonian region, where illegal crop farming has taken place for decades, than in others such as the Pacific region, where coca production is of more recent date (UNODC 2006). Finally, year fixed effects account for shocks affecting all municipalities in a given year, such as changes in the world market for cocaine, shocks to US funding for the war on drugs, and changes in the central government resulting from the transition between the Pastrana and the Uribe administrations.

With these controls, distance from the safety zone of fumigation planes should be an appropriate instrument for Colombian anti-coca policies.

I estimate the effect of coca eradication and alternative development programs using an Instrumental Variables (IV) regression. The empirical specification is the following:

$$(1.2) \quad H_{it} = \delta + \mathbf{F}_{it}'\varphi + \mathbf{X}_i'\theta + b_r + f_t + v_{it}$$

where H_{it} is the number of coca hectares per municipality at year end, $\mathbf{F}_{it}$ is a vector of drug policies, and $\mathbf{X}_i$ is a vector of exogenous covariates. b_r and f_t represent regional and year effects, while v_{it} is a zero mean error term. While OLS estimates may be biased because of a correlation between the policy variables and the error term, if distance from the safety zone is uncorrelated with v_{it} the IV estimation should result in accurate estimates of the causal effect of eradication and alternative development on coca cultivation.

In all regressions, I use standard errors that are robust to heteroskedasticity and clustered by municipality. Clustering is essential because some regressors, as well as the instrument, are fixed at the municipality level. Moulton (1986) shows that when a regressor does not vary within groups of observations, the conventional standard errors underestimate the variance of the coefficients, and Shore-Sheppard (1996) demonstrates that an analogous downward bias exists when an instrument takes the same value for clusters of observations. Fortunately, as long as the number of clusters is large, this concern can be put aside by clustering at the level of aggregation of the regressors (Angrist, J. D. and J.-S. Pischke 2009). With 257 municipalities in the sample, there are enough clusters to ensure the asymptotic validity of the estimates of the standard errors.

IV and OLS estimates of Equation 1.2 are presented in Table 10. The policy variables are hectares of coca eradicated and government spending on alternative development per municipality. All specifications control for regional and year fixed effects, municipality area, and population.

OLS estimates in column (1) show a statistically significant, positive effect of both coca eradication and alternative development spending on coca production. They suggest that a one percent increase in coca eradication will lead to an increase of around 0.24 percent in cultivation, and that a one percent increase in alternative development results in a 0.15 percent increase in hectares of coca cultivated.

Similar results are given by the just identified IV regression in column (2), where the instruments are distance beyond the 80 mile radius of a base and an indicator for whether a municipality is less than 80 miles from a fumigation base. A one percent increase in eradication is estimated to result in a 0.18 percent increase in cultivation, and a one percent increase in alternative development spending leads to a 0.51 percent rise in coca cultivation. However, the coefficients are not statistically significant. In column (3), where interactions between distance beyond 80 miles of a base and the number of right wing/left wing combatants are added to the instrument set, a one percent increase in eradication is estimated to increase coca cultivation by 0.34 percent, but the coefficient is not statistically significant. A one percent increase in alternative development spending results in a 0.39 percent increase in coca cultivation, and the coefficient is significant at the 10 percent level. Finally, specification (4) further adds to the instrument set an interaction between the indicator for distance from a base being less than 80 miles and distance from the base, plus interactions between this variable and the number of right and left wing combatants. The coefficients on eradication and alternative development are of the same order of magnitude as in previous specifications: a one percent increase in eradication results in a 0.30 increase in cultivation, an a one percent increase in alternative development spending leads to a 0.28 percent increase in cultivation. Moreover, the coefficients are significant at the 1 and the 5 percent levels, respectively.

For specifications (3) and (4), the Sargan-Hansen test of the overidentifying restrictions cannot reject the null that the instruments are exogenous, even at the 10 percent level. I estimate (3) and (4) by the LIML method (not reported) to verify the IV results, because while having the same asymptotic distribution of IV, LIML has lower finite-sample bias when the model is overidentified (Angrist, J. D. and J.-S. Pischke 2009). The point estimates remain practically unchanged.

The coefficient on municipality area is always positive and statistically significant, a natural result if the availability of more land results in greater production of coca. The coefficients on all the other exogenous variables are statistically insignificant. A one percent increase in the number of FARC combatants is associated with an increase in coca cultivation of less than one hundredth of a percent in all specifications. Because the presence of illegal armed combatants is generally thought to be linked to greater levels of production of coca, it is interesting that all specifications show that increases in the number of ELN combatants are associated with a reduction in levels of coca cultivation. This may be explained by these organizations having strong historical links with certain areas of the country, tending to stay in those regions for reasons other than coca production levels. At any rate, the effect is small, and in all specifications a one percent increase in ELN combatants leads to reductions in coca cultivation of less than one hundredth of a percent. In the case of the coefficient on the number of AUC combatants, the sign of the point estimates does not take a consistent value. Depending on the specification, the effect of a one percent increase in AUC combatants on coca cultivation ranges between a reduction of 0.03 percent and an increase of 0.04 percent.

VI. CONCLUSION

The data collected by the United Nations Office on Drug and Crime provide an excellent opportunity to shed light on the efficiency of the Colombian government's antinarcotics policies. I evaluate the effectiveness of two major drug control initiatives, coca crop eradication and alternative development programs. The principal challenge to accurately estimating the effectiveness of these programs is the endogeneity of the policy variables. I address it using an IV strategy, exploiting exogenous shocks to the ability of the Colombian government to implement drug control policies.

While the social cost of coca and cocaine production and consumption is difficult to estimate precisely, it is clear that it is high and that the government has good reason to fight drug production. Yet the appropriate course of action remains unclear because coca eradication and alternative development have significant externalities, and because the estimates of their effect on cultivation presented in the previous section suggest they are unsuccessful.

A substantial burden on the state results from the use of drug revenues to finance illegal armed groups. Taxation of the drug trade is thought to account for around half the revenue of FARC, ELN, and AUC, organizations that attack and weaken the state. They bomb the country's oil pipelines, electrical, and telecommunications infrastructure; forcefully displace the rural population; and are the cause of excess defense spending and human capital losses from the combat deaths of members of the armed forces (Pinto Borrego, M. E., A. Vergara Ballen and Y. Lahuerta Percipiano 2005). Furthermore, drug consumption brings about human capital losses at home and abroad.

Addressing the problem of coca and cocaine production by offering farmers alternative sources of income has several positive externalities. The creation of new, legal sources of income raises welfare in impoverished areas of the country, which is particularly desirable in view of the common claim that coca farmers are so impoverished that they "turn to illegal crops out of desperation" (Haugaard, L. 2001). The United Nations recommend that coca farmers be seen as "candidates for development rather than as criminals" (UNODC 2005), and alternative development is favored by farmer advocates and sectors of the international community like the European Union, because it is seen as superior to eradication on humanitarian grounds (Hagen, J. T. 2001). Furthermore, alternative development has favorable political consequences in coca farming regions, where illegal armed groups compete with the authority of the state. Coca farmers tend to distrust a government they perceive as distant, corrupt, and uninterested in their well being (Farthing, L. and B. Kohl 2005, Hagen, J. T. 2001, UNODC 2005). By providing economic opportunities, alternative development can make strides against local ambivalence towards the intentions of the state. If nothing else, alternative development spending has the potential to increase farmer welfare while enhancing the legitimacy of the Colombian state at the local level and internationally.

By contrast, illegal crop eradication has major negative externalities. In particular, aerial eradication may be detrimental to the environment. The area of the country targeted by the spraying campaign is very biologically diverse and it is home to several unique and endangered species, which makes the potential damage caused by herbicides severe (Peterson, S. 2002). There are conflicting claims about the ecological impact of glyphosate: Peterson contends that glyphosate has "well documented deleterious effects on soil micro-organisms, mammalian life (including humans), invertebrates, and aquatic organisms, especially fish." On the other hand, the U.S. Department of State affirms that the substance is safe. It points out that the U.S. Environmental Protection Agency approved the general use of glyphosate in 1974, and that studies have shown it to be easily biodegraded by soil microbes and to be essentially non-toxic to fish and farm animals (USDS 2004). While the effects of glyphosate on the environment may remain controversial, an undisputed environmental externality of eradication has to do with the displacement of illegal crops. Large amounts of rainforest have been cleared to make way for new coca fields, in order to avoid eradication by moving production to plots that have not yet been pinpointed as coca land (Bigwood, J. and P. Coffin 2005). Governmental intervention may thus encourage the destruction of valuable environmental resources.

The bottom line, however, is that neither eradication nor alternative development spending seem to be very effective in reducing coca cultivation. Eradication actually seems to be increasing the area cultivated with coca slightly. Even if coca leaf production is falling because of lower coca yields resulting from eradication, increased productivity in cocaine manufacturing seems to be making up for it and maintaining supply of the drug constant, as mentioned in section II. With regard to alternative development spending, the estimates obtained above show that a one percent increase in spending in alternative development programs is associated with an increase in coca cultivation of between 0.18 and 0.51 percent. One explanation for this is that resources such as agricultural inputs destined to alternative crops could be channeled toward coca production by the farmers, resulting in increased illegal farming.

Coca production has large costs for the Colombian nation, and a high level of investment on antinarcotics efforts seems to be warranted. Nevertheless, these resources should be allocated to programs that reduce coca cultivation and the supply of drugs, and neither eradication nor alternative development programs are furthering this goal. The most cost effective course of action may be to explore new approaches to the problem of coca production in Colombia.

Table 1: Coca Cultivation by Year, by Region

	Hectares of Coca Detected						
Region/Year	2001	2002	2003	2004	2005	2006	**Total**
Catatumbo (Andean Region)	9145	8042	4471	3056	844	488	**26046**
Meta-Guaviare (Amazonian Region)	36978	36599	28977	28510	25963	20540	**177567**
Eastern Plains	11915	7124	4356	6244	9709	6829	**46177**
Pacific Region	11171	17364	19561	15788	17633	18809	**100326**
Putumayo-Caquetá (Amazonian Region)	65404	25155	17297	13474	16271	19125	**156726**
Caribbean Region	865	998	759	1262	542	437	**4863**
Sur de Bolívar (Andean Region)	9329	6789	10910	12014	14788	11642	**65472**
Total	**144807**	**102071**	**86331**	**80348**	**85750**	**77870**	**577177**

Source: United Nations Office on Drug and Crime

Table 2: Coca Eradication by Year, by Region

	Hectares of Coca Eradicated						
Region/Year	2001	2002	2003	2004	2005	2006	**Total**
Catatumbo (Andean Region)	10308	9186	13822	5686	3108	3217	**45327**
Meta-Guaviare (Amazonian Region)	10729	8703	44467	34787	28826	46906	**174418**
Eastern Plains	2820	0	11734	6782	2860	7269	**31465**
Pacific Region	8957	17962	38219	33366	69853	71548	**239904**
Putumayo-Caquetá (Amazonian Region)	49758	90458	9402	34797	19418	37778	**241612**
Caribbean Region	0	0	0	2224	3809	1151	**7185**
Sur de Bolívar (Andean Region)	11581	4055	15173	21119	40802	42442	**135172**
Total	**94153**	**130364**	**132817**	**138762**	**168677**	**210311**	**875083**

Source: Antinarcotics Police

Table 3: Spending in alternative development programs by year by region in millions of 1998 pesos

	Alternative Development Spending						
Region/Year	2001	2002	2003	2004	2005	2006	**Total**
Catatumbo (Andean Region)	13160	7994	6887	1634	0	0	**29675**
Meta-Guaviare (Amazonian Region)	2195	1099	288	941	141	355	**5018**
Eastern Plains	172	0	0	0	0	0	**172**
Pacific Region	4231	2246	1651	1056	1284	1057	**11524**
Putumayo-Caquetá (Amazonian Region)	51642	29520	15351	10522	10371	10211	**127617**
Caribbean Region	10	10	10	0	0	2005	**2035**
Sur de Bolívar (Andean Region)	6315	4668	5098	3626	1138	896	**21740**
Total	**77725**	**45536**	**29285**	**17779**	**12932**	**14524**	**197781**

Source: UNODC

Table 4: Mean annual cultivation, fumigation, eradication, and alternative development spending by location within 80 miles of a fumigation base.

	Coca hectares per municipality	Fumigated coca hectares per municipality	Eradicated coca hectares per municipality	Alternative development spending per municipality in millions of pesos
Distance to a fumigation base is less than 80 miles (N=1020)	397.7 (34.0)	681.7 (71.2)	736.7 (75.2)	174.9 (30.9)
Distance to a fumigation base is 80 miles or more (N=522)	328.6 (49.6)	208.2 (44.9)	236.9 (48.3)	37.1 (11.8)

Table 5: Average Coca Cultivation, Eradication, and Alternative Development Spending per Municipality

Year	Mean number of hectares cultivated per municipality	Mean number of hectares fumigated per municipality	Mean number of hectares manually eradicated per municipality	Mean spending on alternative development programs per municipality
2001	563.45	366.35	0	302.43
	(1709.19)	(1572.04)		(1577.4)
2002	397.16	507.25	0	177.18
	(1273.80)	(2496.13)		(938.82)
2003	335.92	516.80	0	113.95
	(880.41)	(2020.36)		(586.76)
2004	312.64	531.04	8.89	69.18
	(762.41)	(1598.477)	(33.38)	(346.98)
2005	333.66	539.14	117.19	50.32
	(871.03)	(2061.02)	(476.63)	(307.64)
2006	303.00	667.87	150.46	56.51
	(778.312)	(1835.82)	(493.79)	(313.48)

Source: United Nations Office on Drug and Crime and Antinarcotics Police.

Table 6: First Stage Estimates with Eradication as a Dependent Variable

	Dependent Variable is Eradicated Coca Hectares		
	(1)	(2)	(3)
Distance beyond 80 mile radius of a base	-5.142***	-4.470**	-4.326***
	(1.778)	(1.810)	(1.655)
Municipality is less than 80 miles from a fumigation base	562.5***	411.2***	978.9***
	(172.4)	(152.7)	(331.9)
Distance beyond 80 miles of a base * Number of left wing combatants		-0.112**	-0.0562
		(0.0543)	(0.0560)
Distance beyond 80 miles of a base * Number of right wing combatants		-0.356	-1.081*
		(0.252)	(0.577)
Municipality is less than 80 miles from a fumigation base * Distance from base			-12.84**
			(5.025)
Municipality is less than 80 miles from a fumigation base * Distance from base * Number of left wing combatants			0.132
			(0.0868)
Municipality is less than 80 miles from a fumigation base * Distance from base * Number of right wing combatants			-0.970*
			(0.551)
FARC guerrilla combatants	1.720	2.391	2.681
	(2.407)	(2.779)	(2.847)
AUC paramilitary combatants	18.08	20.15	55.39*
	(11.20)	(12.60)	(28.60)
ELN guerrilla combatants	25.63**	28.54**	21.06*
	(10.99)	(11.20)	(11.56)
Population	0.00330	0.00327	-0.000483
	(0.00307)	(0.00292)	(0.00221)
Area in square kilometers	0.0310**	0.0326**	0.0195
	(0.0143)	(0.0145)	(0.0153)
Observations	1536	1536	1536
R-squared	0.161	0.172	0.242

Robust standard errors clustered by municipality in parentheses. All regressions include a constant, year indicators, and indicators for each of the 7 UNODC coca growing regions.
*** p<0.01, ** p<0.05, * p<0.1

Table 7: First Stage Estimates with Alternative Development Spending as a Dependent Variable

	Dependent Variable is Spending in Alternative Development Programs		
	(1)	(2)	(3)
Distance beyond 80 mile radius of a base	-2.670***	-2.546***	-2.492***
	(0.984)	(0.955)	(0.863)
Municipality is less than 80 miles from a fumigation base	101.6*	83.77	342.0***
	(54.82)	(59.39)	(121.4)
Distance beyond 80 miles of a base * Number of left wing combatants		-0.0231	0.000241
		(0.0217)	(0.0184)
Distance beyond 80 miles of a base * Number of right wing combatants		-0.00692	-0.0466
		(0.0354)	(0.0433)
Municipality is less than 80 miles from a fumigation base * Distance from base			-6.578***
			(2.027)
Municipality is less than 80 miles from a fumigation base * Distance from base * Number of left wing combatants			0.0766*
			(0.0392)
Municipality is less than 80 miles from a fumigation base * Distance from base * Number of right wing combatants			-0.0677
			(0.0433)
FARC guerrilla combatants	0.559	0.697	0.504
	(0.458)	(0.550)	(0.339)
AUC paramilitary combatants	2.111*	2.073	3.839*
	(1.197)	(1.349)	(1.992)
ELN guerrilla combatants	13.22	13.76	7.865
	(8.520)	(8.841)	(6.816)
Population	0.000640	0.000702	0.000162
	(0.000551)	(0.000572)	(0.000490)
Area in square kilometers	-0.00142	-0.00106	-0.00559
	(0.00868)	(0.00882)	(0.00772)
Observations	1536	1536	1536
R-squared	0.123	0.125	0.148

Robust standard errors clustered by municipality in parentheses. All regressions include a constant, year indicators, and indicators for each of the 7 UNODC coca growing regions.
*** p<0.01, ** p<0.05, * p<0.1

Table 8: First Stage Estimates with Eradication as a Dependent Variable (Replacing Fumigation Bases with Largest Urban Areas)

	Dependent Variable is Eradicated Coca Hectares		
	(1)	(2)	(3)
Distance beyond 80 mile radius of 10 largest cities	3.297*	-0.0873	-0.155
	(1.964)	(1.260)	(1.287)
Municipality is less than 80 miles from one of the 10 largest cities	-13.55	-54.08	-206.0
	(155.7)	(134.3)	(280.4)
Distance beyond 80 miles of one of the 10 largest cities * Number of left wing combatants		0.103***	0.102**
		(0.0395)	(0.0404)
Distance beyond 80 miles of one of the 10 largest cities * Number of right wing combatants		0.273**	0.331**
		(0.127)	(0.156)
Municipality is less than 80 miles from one of 10 largest cities * Distance from base			0.741
			(4.591)
Municipality is less than 80 miles from one of 10 largest cities * Number of left wing combatants			0.0306
			(0.0916)
Municipality is less than 80 miles from one of 10 largest cities * Distance from base * Number of right wing combatants			0.339
			(0.244)
FARC guerrilla combatants	2.003	-7.518**	-7.575*
	(2.657)	(3.718)	(3.854)
AUC paramilitary combatants	19.47*	-19.66	-29.44*
	(10.86)	(12.14)	(17.59)
ELN guerrilla combatants	22.32*	30.57**	30.68**
	(11.46)	(13.36)	(15.03)
Population	0.00365	0.00426*	0.00378*
	(0.00330)	(0.00228)	(0.00221)
Area in square kilometers	-0.00200	-0.00617	-0.00553
	(0.0187)	(0.0180)	(0.0182)
Observations	1536	1536	1536
R-squared	0.104	0.109	0.124

Robust standard errors clustered by municipality in parentheses. All regressions include a constant, year indicators, and indicators for each of the 7 UNODC coca growing regions.
*** p<0.01, ** p<0.05, * p<0.1

Table 9: First Stage Estimates with Alternative Development Spending as a Dependent Variable (Replacing Fumigation Bases with Largest Urban Areas)

	Dependent Variable is Spending in Alternative Development Programs		
	(1)	(2)	(3)
Distance beyond 80 mile radius of 10 largest cities	0.196	-0.225	-0.223
	(0.417)	(0.445)	(0.467)
Municipality is less than 80 miles from one of the 10 largest cities	0.398	-8.157	129.3**
	(36.78)	(35.09)	(62.50)
Distance beyond 80 miles of one of the 10 largest cities * Number of left wing combatants		0.0209	0.0207
		(0.0127)	(0.0137)
Distance beyond 80 miles of one of the 10 largest cities * Number of right wing combatants		0.00924	-0.00159
		(0.0181)	(0.0305)
Municipality is less than 80 miles from one of 10 largest cities * Distance from base			-1.915
			(1.460)
Municipality is less than 80 miles from one of 10 largest cities * Number of left wing combatants			-0.0128
			(0.0437)
Municipality is less than 80 miles from one of 10 largest cities * Distance from base * Number of right wing combatants			-0.0603
			(0.0844)
FARC guerrilla combatants	0.691	-1.108	-1.063
	(0.530)	(0.993)	(1.146)
AUC paramilitary combatants	2.708**	1.000	2.828
	(1.253)	(2.830)	(5.107)
ELN guerrilla combatants	11.95	12.97	13.05
	(8.495)	(8.432)	(9.068)
Population	0.000730	0.000783	0.000826
	(0.000628)	(0.000602)	(0.000547)
Area in square kilometers	-0.00954	-0.0115	-0.0117
	(0.0104)	(0.0105)	(0.0106)
Observations	1536	1536	1536
R-squared	0.139	0.223	0.244

Robust standard errors clustered by municipality in parentheses. All regressions include a constant, year indicators, and indicators for each of the 7 UNODC coca growing regions.
*** p<0.01, ** p<0.05, * p<0.1

Table 10: Estimates of the Effect of Eradication and Alternative Development Spending on Coca Production

	Dependent Variable is Hectares of Coca Detected at the End of the Year in a Municipality			
	(1)	(2)	(3)	(4)
	OLS	IV	IV	IV
Eradicated Coca Hectares	0.158***	0.117	0.226	0.198***
	(0.0365)	(0.393)	(0.160)	(0.0749)
Spending on Alternative Development Programs	0.437***	1.491	1.146*	0.808**
	(0.0846)	(1.250)	(0.609)	(0.319)
FARC guerrilla combatants	0.646	0.00307	0.0292	0.316
	(0.814)	(0.773)	(0.680)	(0.657)
AUC paramilitary combatants	1.952	-0.0816	-1.342	0.168
	(1.798)	(5.029)	(1.818)	(1.324)
ELN guerrilla combatants	-0.434	-12.09	-10.38	-5.719
	(3.268)	(11.30)	(8.988)	(5.335)
Population	0.000145	-0.000493	-0.000610	-0.000275
	(0.000443)	(0.000719)	(0.000586)	(0.000394)
Area in square kilometers	0.0596***	0.0693***	0.0651***	0.0624***
	(0.0152)	(0.0229)	(0.0154)	(0.0140)
Observations	1542	1536	1536	1536
R-squared	0.518	-0.005	0.208	0.430

Instruments in (2) are distance beyond the 80 mile radius of a base and an indicator for whether a municipality is less than 80 miles from a fumigation base. In (3), interactions between distance beyond 80 miles of a base and the number of right wing/left wing combatants are also included. Specification (4) further adds an interaction between the indicator for distance from a base being less than 80 miles and distance from the base, plus interactions between this variable and the number of right wing/left wing combatants. All regressions include a constant, year indicators, and indicators for each of the 7 UNODC coca growing regions. Robust standard errors clustered by municipality are shown in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

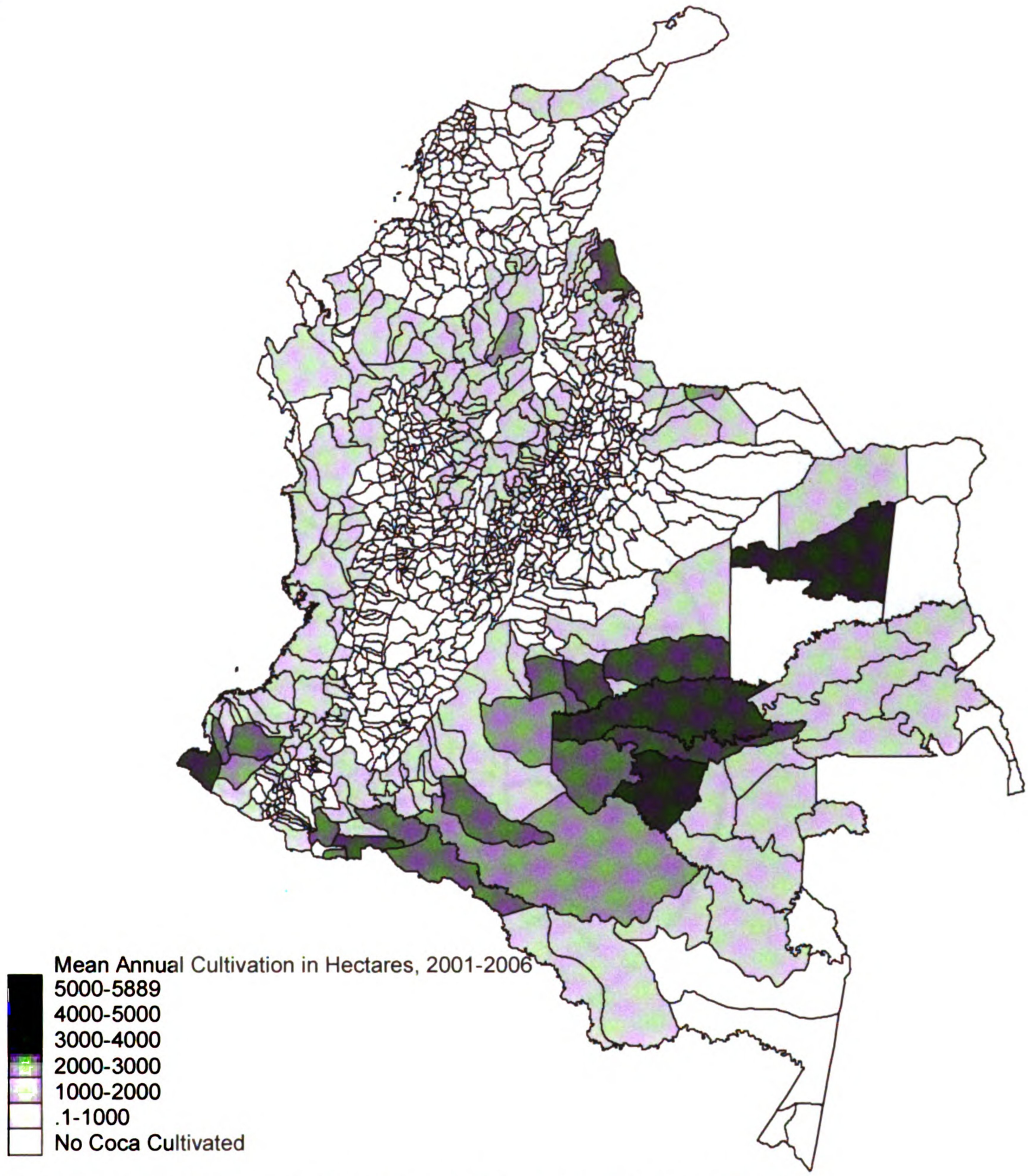

Figure 1: Map of Mean Annual Cultivation of Coca by Municipality, 2001-2006

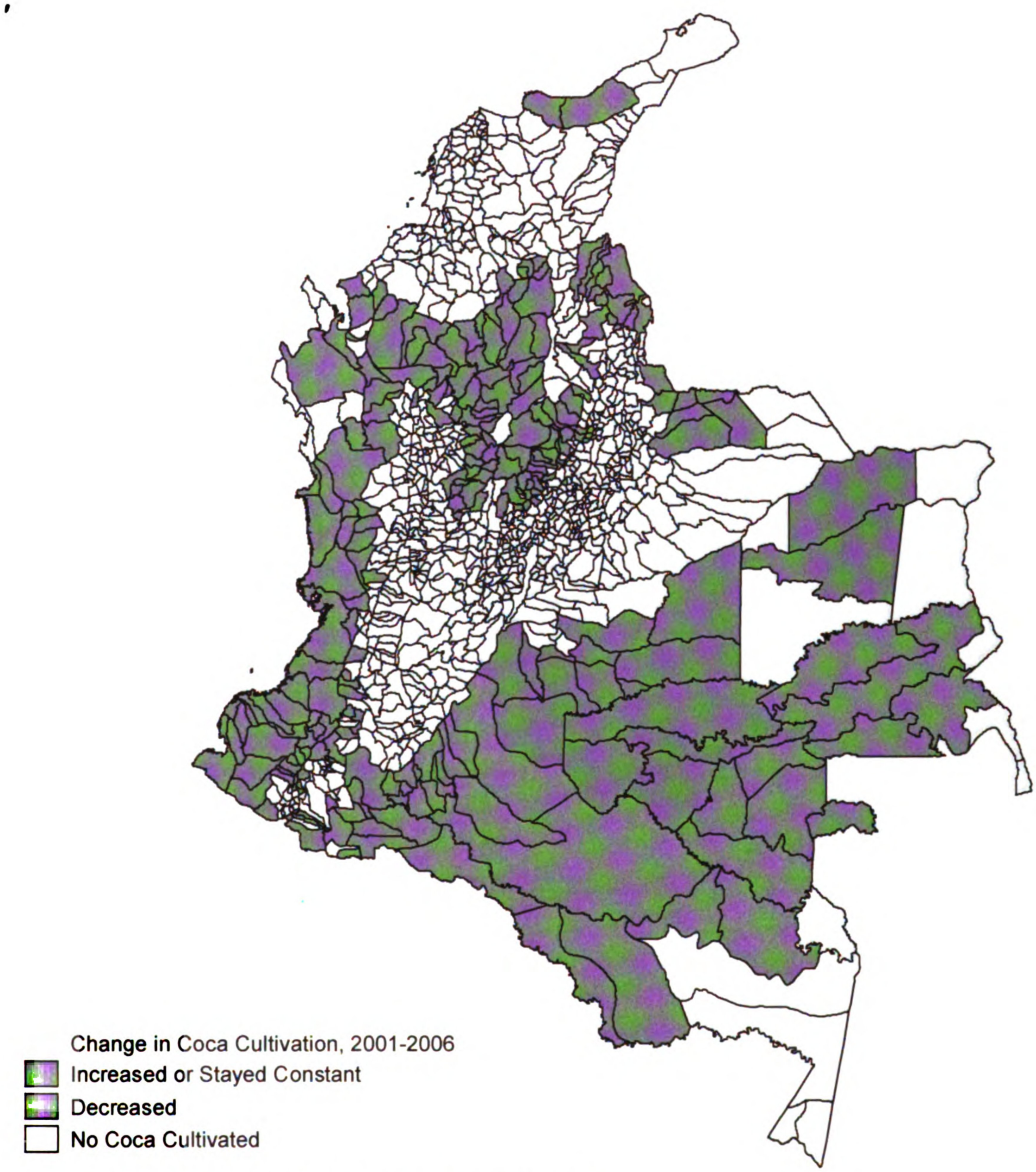

Figure 2: Map of Change in Coca Cultivation, 2001-2006

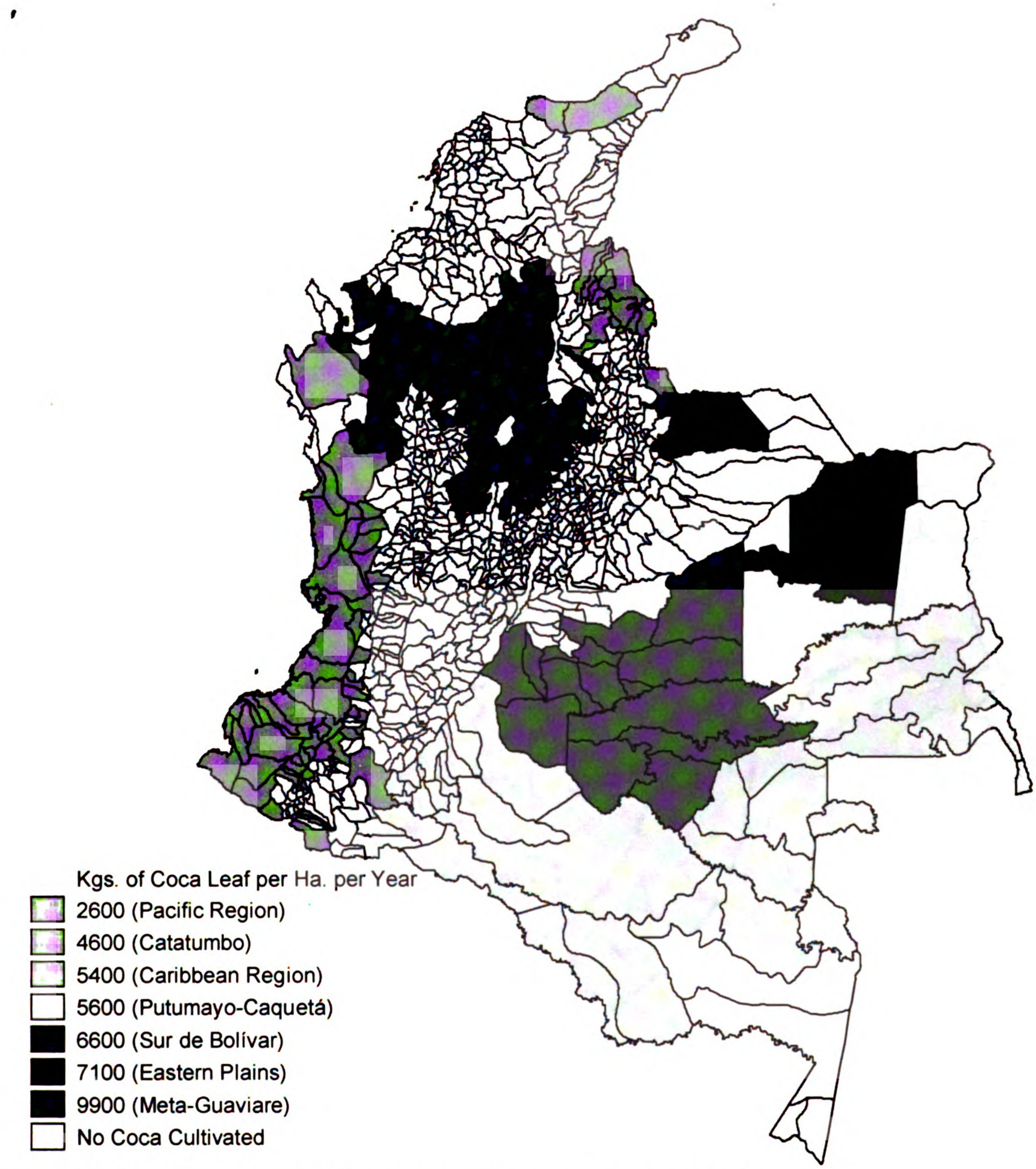

Figure 3: Map of Kilograms of Coca Leaf per Hectare per Year by Region.

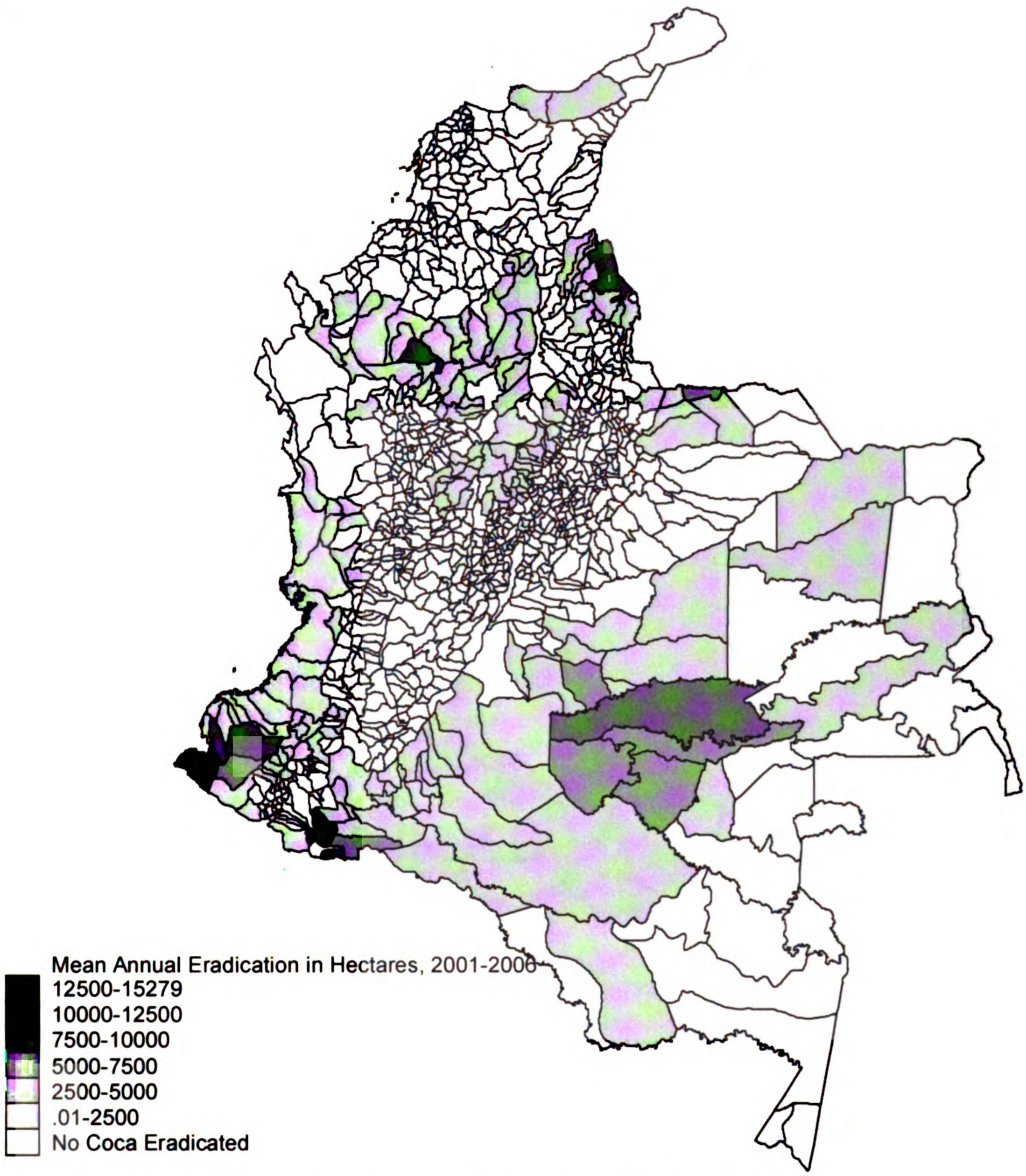

Figure 4: Map of Mean Annual Eradication of Coca by Municipality, 2001-2006

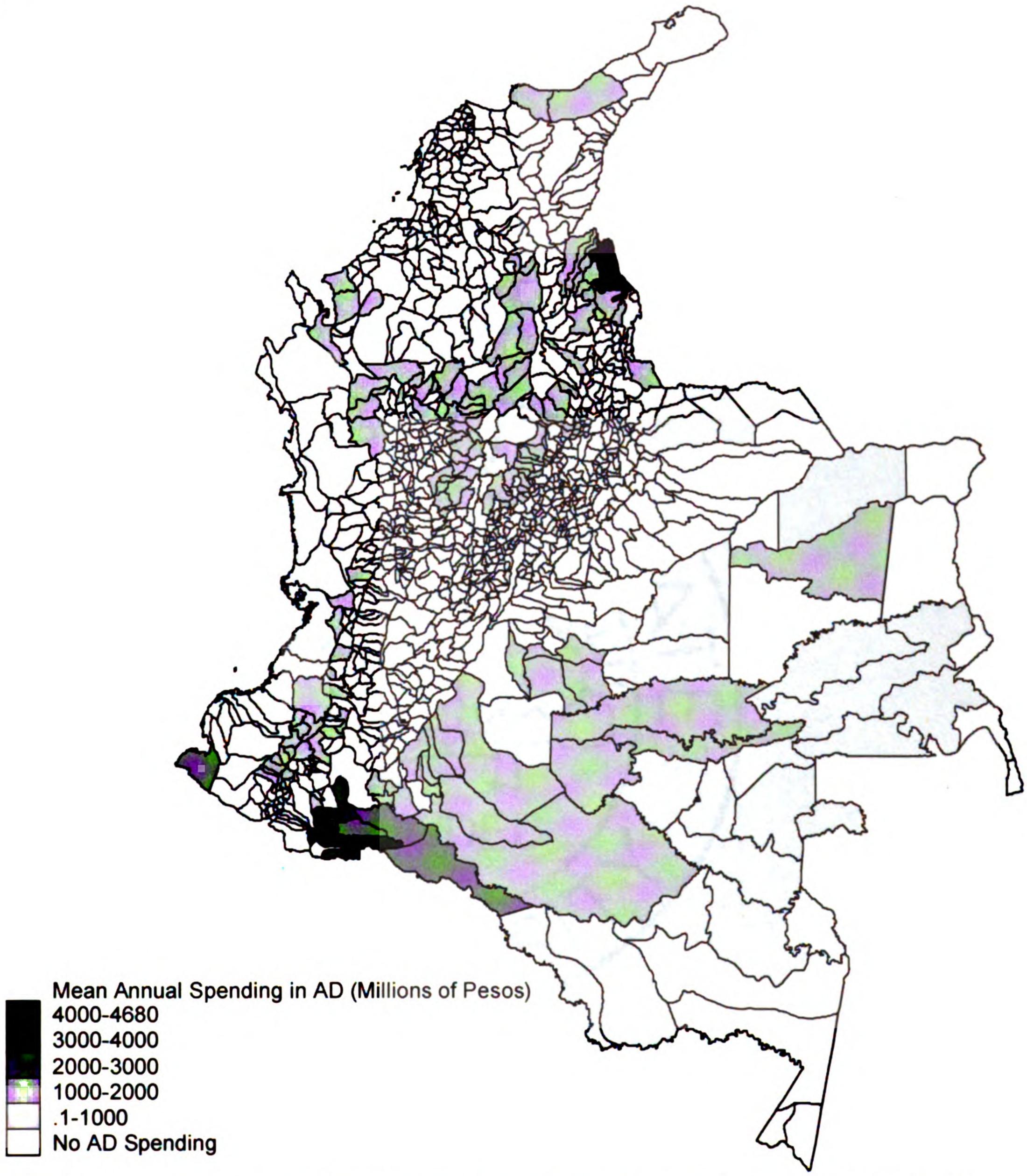

Figure 5: Map of Mean Annual Spending in Alternative Development Programs, 2001-2006 (in Millions of Pesos)

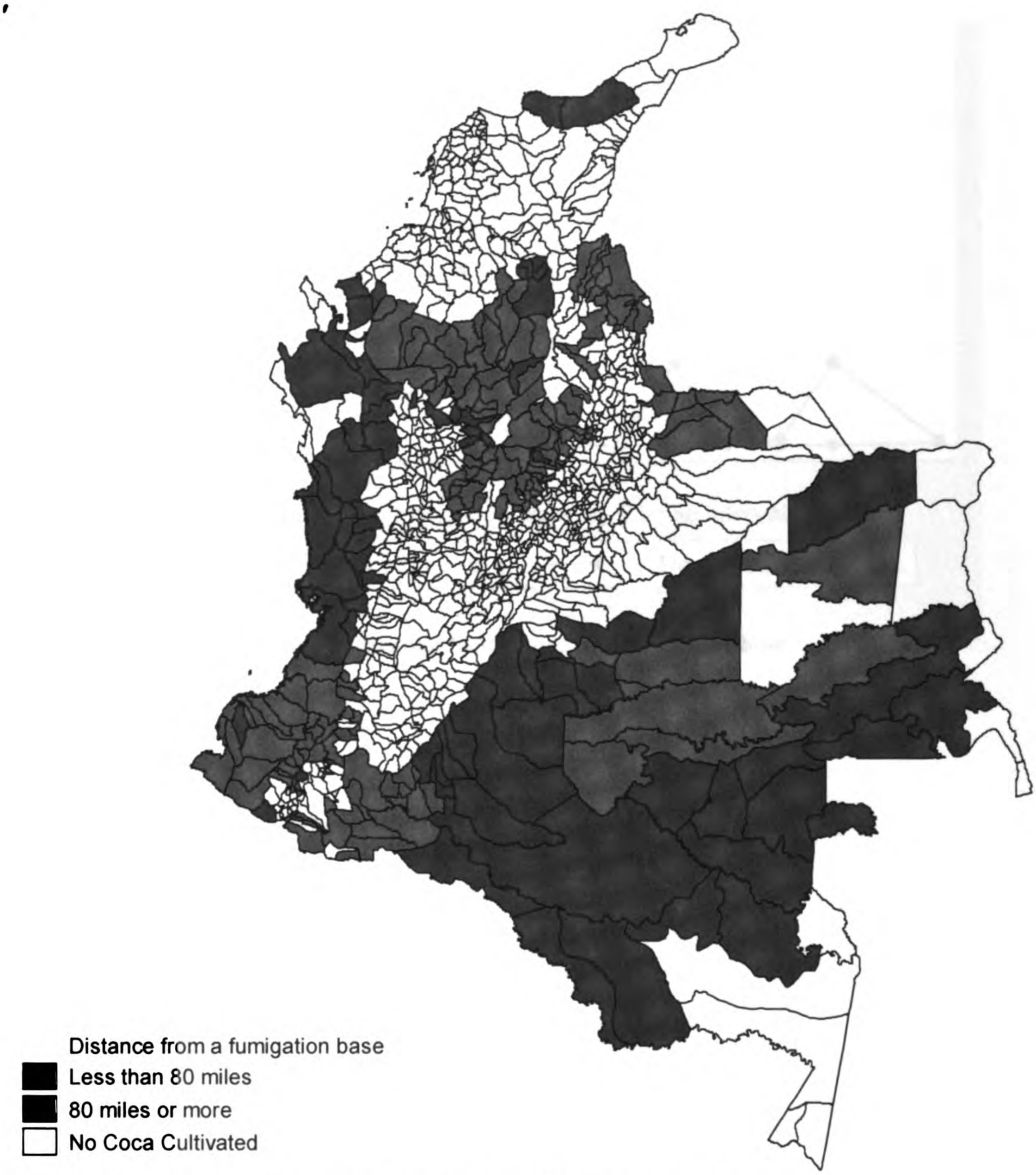

Figure 6: Map of Distance from a Fumigation Base (Except Larandia)

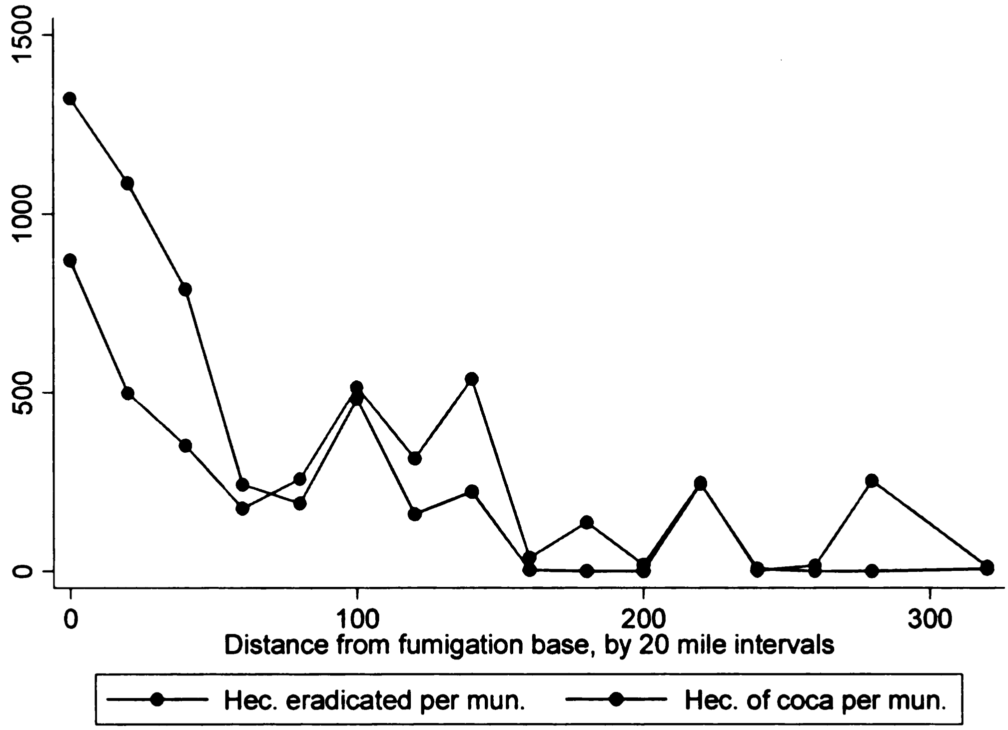

Figure 7: Coca eradication and cultivation by distance to a fumigation base

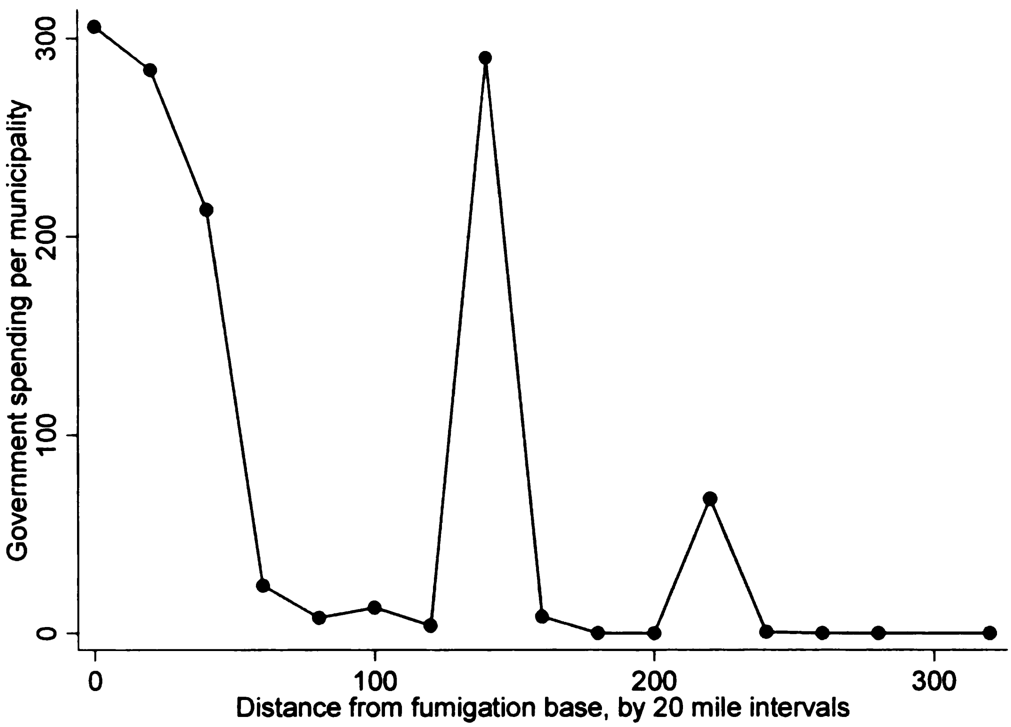

Figure 8: Alternative development spending in millions of pesos by distance to a fumigation base

CHAPTER 2: THE EFFECT OF ERADICATION ON COCA PRODUCTION AT THE FARM LEVEL

I. INTRODUCTION

Some 200 million people consumed illegal drugs at least once during the last year. Cocaine accounted for 16-21 million users, ranking third most consumed after cannabis (143-190 million) and amphetamine type drugs (16-51 million). The United Nations estimates that the retail value of the overall drug market is around 321 billion dollars a year. As a result of the health consequences of drug abuse, the international community strongly condemned and agreed to fight the production and use of drugs in three major treaties (UNODC 2005, 2009)

Many observers point out that the drug trade seems to flourish in spite of the efforts of the governments of producer and consumer countries. The *New York Times* (Kristof, N. 2009) reports that forty years after the United States declared a "war" on drugs under President Nixon, they are "more readily available, at lower prices and higher levels of potency" than before. The most recent United Nations World Drug Report devotes its preface to countering what it acknowledges to be a "growing chorus" of politicians, the press, and public opinion claiming that drug controls should be repealed because they are not working (UNODC 2009). Yet the debate often misses the fact that careful evaluations of the effects of enforcement efforts have rarely been undertaken, often because of the difficulties inherent in gathering data on illegal activity. Thus, according to Reuter (2008), "the body of research and evaluation on drug policy interventions, apart from drug treatment, is thin."

This paper's goal is to contribute to the ongoing research on drug policy by evaluating the effect of aerial eradication of illegal crops on the cultivation decisions made by coca farmers in Colombia. Colombia is the source of the majority of the world's cocaine supply. At the same time, it has received over US$ 6 billion in aid to combat the production of coca and cocaine through Plan Colombia, a joint initiative with the United States government (GAO 2008). Unlike the two other major coca producing countries, Peru and Bolivia, it has pursued aerial fumigation of coca in a vigorous attempt to eliminate illegal crops (Mejía, D. and C. E. Posada 2007). Thus the importance of the Andean country as a front in the war on drugs makes it an ideal place to conduct an evaluation of the effectiveness of a major drug control policy.

I use a novel data set collected by the United Nations Office on Drug and Crime. The Survey of Agro-Cultural Characteristics of Coca Crops in Colombia[5] was conducted by UNODC in 2005, by going directly into the sometimes dangerous areas where coca leaf is grown and promising farmers that their cooperation would not in any way lead to charges being brought against them. The survey resulted in a wealth of demographic and socioeconomic data about coca producers, as well as a detailed measure of the plots of legal and illegal crops owned by the farmers. I merge these data with another unique data set containing information on aerial eradication, provided by the Colombian Anti-Narcotics police. This allows me to estimate the effectiveness of fumigation and the effect of characteristics like level of education and mode of ownership of the land on farmers' cultivation decisions. This adds significantly to our empirical knowledge of the economic behavior of coca farmers at this level of disaggregation, which at present

[5] UNODC (2006): "Características Agroculturales De Los Cultivos De Coca En Colombia," Bogota: United Nations Office on Drug and Crime

consists of having documented an exogenous coca price increase that raised self employment income and led to higher levels of child labor in Colombia (Angrist, J. D. and A. D. Kugler 2008), and a fall in coca cultivation that seems to have resulted in an increase in child labor in Peru (Dammert, A. C. 2008).

Estimating the effect of the fumigation of coca crops, like other optimally distributed policy interventions, is econometrically challenging because of the endogeneity of the policy variable (Rosenzweig, M. R. and K. I. Wolpin 1986). This problem is commonly found in the broader economic literature on crime, which shows that unless policy endogeneity is taken into account the effectiveness of anti-crime efforts can be underestimated. A classical example is Levitt (1997), who remarks on the seemingly paradoxical positive relationship between the size of police force and the incidence of crime found by numerous studies. Using mayoral and gubernatorial election cycles as an instrument for the potentially endogenous police force size, he estimates a negative relation between police and crime. Klick and Tabarrok (2005) make a similar point using terror alert levels as a source of exogenous variation in police deployments in Washington D.C., as do Johnson et al. (2007) in their study of the effect of government spending on crime in the United States during the Great Depression.

To account for the endogeneity that arises as a consequence of targeting more intensively the areas that have higher coca farming levels, I instrument fumigation with variations in the expected cost faced by the Anti-Narcotics Police as it carries out its eradication missions. According to the interviews I conducted with the police, their ability to fumigate is restricted by the distance of a coca field from the safety zone surrounding a fumigation base. The reason is that fumigation crews are sometimes attacked by illegal armed groups when they approach their target. As a means of protection, fumigation planes are escorted by military helicopters, which can travel up to 80 miles from a fumigation base without refueling. The fumigation planes can go beyond that distance, but only unescorted and at a significant risk. As distance from the 80 mile radius of a base increases, the expected cost of the mission goes up because of the increased probability of an airplane being shot down. Furthermore, expected costs increase at a higher rate when the known presence of illegal armed groups is greater. The resulting variation in fumigation allows me to use a municipality's distance from a fumigation base and the number of illegal armed combatants to generate instruments that can be used when I regress coca cultivation on fumigation rates. I find that while the OLS and IV estimates of the coefficient on fumigation are statistically insignificant, the sign of the coefficient shifts from positive to negative when the instruments are used. This suggests that enforcement affects the behavior of farmers in the direction expected by the government, but that like in the relevant crime literature care must be taken to control for the endogeneity of the policy.

The paper proceeds as follows. In section II I describe the institutional framework of coca production in Colombia. Then I describe the data, and in Section IV I elaborate on the empirical strategy. Section V gives the results, and section VI concludes.

II. INSTITUTIONAL FRAMEWORK

Cocaine, like heroin, is different from drugs such as marijuana and amphetamines in that its production requires large extensions of land. As a result, coca leaf farming has prospered in remote areas of Colombia, Bolivia, and Peru, where the absence of the state creates havens that allow large scale illegal activities to take place. Currently, Colombia is the largest producer of cocaine in the world, with 53 percent of the world supply (UNODC 2009)

There are four stages in the production of cocaine, which is chemically extracted from coca leaves. First, farmers grow the leaves, which are then sold to intermediaries who transform them into coca paste and then into coca base. Finally, coca base is bought by cocaine producers, who use it to manufacture the drug in clandestine laboratories. Farmers are often able to produce coca paste and coca base themselves, but not cocaine, which requires the most sophisticated processes.

Even though growing coca is illegal, and despite the government's ability to detect illegal crops, coca farmers rarely face prosecution or lose their land as a result of their activities. There are two main reasons for this. First, coca farmers are invariably poor, which would make prosecution unpopular and thus politically challenging. Second, it would be impractical to confiscate and oversee large tracts of land in the countryside, where government presence is thin. As a result, the government fights coca production primarily by aerially fumigating the coca bushes that produce the leaf, hoping to raise the costs of production. Fumigation is not extensive or periodic enough so as to destroy every coca harvest, but the government's rationale is simple: if as a consequence of fumigation coca bushes become a less productive crop in terms of the amount of coca leaf they produce per year, legal crops will eventually become the more attractive alternative. A rather similar situation, that of opium poppy growers facing eradication in Afghanistan, has been modeled by Clemens (2008).

An annual census of coca crops is done through satellite imaging, and a semiannual one through aerial surveys. The Colombian Antinarcotics Police use this information to spray coca crops with glyphosate. When coca fields are sprayed the harvest is lost, but the coca bush survives, and a new harvest can be produced within three to six months. Multiple annual harvests result in fumigation sometimes occurring more than once a year in a particular area. Unless the farmer decides to uproot the coca bush and replace it with a new crop, the area of the land allocated to coca as recorded in the Survey of Agro-Cultural Characteristics of Coca Crops in Colombia stays the same. Because of this, and because new coca bushes can be planted year-round the area devoted to coca can increase after eradication has occurred.

The government chooses the crops to be fumigated on the basis of the concentration of coca in a region. Because the success of eradication campaigns is measured by the number of coca hectares sprayed nationwide throughout the year, fumigation concentrates in areas of the country where there is a high density of coca fields. Once a region is chosen for fumigation, intelligence reports are used to determine the safety conditions for the fumigation planes, and plans to escort them with Black Hawks are made accordingly. This is necessary because there are left and right wing militias that roam the Colombian countryside that have a vested interest in protecting the coca crops, whose production they tax. Occasionally, these militias attack the fumigation planes (Luna, A. O. 2007).

Legal crops are sometimes damaged in these operations, but only coca is targeted. When legal crops are damaged, farmers can claim compensation from the government, provided that they are not growing coca. As a further incentive to grow legal crops, there are a variety of alternative programs aimed at discouraging the production of coca and encouraging that of cacao, coffee, rubber, palm trees, and others. Another variety of alternative programs consists of training for the farmers, introduction of new agricultural techniques, help to commercialize farm products, and various types of infrastructure such as roads and electricity, all in the hope that farmers will abandon coca farming. However, support for these programs had dwindled by 2005 from a peak in spending attained in 2001. Because the UNODC survey reports that only six percent of the farmers interviewed had received some type of incentive to stop growing coca, here I focus exclusively on the effects of coca eradication.

III. DATA

The data on coca cultivation comes from the 2005 survey of coca growers conducted by UNODC and its associates. UNODC chose a random sample of coca fields detected by satellite as follows. First, the country was divided into seven regions. The coca producing areas of each region were divided into plots of one square kilometer. Then they chose a sample of coca plots for each region, each square having a probability proportional to the size of the coca crops in it of being chosen. UNODC selected a sub-plot within each of the initial squares using the same technique, and divided into parcels that had identical probabilities of being included in the sample. The farmers in charge of the chosen parcels were interviewed, as well as two neighboring coca farming households. The interviews were conducted on-site.

Access to some of the farms was not possible because of ongoing public order issues involving illegal armed groups, so UNODC substituted 93 of the original 463 sampling sites with comparable ones. In the final sample, careful interaction with the local authorities and clear assurances that the data collected would not be used to prosecute the farmers ensured their cooperation. On each of the 463 sites, the interviewers had to find one household where coca was in harvest so that they could collect samples. For the other two households, the data reported was on the area covered with coca bushes whether or not coca was in harvest.

There were 1389 surveys filled out. Descriptive statistics are shown in Table 11. They offer a unique glimpse into the world of coca growers, who turn out to be farmers of relatively modest means. The respondents are the heads of the households sampled, and the fact that 91 percent of them are male (compared with 70 percent for the general Colombian population[6]) is evidence of a more traditional family structure. The average age of the heads of household is 38 years, below the national average of 46 years. As one would expect, coca farmers are not highly educated: only 30 percent have studied beyond elementary school. By contrast, 60 percent of all Colombians in the same age group have surpassed this educational level[7]. By and large, coca is the farmers' main source of income: 82 percent report as much. Some of them control more than one coca farm, but the prevalent tendency is toward having just one, as the average farmer controls 1.2 farms.

In contrast with countries like Bolivia, where coca farmers belong to indigenous groups that culturally value the production of coca leaves, coca is not a traditional crop in

[6] Data for the general Colombian population are taken from the 2005 census.

[7] The comparison is between coca farmers from the UNODC survey and Colombians 14 years and older.

Colombia. Widespread cultivation started in the mid-1990s as a consequence of an abrupt interruption in coca leaf imports from Bolivia and Peru resulting from heightened enforcement at the border (Angrist, J. D. and A. D. Kugler 2008, Perafán, C. C. 1999). The survey confirms that the motivations for growing coca are not primarily cultural, but of an economic nature: 67 percent of farmers say they grow coca because of its good market price, 40 percent say that they grow it because it is easy to market, and only 30 percent attribute their decision to a regional custom. 52 percent say they grow it because there is no other option, and it is a bit unclear what they mean by this. There are several other crops that could be grown instead of coca in these regions. In all likelihood, what is meant is that the opportunity cost of not growing coca is very high.

76 percent of farmers report hiring laborers for the harvest, and 9 percent of all coca farms are rented. The majority (52 percent) of the land is legally titled to those who occupy it. 32 percent is occupied without a title, and sharecropping and other modes of ownership account for only 6 percent of the total.

Fumigation data corresponding to 2004 come from the Colombian Antinarcotics Police, who use GPS equipment in the fumigation planes used to spray coca crops and record the number of hectares fumigated in each municipality they target. To obtain a measure of the probability of fumigation faced by a farmer, I divide the number of coca hectares fumigated in a municipality throughout the year by the area of the municipality. I match this information with the survey data at the municipality level. The Antinarcotics Police also provided the location of their fumigation bases, which is key to the development of the instrumental variable. Table 13 shows descriptive statistics for the 43 municipalities in the sample.

IV. EMPIRICAL STRATEGY

I use a simple linear model, shown in Equation 2.1, to relate the share of cultivated land that farmer i of municipality m devotes to coca, H_{im}, to the rate of fumigation of the previous year in that municipality, f_m, a vector of controls at the individual level $\mathbf{X}_{im}$, a vector of controls at the municipality level $\mathbf{Z}_m$, a regional fixed effect[8] b_r, and an error term v_{it}:

$$(2.1) \quad H_{im} = \delta + \varphi f_m + \mathbf{X}_{im}'\theta + \mathbf{Z}_m'\zeta + b_r + v_{it}$$

Vector $\mathbf{X}_{im}$ includes titling to the land, the farmer's years of schooling, and whether the head of the household is male. I control for titling to the land because untitled land cannot be used as collateral in credit markets. Consequently, titling has the potential of affecting farmers' ability to make investments in the land, acquire capital goods and working capital (Besley, T. 1995, Besley, T. and R. Burgess 2000, de Soto, H. 2000). Titling could therefore widen the range of uses of the land to which the farmers have access, acting as a disincentive to grow coca. Education and gender proxy for the value of the farmers' labor in alternative occupations. $\mathbf{Z}_m$ includes the number of members of the

[8] Colombia is divided into five natural regions: Amazonian, Andean, Caribbean, Eastern Plains, and Pacific. These regions vary in socioeconomic conditions, climate, soil, flora, and fauna, and they provide different conditions for the cultivation of coca. When analyzing regional differences in coca cultivation, UNODC further subdivides the Amazonian region into Meta-Guaviare and Putumayo-Caquetá, and the Andean region into Catatumbo and Sur de Bolívar. In all regressions, I use UNODC's regional divisions.

Revolutionary Armed Forces of Colombia (FARC), the National Liberation Army (ELN), and the United Self-Defense Forces of Colombia (AUC) in the farmer's municipality. I control for the presence of these illegal armed groups because they may change the incentives for coca production. For example, they are known to protect coca farmers from government sponsored eradication of their crops, as well as to tax the drug trade.

The parameter that measures the effect of the drug control policy is φ, the coefficient on fumigation. If the government's strategy of fumigating coca crops to increase production costs and reduce cultivation is based on the amount of coca that farmers grow, OLS estimates of φ may be biased. Because the government's goal is to maximize the number of hectares of coca eliminated, constrained by the amount of resources available, it will choose to fumigate the areas where the marginal cost of fumigation is lowest. There are economies of scale in fumigating areas with a high density of coca crops, as several hectares can be fumigated in a single mission, so the result is that the government targets more intensively those areas where more coca is grown.

Therefore, the level of illegal crop fumigation is likely to be endogenous, resulting in biased OLS estimates. When this is taken into account, the institutional details learned from the Antinarcotics Police become crucial, as they contain the exogenous source of variation necessary to identify φ. According to the police, for security reasons the fumigation planes often have to be escorted by military helicopters back and forth from their bases. The helicopters cannot travel beyond 80 miles from the base without refueling, which limits their ability to escort planes that go past that distance. Hence, the areas beyond the 80 mile radius of a fumigation base are less likely to be fumigated the greater their distance from a fumigation base. Because this variation in fumigation results from a technological limitation that is not controlled by the police, it is in no way a response to the land allocations made by the farmers. In other words, distance to the 80 mile radius of a fumigation base is uncorrelated with the error term in Equation 2.1. I use this as the exclusion restriction when instrumenting fumigation with distance to the 80 mile radius of a fumigation base.

The exclusion restriction could break down if the location of the fumigation bases were endogenously determined. The main scenario under which this could be true would be one in which the bases were strategically situated near areas with high densities of coca crops. Such a concern can be allayed by pointing out that the construction of airport facilities is expensive and takes years. Therefore, the bases are usually located in urban areas and near to previously existing airports, which were built to service the demands of commercial flights before coca became a major cash crop in the mid 1990s. The exception to the rule is the Larandia military fort, located in a rural zone of the Caquetá department. This base was excluded from the calculations of distance to the nearest fumigation base.

The implementation of the IV strategy furthermore requires correlation between the instrument and the instrumented variable. The first stage is shown in Equation 2.2, where f_m - the share of hectares of coca fumigated last year in the farmer's municipality – is a function of $\mathbf{D}_m$, a vector of instruments, farmer characteristics $\mathbf{X}_{im}$, municipality level characteristics $\mathbf{Z}_m$, and regional characteristics a_r:

$$(2.2)\ f_m = \alpha + \beta \mathbf{D}_m + \mathbf{X}_{im}'\gamma + \mathbf{Z}_m'\xi + a_r + u_m$$

Table 14 shows OLS estimates of 2.2 using four different instrument sets. Column (1) corresponds to the just identified case, with distance from the 80 mile radius of a base as the instrument. Column (2) adds an indicator for whether the municipality is in the safety zone. In column (3), interactions between distance from the safety zone and the number of right wing and left wing combatants are included. Finally, column (4) adds the interaction of the safety zone indicator and distance from the base, plus interactions of this variable with the number of right and left wing combatants. The coefficient on (1) is significant at the 5 percent level. While individual coefficients in (2) - (4) are not statistically significant, a joint test of the instruments in (2) has a p-value of 0.11, and joint tests of the instruments in (3) and (4) show them to be significant at the 1 percent level.

V. RESULTS

OLS estimates of Equation 2.1 are reported in Table 15. The coefficient on fumigation, while statistically insignificant, is positive. For the average farmer, it implies that a one percent increase in fumigation would result in an increase of about 0.02 percent in the share of cultivated land that a farmer devotes to coca. This implies that the policy is likely not having its intended effect, a result that one should be careful to accept if the endogeneity of fumigation has not been accounted for. To address this concern, Table 15 also shows the results of IV estimation of Equation 2.1. In contrast with the initial attempt at OLS estimation, the coefficient on coca fumigation is negative, although still statistically insignificant. It suggests that there may be an upward bias in the OLS estimate. Depending on which IV point estimate is chosen, a one percent increase in fumigation could result in a reduction of between 0.02 and 0.20 percent in the share of cultivated land devoted to coca. The large standard errors, however, keep us from reaching a conclusion about the effect of fumigation on coca cultivation, other than that it does not seem to bring about any noticeable changes.

In view of the fact that eradication lowers coca yields and makes the crop less attractive compared to others, the persistent levels of coca production may be the result of an inelastic demand for coca. Higher production costs would thus be met with higher prices offered by coca leaf buyers, making the change in coca production as a result of eradication negligible.

The coefficient on years of schooling is positive and statistically significant across specifications. The OLS and IV estimates show that an additional year of schooling is associated with an increase of about 2.5 percent in the share of land allocated to coca. The fact that additional years of schooling are correlated with higher reliance on coca production suggests that education provides human capital that is particularly useful for the production and commercialization of illegal crops, more so than for other alternatives in the labor market.

Interestingly, land titling has a negative and statistically significant coefficient, lending support to the hypothesis that it may lead to improved access to credit markets and thus widen the range of economic activities other than coca cultivation available to the farmers. Acquiring a formal title to at least part of their land would reduce the share of cultivated land devoted to coca by about 11% according to the OLS estimate, or between 11 and 13 percent depending on the IV estimate chosen.

The coefficients on the number of illegal armed combatants are generally statistically insignificant. In the OLS regression, all are associated with decreases in the share of farmland that a farmer devotes to coca. An increase of one percent in the number of FARC combatants in the farmer's municipality is associated with a reduction in the share of farmland that a farmer devotes to coca of less than a hundredth of a percent. For both ELN and AUC, the reduction is close to 0.02 percent.

Depending on the IV specification, the coefficients imply that a one percent increase in the number of FARC combatants leads to an increase of between less than a hundredth of a percent and 0.04 percent in the share of farmland with coca. A one percent increase in the number of ELN combatants in the farmer's municipality is associated with a decrease in the share of farmland devoted to coca of between 0.02 and 0.03 percent. In the case of AUC, a one percent increase in the number of combatants in the farmer's municipality results in somewhere between a reduction of less than a hundredth of a percent and a 0.06 percent increase in the share of farmland devoted to coca. However, because of the lack of statistical significance of most of the coefficients, it cannot be established with certainty what influence if any these groups have on farmers' coca production decisions.

VI. CONCLUSION

This paper documents variations in the Colombian government's expected cost of fumigating coca crops. Because the distance between fumigation bases and their targets is known and is uncorrelated with the unobserved determinants of the share of cultivated land that a farmer devotes to coca, it is used to generate instrument sets that are used when estimating the effect of municipality level fumigation on the share of land a farmer devotes to coca. Neither OLS nor IV estimation find a statistically significant effect of fumigation on coca cultivation. Using the IV results as a benchmark, it is estimated that a one percent increase in fumigation may bring about a reduction of as much as 0.20 percent in the share of land devoted to coca. But while the IV estimates suggest a reduction in the land allocated to coca crops is the outcome of enforcement policies, the hypothesis that fumigation has no effect on coca cultivation cannot be rejected.

The results, then, do not find conclusive evidence that fumigation has its intended results. One may conclude that the reduction in the expected yield of coca crops that results from the threat of eradication is not dissuasive enough for farmers to significantly reduce the area of land that they allocate to this illegal crop. This provides some perspective to the current climate of public opinion on the war on drugs. At the very least in the case of illegal crop eradication through fumigation, the ultimate goal of eliminating the entire supply of coca remains elusive.

Beyond the main result, an interesting find is that a farmer's level of education has a statistically significant, positive impact on the share of land he or she devotes to coca. Thus, increased education seems to enhance a farmer's performance as a coca grower. Another result worth highlighting is that titling to the land seems to be acting as a disincentive to grow coca, presumably by improving access to credit markets as a result of the ability to use the land as collateral.

Finally, it is worth emphasizing that the environmental and social costs of fumigation, which have been documented elsewhere, must be taken into account in any policy decision resulting from the estimates obtained here. In particular, the effects of glyphosate on the local flora, and the low income of the coca farmers who often have few sources of earnings aside from coca, must be incorporated into any policy decision.

Table 11: Descriptive statistics of the Survey of Agro-Cultural Characteristics of Coca Crops in Colombia

Variable	Mean (s.d)
Male	0.910
Age	38.567 (11.643)
No education	0.101
Primary education	0.601
Secondary education	0.285
Some college	0.010
College	0.003
Coca is main source of income	0.823
Farms ("fincas") per coca producer	1.252 (0.542)
Total area controlled by producer (in hectares)	22.042 (112.040)
Area with coca	1.641 (1.833)
Area with fallow land	(0.405) (1.831)
Share of farmland devoted to coca	0.628 (0.316)
Arrobas of coca sold per year	311.445 (284.398)
Price per *arroba* in Colombian pesos	25566.23 (10462.2)
Arrobas of coca per hectare	177.096 (47.540)
Coca producer pays for harvesting wages	.768
Most productive age in years of coca bush	2.557 (.666)
Grows coca because of good prices	0.676
Grows coca because of regional custom	0.309
Grows coca because of easy marketing	0.403
Grows coca because there are no other options	0.527
Grows coca because it is easy to finance	0.019
Has received support to replace coca crops	0.060

Sample size: 1389 coca producers

Table 12: Descriptive statistics by farm

Variable	Mean
Land is titled	0.525
Farm is occupied without a title	0.321
Farm is rented	0.089
Sharecropping	0.048
Other modes of ownership	0.017
Sample size: 1740 farms	

Source: Author's calculations from UNODC database

Table 13: Descriptive statistics of the municipalities in the sample

Variable	Mean (s.d)
Hectares of coca fumigated in 2004	2134 (2946)
Hectares of coca manually eradicated in 2004	17.763 (42.348)
Municipality area in squared kilometers	3621 (10032)
Share of municipality fumigated in 2004	0.010 (0.0112)
Share of municipality manually eradicated in 2004	0.00033 (0.00139)
FARC combatants	52.047 (71.538)
ELN combatants	14.326 (27.682)
AUC combatants	20.628 (38.743)
Distance to the closest fumigation base in miles	52 (53)

Source: Author's calculations from Anti-Narcotics Police database, cultivation data from Project SIMCI II, Instituto Geográfico Agustín Codazzi.

Table 14: First stage regression

	(1)	(2)	(3)	(4)
	Dependent variable is share of the municipality fumigated in 2004			
Distance beyond 80 mile radius of a base	-0.000181**	-0.000113	-0.000332	-0.000209
	(0.000086)	(0.000182)	(0.000277)	(0.000371)
Municipality is less than 80 miles from a fumigation base		0.00273	-0.000143	0.00646
		(0.00636)	(0.00737)	(0.00829)
Distance beyond 80 miles of a base * Number of left wing combatants			0.000134	0.000139
			(0.000081)	(0.000094)
Distance beyond 80 miles of a base * Number of right wing combatants			-0.000182	-0.000223
			(0.000138)	(0.000184)
Municipality is less than 80 miles from a fumigation base * Distance from base				-0.000111
				(0.000124)
Municipality is less than 80 miles from a fumigation base * Distance from base * Number of left wing combatants				0.000106
				(0.000085)
Municipality is less than 80 miles from a fumigation base * Distance from base * Number of right wing combatants				-0.000218*
				(0.000121)
Male	0.000293	0.000317	0.000202	0.000003
	(0.000712)	(0.000683)	(0.000683)	(0.000592)
Years of schooling	-0.000025	-0.000024	-0.000060	-0.000064
	(0.000111)	(0.000110)	(0.000112)	(0.000114)
Has title to at least part of the land	-0.000247	-0.000274	-0.000433	-0.000353
	(0.000601)	(0.000609)	(0.000557)	(0.000504)
Hundreds of FARC combatants	0.00210*	0.00198	0.00166	0.000236
	(0.00122)	(0.00130)	(0.00140)	(0.00182)
Hundreds of ELN combatants	0.00493	0.00425	0.00504	-0.000419
	(0.00463)	(0.00452)	(0.00472)	(0.00885)
Hundreds of AUC combatants	0.00870**	0.00837**	0.00799**	0.00940*
	(0.00335)	(0.00372)	(0.00391)	(0.00505)
Constant	0.00302	0.000991	0.00411	0.00117
	(0.00388)	(0.00556)	(0.00620)	(0.00871)
Observations	1389	1389	1389	1389
R-squared	0.412	0.413	0.420	0.508

Robust standard errors clustered at the municipality level in parentheses. Regional fixed effects are included in the regression.
*** p<0.01, ** p<0.05, * p<0.1

Table 15: OLS and IV regressions with share of cultivated land devoted to coca as a dependent variable

	Dependent variable is share of cultivated land devoted to coca				
	(1)	(2)	(3)	(4)	(5)
	OLS	IV	IV	IV	IV
Share of municipality fumigated in 2004	1.098	-13.46	-13.53	-7.646	-1.415
	(1.362)	(10.72)	(10.93)	(9.918)	(3.768)
Male	0.00588	0.0120	0.0120	0.00955	0.00694
	(0.0301)	(0.0318)	(0.0320)	(0.0305)	(0.0298)
School	0.0157***	0.0153***	0.0153***	0.0155***	0.0157***
	(0.00354)	(0.00401)	(0.00402)	(0.00381)	(0.00356)
Has title to at least part of the land	-0.0714***	-0.0805***	-0.0805***	-0.0769**	-0.0730***
	(0.0245)	(0.0285)	(0.0287)	(0.0288)	(0.0255)
Hundreds of FARC combatants	-0.00175	0.0413	0.0415	0.0241	0.00569
	(0.0179)	(0.0322)	(0.0322)	(0.0267)	(0.0140)
Hundreds of ELN combatants	-0.0975	-0.125*	-0.125*	-0.114*	-0.102
	(0.0724)	(0.0733)	(0.0741)	(0.0673)	(0.0670)
Hundreds of AUC combatants	-0.0434	0.114	0.114	0.0509	-0.0163
	(0.0363)	(0.132)	(0.135)	(0.118)	(0.0563)
Constant	0.552***	0.640***	0.640***	0.605***	0.567***
	(0.0884)	(0.0983)	(0.0993)	(0.109)	(0.0907)
Observations	1389	1389	1389	1389	1389
R-squared	0.227	0.065	0.063	0.168	0.222

The instrument in (2) is distance beyond the 80 mile radius of a base. In (3), an indicator for whether a municipality is less than 80 miles from a fumigation base is added. In (4), interactions between distance beyond 80 miles of a base and the number of right wing/left wing combatants are also included. Specification (5) further adds an interaction between the indicator for distance from a base being less than 80 miles and distance from the base, plus interactions between this variable and the number of right wing/left wing combatants. All regressions include a constant, year indicators, and indicators for each of the 7 UNODC coca growing regions. Robust standard errors clustered by municipality are shown in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

APPENDIX A: UNODC ESTIMATES OF COCA CULTIVATION

When the sky is clouded, satellite observations of coca fields cannot detect the crops that lie below the clouds. Furthermore, sometimes technical difficulties create gaps in the photographs. To account for clouds and gaps in the images, SIMCI II estimates the number of coca hectares that are not observed, in the following way. First, coca hectares that are up to one kilometer away from the perimeter of the cloud (300 meters for a gap in the picture) are counted. Then, the number of coca hectares in the ring surrounding the unobserved area is compared to the one from the previous year's survey. Thus, a rate of change is obtained, and it is applied to the number of coca hectares observed last year in the area that is now below the cloud or gap.

A further difficulty is that satellite photographs are taken over a period that spans five months (September through February). Because eradication of coca crops may take place after an area is photographed, hectares that are manually eradicated after a picture is taken are subtracted from the Dec. 31st estimate. Sprayed coca bushes have an estimated survival rate of 12 percent. Thus, when fumigation takes place after a satellite photograph is taken, the destroyed area is subtracted accordingly. Finally, SIMCI II adjusts the data so that the photographs taken over the five month period reflect the number of hectares of coca that existed in December 31st. It is unclear how this adjustment is done. SIMCI II simply states that trends from previous surveys are used to obtain an adjustment factor.

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