Climate, Conflict and Labor Markets: Evidence from Colombia's Illegal Drug Production

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Abstract

This research aims at linking two strands of the literature: the recent works on climate and conflict (Burke, Hsiang and Miguel, 2015) and the economics of labor coercion (Acemoglu & Wolitzky, 2011, Dippel, Greif and Trefler, 2015). In the first area of knowledge, my research addresses an important knowledge gap on the role that institutional quality plays to help explain the directions and magnitudes of the impact of weather fluctuations on conflict through their effect on economic outcomes. Regarding the second knowledge area, my research contributes to the creation of new knowledge by bringing rich individual data and the use of satellite-generated information to the analysis of coerced labor. Also, by analyzing the current phenomenon of coca planting and exploitation by non-State armed actors, my research can inform illegal drug policy as well as rural development policies.

More precisely, this research aims at understanding the causal effect of weather-induced agricultural shocks on labor market conditions and forced displacement in the context of the Colombian civil conflict. I first match monthly municipal rainfall to coca leaf yield, to show that rainfall is a strong predictor of coca yield. Standard economic theory predicts that the rising productivity should translate into larger wages. However, when I estimate the effect of the positive productivity shock on rural unemployment and wages in coca areas, I find that the increasing production due to good weather rises labor demand but labor income remains constant.

To estimate the effect of the positive productivity shock to coca-suitable areas on labor demand and wages, I estimate OLS equations of (log) wages and the probability of unemployment on individual characteristics that determine labor market outcomes and rainfall. I also control for municipality fixed-effects that absorb time-invariant characteristics, whether observed or unobserved, disentangling the precipitation shock from other sources of omitted variable bias, month*year fixed effects during the period January 2004-June 2010 and a department-specific linear time trend. Coca-suitable municipalities are those where coca has been cultivated in the municipality during at least one year during the period 1999-2011. These estimates are explicitly reduced form, and they focus on the effect of the variation in precipitation in coca-suitable areas on labor market outcomes. Given that precipitation varies plausibly randomly over time, as random draws from the municipality climate distribution, this approach has strong identification properties (Dell, Jones and Olken, 2014).

To explain the unexpected result of unchanged rural wages in response to increasing productivity, I draw on labor coercion models, where the role of coercion is to decrease the outside option of the coca farmers (Acemoglu & Wolitzky, 2011, Dippel, Greif and

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Trefler, 2015). These models hypothesize that an increase in coca productivity should be associated with expansion efforts by the coercive non-State armed groups and a decrease in forced displacement. Forced displacement occurs when farmers are able to leave the coca farming contract. Because the coerced sector yields higher returns with better rainfall, I first test that excess rainfall causes differentially lower forced displacement in coca suitable areas than in non-suitable areas. Results confirm, that in fact, an additional milimeter of precipitation above the municipality mean decreases forced displacement by 1.22% in coca-suitable areas; by contrast in non-coca areas the effect of positive rainfall shocks is approximately ten times smaller and insignificant.

A second way to test for coercion in coca suitable labor markets is to test whether high productivity months witness lower forced displacement. I therefore match coca leaf yield data with local violence in a small sample of municipalities with rich harvest data. I employ an Instrumental Variables estimation where changes in forced displacement are explained by coca leaf yield variations, and I instrument changes in coca leaf yield with rainfall. One additional arroba of coca leaf per hectare harvested is associated with a reduction of forced displacement of 4 people on average, and this estimate is significant at the 5 percent level.

Finally, I regress coercion efforts measured by confrontations between non-State actors who profit with cocaine and government forces as well as mayor killings on coca yield, instrumented with rainfall. As suggested by the labor coercion models, the IV estimates of the effect of positive productivity shocks on violence in coca areas are statistically significant and economically important, suggesting that the effect of weather shocks on labor markets is mediated by the quality of the institutions where these markets are embedded.

Keywords: Climate, Conflict, Cocaine, Institutions, Economic Development, Instrumental Variables

JEL Codes: O10, O13, Q54

1 Introduction

Forced displacement by violence has been called the new 21st century challenge (UNHCR, 2012). In 2012, developing countries hosted over 80 percent of the world's refugees, and the 49 least developed countries were providing asylum to 2.4 million refugees by year-end. This paper aims at understanding the causal effect of weather-induced agricultural shocks on labor market conditions and forced displacement in the context of the Colombian civil conflict. I first match monthly municipal rainfall to coca leaf yield, to show that rainfall is a strong predictor of coca yield. Then, I estimate the effect of the positive productivity shock on rural unemployment and wages in coca areas, finding that increasing production due to good weather rises labor demand but is not translated into larger wages. I then turn to a municipal violence dataset and in a structural equation for violence, I regress confrontations between non-State actors who profit with cocaine and government forces, mayor killings as well as forced displacement on coca yield, instrumented with rainfall. My Instrumental Variables estimates of the effect of positive productivity shocks on violence in coca area are statistically significant and economically important.

The study of the intersection of climate and conflict has moved center stage over the past decade (Burke, Hsiang and Miguel, 2015). This shift is due in part to greater awareness about the role of climate in driving economic outcomes, and the broader fact that conflict remains widespread in most low and middle income regions. In fact, civil conflicts inflict more suffering on humanity than any other social phenomenon, they are central to political evolution and key impediments to global development (Miguel and Blattman, 2010), and the estimates from a meta-study that evaluated data from 60 studies and 45 conflict datasets from different regions of the world and a time period that spans from 10,000 BCE to the present, show that each standard deviation change in climate toward warmer temperatures or more extreme rainfall increases the frequency of interpersonal violence by 4% and interconflict violence by 14% (Hsiang, Burke and Miguel, 2013). These results underline the importance of further examination of the open questions in the literature relating to mechanims, heterogeneity, and which types of weather shocks matter most (Dell, Jones and Olken, 2014).

While there is a consensus in the literature that bad economic conditions increase casualties from war (Miguel, Satyanath and Sergenti, 2004, Barron, Kaiser and Pradhan, 2004; Chen, 2007; Murshed and Gates, 2005; Quy-Toan Do and Lakshmi Iyer, 2007; Oeindrila Dube and Juan F. Vargas, 2013), and that climate plays a role in the link between economic conditions and conflict, numerous pathways linking climate and conflict have been proposed. This research posits a new channel through which climate impacts conflict: changes in the expectation of profits that non-State actors derive from cocaine production, which relies heavily and differently from legal crops on rainfall patterns, explains the variation in violence and welfare of rural workers in coca areas.

A related literature has examined how disfavorable changes in income may exacerbate the conflict over resources. For example, Hidalgo et al (2010) find that rural poor invade and occupy large landholdings more when rainfall is worse, in the context of Brazilian municipalities between 1988 and 2004. In subnational regions in Africa, Fjelde and von Uexkull (2012) show that negative rainfall shocks increase communal conflict, and in particular, in areas dominated by groups outside the political mainstream. In the Americas, Dell (2012) finds that municipalities that experienced more severe drought in the early 20th century were more likely to have insurgency during the Mexican Revolution than nearby municipalities with less severe drought. I contribute to that literature by examining how random deviations in local weather from its long term mean directly modifies the payoffs of coca-profiting illegal armed groups, changing the expectations of coca income that can be sourced from different locations. In other words, a positive weather shock in one place at a certain time means a higher coca income stream from coca cultivated in that place versus another, or from the same place at a different moment in time. This has implications for the confrontations of different groups for the control of these areas. Since there are multiple armed groups fighting over resources, any shock which raises the return to appropriation will increase conflict over land control by increasing the war prize if the contest is won (rapacity effect). On the other hand, the positive productivity shock directly affects the coca farmers' participation constraint: if excess rainfall favors coca disproportionally over other legal crops, and under the presence coercive activity, wetter months associated with higher yields should produce higher labor demand for coca planting as well as larger violence activity (Acemoglu & Wolitzky, 2011), and lower displacement.

To estimate the effect of the positive productivity shock to coca-suitable areas on labor demand and wages, I estimate OLS equations of (log) wages and the probability of unemployment on individual characteristics that determine labor market outcomes and rainfall, controlling for municipality fixed-effects that absorb time-invariant characteristics, whether observed or unobserved, disentangling the precipitation shock from other sources of omitted variable bias, month*year fixed effects during the period January 2004-June 2010 and a department-specific linear time trend. Coca-suitable municipalities are those where coca has been cultivated in the municipality during at least one year during the period 1999-2010. These estimates are explicity reduced form, and they focus on the effect of the variation in precipitation in coca-suitable areas on labor market outcomes. Given that precipitation varies plausibly randomly over time, as random draws from the municipality climate distribution, this approach has strong identification properties (Dell, Jones and Olken, 2014).

Despite the increase in labor demand as measured by a decrease in unemployment, my results show that the positive producitivity shock to coca production does not translate into better rural wages. To better understand the market-clearance mechanism in this context, I then match coca leaf yield data with local violence in a small sample of municipalities with rich harvest data. I employ an Instrumental Variables estimation where changes in confrontations, mayor killings and forced displacement are explained by coca leaf yield, and I instrument changes in coca leaf yield with unexpected rainfall shocks. Since the seminal work of Miguel, Satyanath and Sergenti (2004) on the impact of unforseeable weather conditions on economic growth and the outbreak of civil conflict and war in Africa, a body of literature has relied on rainfall to establish causality when looking at a host of political and economic outcomes (Bruckner and Ciccone, 2011, Mehlum, Miguel and Torvik, 2006, Bohlken and Sergenti, 2010). Since rainfall can affect many social phenomena simultenously (see Dell, Jones and Olken, 2014, for a review), I restrict my sample to a small set of municipalities that are highly dependent on coca plantation and transformation into cocaine, and follow cocaleros (coca farmers) during every month for one year from these municipalities, matching their yields to local monthly violence. I also show, using yield information from 11,624 harvests, that rainfall and coca yield are strongly correlated. Excess rainfall is less good for legal crops than coca since the coca leaf plant has been modified through history to maximize the levels of its alcaloid (which maximizes the level of cocaine that can be obtained from it but kills the pests that are associated with abnormaly high precipitation).

This research also contributes to the literature on the origin of States, broadly defined as a monopoly of violence that violent actors impose in order to extract taxes (Carneiro, 1970, Olson, 1993, Tilly, 1985, Weber, 1946). A related empirical work is the study of stationary bandits in the Democratic Republic of Congo by Sanchez de la Sierra (2014). The author finds that the decision of violent actors to impose monopolies of violence on their ability to tax the local population. Sanchez de la Sierra uses a sharp change in the price of coltan, the main raw material of electronic products, to show that an increase in its price caused the armed actors to impose a taxation system and the monopoly of violence systematically in coltan villages. My research studies forced displacement in the context of State formation, which has been overlooked in this literature. Colombia is a good context to stuy forced displacement as a result of violence given that it is currently the country with the second largest number of forcefully displaced population after Siria (Comision Historica del Conflicto y sus Victimas, 2015, GMH, 2013), and that the availability of data at municipal level on a monthly basis facilitates the analysis of short term changes in violence outcomes generated by variation in short term economic production and climate.

The result that institutional quality is of the utmost importance in labor markets and that therefore it can even offset market forces is consistent with findings by Dippel, Greif and Trefler (2015), who find that an institutional channel explains labor market outcomes in the coercive environment of the 14 sugar British Caribbean colonies. The authors conclude that the collapse of the coercive plantation system in these places raised wages (offseting the fall in wages generated by the market channel) and lowered coercion, measured by incarceration rates. While the collapse of the coercive plantation system decreased labor demand in the sugar sector (which should have depressed wages), workers were more able to move to non-plantation opportunities, which increased earnings.

The effect that shocks to the coca leaf planting and processing sector have on civil conflict dynamics is relevant to study for policy reasons as well. From a policy perspective, understanding the effects of changes in the production of illegal goods that fuel internal conflicts is of pressing concern. Eradication of these goods has been globally devoted increasing amounts of resources under the premise that decreasing the income of rebels will make them more likely to disappear or negotiate.

Cocaine is the second-most consumed illegal drug in the United States -after marijuana- and the third in most European countries -after marijuana and heroin- (Mejia and Posada, 2010). The coca bush can grow almost everywhere in the country, in areas from 100 meters of altitude to 2000 meters. Farmers who plant and harvest the leaf add 9% of the total added value. Cocaine production and commercialization high investments and are the most profitable activities of the production chain.

Colombia's current civil war involves left-wing guerillas, private militias with no political objectives, and government forces. Both guerrilla groups and private militias are heavily involved in the production and trade of coca leaf and its derivatives, from which they benefit abundantly (Mejia and Rico, 2010). They offer seeds, technical assistance and credit to coca farmers (Cano, 2002), control prices acting either as a monopsonistic buyer or as a market regulator and enforces «contracts» with violence.

This research is closely related to Dube and Vargas (2013) study of commodity price shocks and civil conflict in Colombia, and Angrist and Kugler (2008) research about coca, income and civil conflict in Colombia. Angrist and Kugler (2008) study the consequences of the shift of coca production of coca from neighboring Andean countries to Colombia on labor market outcomes and violent death rates. They find some evidence of increases in self-employment income, though not in the likelihood of of having income from this source, in the probability of working more generally, or in wage and salary earnings. Their results also show increased violent death rates in growing areas after the increase in coca cultivation (but these results are weaker in models that include department trends). Even though the autors cannot identify the channels through which coca cultivation might abet violence their results are consistent with the notion that coca supports rural insurgents and paramilitaries (Angrist and Kugler, 2008, p. 210).

Dube and Vargas (2013) research exploits exogenous price shocks to coffee and oil to find that a sharp fall in the coffee prices during the 1990s lowered wages and increased violence differentially more in municipalities cultivating more coffee. This is consistent with the coffee shock inducing an opportunity cost effect. In contrast, a rise in oil prices increased both municipal revenue and violence differentially in the oil region. This is in line with the oil shock inducing a rapacity effect. My paper differs from Dube and Vargas (2013) paper in a very fundamental way: coca planting, harvesting and processing into cocaine are economic activities enforced with violence. If living in coca-growing contested areas, outside options for coca farmers are very limited or nonexistent (Fichtl, 2004:4), if they are not explicitly coerced to coca planting and harvesting. Therefore, the mechanism at work in their research, which is the increasing opportunity cost of joining the armed groups does not hold here.

The rest of the paper describes firstly the institutional context where coca growing and associated violence takes place. This section is followed by a simple conceptual framework on labor coercion. Next, the paper presents the data sources and summary statistics of the main outcomes (labor market and violence). I then describe the empirical strategy to estimate the effect of weather-induced agricultural productivity shocks on labor market outcomes in coca-suitable municipalities, as well as on forced displacement. The following section presents Instrumental Variable estimations of the effect of coca productivity instrumented with rainfall on violence in coca growing municipalities (forced displacement, confrontations and mayor killings). Finally, I interpret the results and conclude.

2 Institutional context

Colombia has a long history of state weakness and civil conflict (Acemoglu, Garcia-Jimeno and Robinson, 2014). Nonstate armed actors and many of the most recent emerged from a civil war known as La Violencia which lasted from the late 1940s into the early 1960s (Acemoglu, Robinson and Santos, 2013). This civil war was initially the consequence of fighting between the Liberal and Conservative political parties. The Revolutionary Armed Forces of Colombia, FARC and National Liberation Army, ELN, formed in 1964 (ibid). As a corollary to both, the State's weakness and the bipartisan conflict, private armed militias were created during the Cold War era. They emerged in the fifties as individualized attempts to quell regional and local foci of unrest. Some members of the military, large landowners, and/or politicians welcomed, fostered, and financially assisted motley groups of guards and defense escorts, who came to be known under different appellations ("chulavitas," "pajaros," "guerrillas limpias," "guerrillas de paz" ...) according to the area (Garces, 2005). Their existence was legally sanctioned in 1968, a decision eventually overturned in April 1989, when their collusion with some sections of the armed forces awoke criticism from Amnesty International and other human rights groups. Initially, the law had approved the "collective defense" and the creation of groups to support the Army (Pardo, 1997).

The paramilitary consolidated themselves considerably in the 1980s and 1990s. Three main causes explain the expansion of the paramilitaries during the 80s (Pardo, 2007). Firstly, the pre-existence of private armed militias mentioned before, some of them created by Colombian Army. Secondly, the peace treaty with left-wing guerrillas during the 80s, which obliged the Army to stay in their camps without fighting any groups, while the leftist guerrilla groups expanded considerably, from 1,600 to 3,600 men between 1984 to 1986. Not only drug traffickers but businessmen decided to organize small or big groups to defense themselves from the guerrilla, according to their capacity. C) The third factor was the kidnap of Martha Ochoa, member of one of the drug cartels, by one of the guerrillas. All the mafia members grouped to rescue the woman and informed during a soccer game in Cali that they had conformed the "Kill Kidnappers" group, in order to defend their interests, members and properties.

In 1987, the groups had become a single terrorist unity with the main goal of providing the mechanisms for drug trade without any complications. The businessmen that had participated at the beginning in the creation of the groups got involved and many of them became the victims of the movements they had helped to create, having had to sell their lands at very low prices. Others preferred to stay despite being aware of the new goals of the organization (Pardo, 1997). Like the guerrillas, the paramilitaries benefited abundantly from drug money. Illegal funds were even used for their training by Israeli instructors. And like the guerrillas, they also relied for their financing on fees charged for protection. They generalized the practice of mass killings, seeking to eliminate peasants even when only vaguely suspected of colluding with the guerrillas. They mimicked the guerrillas in their carefully led insurrectional war, establishing local fronts to cleanse them from rebel-guerrilla presence (Garces, 2005). They also killed Luis Carlos Galan in 1989, presidential candidate who could have led a socialist party in Colombia (Robinson, 2005).

The United Self-Defense Forces of Colombia (AUC) were formed in April 1997 as an umbrella paramilitary federation. They sought to consolidate many local and regional paramilitary groups in Colombia, each intending to protect different local economic, social and political interests by fighting insurgents in their areas. AUC itself previously estimated that it had authority over most of the paramilitary forces within Colombia, with the remainder being independent or splinter factions. This organization was conformed by 9 groups initially and then expanded to coca growing areas controlled by the leftist guerrillas afterwards. The illegal drug business became a major source of funding for many, if not all, paramilitary groups; in 2005, Colombia's General Comptroller estimated that around 48 percent of the best lands in the country are controlled by drug trafickers (General Comptroller of the Republic, 2005). For some paramilitary commanders, profiting from illegal drug trafficking was not new as they had been deeply involved in the activity even before they joined or started paramilitary groups (Revista Semana, 2005).

During the mid 2000's, the emphasis on obtaining control over valuable areas grew to the point that there is evidence of paramilitary groups fighting against each other because of the business and some paramilitary groups even forged alliances with leftist guerrillas in some drug trafficking operations (Human Rights Watch, 2005, based on interviews to demobilized parmilitary members). In interviews made by the human rights organization Human Rights Watch to former paramilitary leaders, it was established that paramilitary groups' involvement in the drug business frequently included taxing growers, and includes processing and direct trafficking (ibid). They also declared that they could profit from coca crops previously cultivated by areas controlled by guerrillas once that land was "recovered". FARC's own strategy of locating its armies in the resource-richest areas of the country (gold, emeralds and coca) had started at the end of the eighties, in contrast with their previous objective of occupying the poorest regions of the country (Labrousse, 2005 , p.9). This would allow the group to strongly increase their finances and their presence all over the nation. In 1982, the Secretariat increased the coca area armies contribution to the central authorities which allowed them to make themselves independent from the assistance provided by the Communist countries (Duncan, 2005). In practice, FARC has obtained resources from the coca business in a myriad channels. In rural areas, FARC has collected coca leaf sales and/or production taxes, as well as for the security provided to drug lords' built airports to export cocaine (Labrousse, 2005, p.4). This allowed FARC to become the richest guerrilla in the world (Richani, 1997).

In 2002, AUC leaders expressed their willingness to negotiate a peace treaty with the government, and they had previously presented their political objectives. Thanks to changes in some Colombian laws that prohibited negotiations with paramilitary groups, the government could start negotiations with AUC, that ended up with the Ralito Agreement in 2003, with the main objective of the demobilization of the AUC members. When they finished their demobilization in December 2006, they were present in 223 Colombian municipalities (out of the 1,100), controlled by between 15,000 and 17,000 men (Pardo, 2007). At this point in time, there were around 15,100 people enrolled in left-wing guerrillas (Revolutionary Armed Forces of Colombia, FARC and National Liberation Army, ELN).

There is controversy regarding to what extent paramilitary members actually demobilized and their role in the creation of the so-called criminal bands (BACRIM, bandas criminales). There is evidence that these criminal bands also engaged in drug trafficking (Human Right Watch, 2010).

In summary , during the period of study of this research, all armed groups fight to appropriate resources.

Because the paper focuses on the role that shocks to coca productivity plays on the displacement changes, the next two sections present more information on displacement and on coca cultivation.

2.1 Displacement

Colombia is currently the country with the second largest number of forcefully displaced population (Comision Historica del Conflicto y sus Victimas, 2015, GMH, 2013) in the world. Colombian Law defines a victim of forced displacement as "every person who has been forced to migrate within the Colombian territory, abandoning his place of residence or economic activities because his life, physical integrity, safety or personal freedom have been infringed or they are directly threatened" (Law 1448, 2008). The direct consequence of displacement is an abrupt loss of assets and impoverishment.

Displacement caused with the objective of illegally appropriate land is one of the reasons displacement occurss in the context of the Colombian civil conflict and this research seeks to identify solely the causal effect of shocks to coca productivity that affect the returns to coca suitable land on forced displacement[1].

The land that has been grabbed by the displacement mechanism reaches 4 million hectares, or 33% of all Colombian land (Ibañez and Querubin, 2003, p. 56). The extension of land illegally appropriated through displacement and other land grabbing mechanisms is larger than the amount of land redistributed during the main agrarian reform in 1961 (Kalmanovitz, 2009). Land grabbing mechanisms include coercion to transfer title to non-State armed groups[2]; illegal change of limits of one parcel to "include" the neighbor's parcel into thief's land limits if the neighbor has left the area (has been displaced); sell to a false name (testaferro); land rights adjudication to combatant farmers, in many cases who have been displaced by enemy armies; if farmers could not re-pay land loans, the commander in charge of the area made the repayment and grabbed the land; legally purchase land by drug traffickers with or without simultaneous money laundering (Reyes, 2011)[3].

Displaced households enjoyed better living conditions, higher educational attainment, and higher access to informal risk-sharing mechanisms and were, in general, less vulnerable to poverty before the displacement shock than other poor rural households (Ibanez and Moya, 2007). Once in the reception site, displaced households face extreme difficulties in generating income, and overall adult labor income declines an average of 50%, or from an average of $994 per year before displacement to $394 after a year of settlement. As a result, consumption decreases to 64% of the pre-displacement levels, and food expenditures represent almost 65% of total consumption of this population (Ibanez and Moya, 2009, p.653).

[1]The conflict's armed actors use displacement within the framework of struggles for territorial control of strategic areas (Molano, 2005): 1) to control corridors or those areas used for the trafficking of weapons and/or the transport of illegal products; 2) to destroy the enemy's real or potential social bases. For example, the paramilitary groups use displacement in regions that support a significant presence of social actors and a tradition of organization in the form of unions, farmer's associations, and/or indigenous organizations; 3) depending on the region, displacements take place in areas sought after for export-oriented stockbreeding or one-crop farming exploitation (such as African palm or banana); where mega-projects (an interoceanic canal) are planned; where land has been appraised based upon foreign investment plans (road, port and air projects); where energy and natural resources are extracted (gold, hydroelectric dams in Choco).

[2]

In interviews several forced displaced individuals explained that, non-State armed actors came to their farms with the same bone-chilling offer: "Sell us your land, or we'll negotiate with your widow." What followed was a crescendo of terror that locals simply call 'la violencia' (the violence), an odyssey that would eventually leave thousands either dead or landless (Ballve, 2011).

[3] Both guerrilla and paramilitary groups provide a right to use the land to their own supporters, after those peasants against them have left the area under their control. This is called "repopulation" (Reyes, 2009).

A variety of factors can explain inter-group confrontation and forced displacement, and my research seeks to identify the role of shocks to coca productivity, which I focus on next.

2.2 Coca production

The coca bush can grow almost everywhere in the country, in areas from 100 meters of altitude to 2000 meters. The coca tree is harvested around 6 months after it was planted, and after that coca leaves are harvested throughout the year, three to six times per year (Lopez-Rodriguez and Blanco-Libreros, 2008). Coca bushes younger than 18 months produce little or no coca leaf-yield; Bushes from 18 months-7 years produce experience a linear increase in yield each year; a mature coca bush (age >7 years) produce a consistent yield of harvest to harvest and after 11 years the yield begin to decline due to soil impoverishment and disease (Keller and Aitken 1974).

Coca leaf yield depends positively on rainfall: holding constant soil and location characteristics of the coca plot, higher levels of precipitation is associated with higher yields (Table 2). However, rainfall affects coca plants differently than other legal crops. Rainfall and plagues are positively correlated, and the alcaloid contained in the coca plant helps it fight plagues more efficiently than other legal plants, which have been adapted to offer desirable characteristics (such as larger sizes). Coca leaf cultivation depends entirely on rainfall as irrigation is nonexistent.

Non-State armed groups procure coca leaves from farmers in their local areas of control. Once farmers are growing coca under contract for these illegal armed groups, they may offer seeds, technical assistance and credit (Cano, 2002). Prices are set by these armed groups as a monopsony in their regions of control and enforce the «contracts» with violence. Coca plantations are found in places of agricultural frontier: the average distance to a local market is 60 kilometers (37 miles) (UNODC, 2005). Coca farmers depend heavily on coca-related income: 82% of coca farmers report coca as their main household income, and their outside options are limited due to the coercive environment where they live and their low educational attainment. Elementary school is the highest educational attainment of 50% coca farmers and their average per capita net income is less than a dollar a day (UNODC, 2005).

3 Economic Framework

Increasing coca production raises rents from cocaine trade that accrue to non-State armed groups, and yields more resources for investing in coercive institutions (guns, weapons, among others). These factors generate an expansion of the coercive sector and therefore an increased demand for labor (Acemoglu & Wolitzky, 2011). However, given the coercive nature of the coca trade, an increase in coca production do not translate into better wages due to the fact that non-State armed actors also use their power to limit coca farmers' opportunities for earning a living outside off coca plantation and trade.

To help me formulate hypothesis about the directions of the changes in forced displacement caused by increasing coca productions, I follow Acemoglu and Wolitzky (2011)'s labor coercion model in the presence of moral harzard and limited liability. In this model, the participation constraint of the coca farmer can be expressed as:

$$Wage - Effort \geq \bar{u} - coercion$$

Where $\bar{u}$ is the outside option of the farmer, and $\bar{u} - coercion$ is the effective outside option, which takes into account the reduction in expected utility due to the coercive system (Acemouglu & Wolitzky, 2011, Dippel, Greif and Trefler, 2015). This includes cattle stealing from farms, road blockings and illegal taxation of legal activities.

I use changes in production that are not caused by non-State actors or coca farmers, but are due solely to random weather draws from the climate distribution, to examine forced displacement in coca-suitable areas. In this research, farmers become displaced if they leave their farms rather to stay and accept their coca planting contract if their payoff from cultivating coca plants is larger than their outside option. Their outside option is limited by the coercive system, as non-State armed actors limit farmers' opportunities for earning a living in non-coca opportunities. The increasing production and associated violence that results from the expansion of the coercive institutions therefore reduces the "effective" outside option (which takes into account the reduction in opportunities due to coercion).

As a result, I expect that as coercion levels increase and the effective outside option reduces, less likely for the farmer to leave coca growing areas (more likely to stay in the coca business). Therefore, an increase in coca productivity should be associated with expansion efforts by the coercive non-State armed groups and a decrease in forced displacement.

4 Data sources and measurement of key variables

Rainfall

My precipitation measure is a monthly-municipal estimate of mean precipitation. To obtain this estimate, I initially downloaded the publicly available precipitation data set produced by NASA's Tropical Rainfall Meassurement Mission (TRMM) plattform. The output of this database is precipitation in mm/hr for 0.25x0.25 degree grid boxes on the latitude band 50 ° N-S every 3 hours. I calculated a daily accumulated rainfall product from this 3-hourly product, and then, using standard geographic information system software, matched these daily estimates with the Colombian municipalities. Finally, I computed a weighted average daily precipitation for each month-municipality pair, where weights correspond to the proportion of the municipality area that falls inside each NASA grid.

Coca Suitability

The coca suitability variable is a binary indicator of whether coca has been cultivated in the municipality during at least one year during the period 1994, or 1999-2011. The source of this data is satellite-identified coca fields by the United Nations Office on Drugs and Crime (UNODC)[4]. UNODC has supported the monitoring of illicit crops in Colombia since 1999, and has produced annual surveys through a special satellite-based analysis program called SIMCI (from the Spanish initials). Annex A shows the geographic distribution of coca suitability in the Colombian territory.

Coca Leaf Yield

Coca leaf yield data comes from UNODC's coca farmer survey. The survey collected household and coca production technology information during 2004 to 2010, allowing me to obtain data from 2,535 farmers located in 72 municipalities in Colombia. This data set contains monthly yield information for each farmer, for the year previous to the survey. For each farmer, I have close to 5 observations on average. This generates a sample size of 11,124 observations at the harvest level.

To collect data for the first national survey, the country was divided into 7 regions, each one covering 2 or 3 departmentos (equivalent to US States) where coca had been

[4]The 1994 indicator source is the National Police

identified by satellites in 2003. Each region was then divided into 1Km2 grids. Each grid was classified according to geographic characteristics relevant to coca planting, and assigned to pre-determined strata. 12 strata were defined. Each grid had a likelihood of being chosen equal to the area planted with coca in the grid divided by the area planted with coca in the strata. Subsequent regions after the national survey in 2005 were chosen according to budgetary reasons.

Labor Market Outcomes

The Colombian Statistics Office (DANE) collects individual labor market information on its "Great Integrated Household Survey". The Great Integrated Household Survey (GEIH) gathers information about employment conditions of individuals (whether they work, what they work in, how much they earn, if they have social security for health care, or if they are looking for a job), as well as about the general characteristics of the population, such as gender, age, marital status, and educational level, sources of income and expenses (what they buy, how often they buy, and where they buy). Currently, the survey specializes in the measurement of the labor market structure and household incomes; it has an annual total sample of approximately 240,000 households, which makes it the largest survey in coverage in the country. This data is rich in both temporal and spatial dimension, as it is collected multiple times a year in each municipality.

The particular questions that I employ in the context of this study are the following: Employment status (employed, self-employed, unemployed), labor income last week, demographic characteristics (gender, age, marital status, and educational attainment).

The main labor market outcomes studied here are two: 1) Labor earnings and 2) Unemployment in coca-suitable areas.

Labor earnings

The measure of labor income in this research is the logarithm of the real wage per hour. To obtain this variable, I took the self-reported weekly nominal labor earnings from DANE's Great Integrated Household Survey in pesos, deflated all the series to constant Colombian pesos, and divided by weekly hours worked. Finally, I calculated the log of the real wage per hour.

Unemployment

In this research, an unemployed person is someone who is older than 18 years old in DANE's Great Integrated Household Survey, who indicated his/her willingness to work the week of the survey but his/her inability to find a job. Unemployment, then, is an inverse approximation to labor demand in the studied coca areas. Self-reported unemployment is preferred to a self-reported indicator of employment, given that people who perceive rural income may do so in different capacities: as an employee, as a self-employed worker, as a landowner, or contractor.

28% of the labor market observations fall within coca-suitable municipalities, corresponding to 164 municipalities. The rest (71% of observations, from 408 municipalities) correspond to non-coca suitable municipalities.

Forced displacement

The source of violence data is the Vicepresidencia de la Republica, who has in turn gathered the conflict information originally collected by the National Police, the National Army and the Department of Social Prosperity. The frequency of this data is monthly and is reported per municipality. In order for households to be recognized as displaced by the civil conflict, and obtain access to State aid programs, households must be registered in the State Registry for the Displaced Population (RUPD by its Spanish acronym), an information system whose purpose is to legally identify Internally Displaced Population. To be registered in the RUPD, individuals must declare, under oath, and inform about the dates of displacement, the facts leading to their displacement, and the household's socio-demographic characteristics. Once the declaration is complete, the State evaluates within 15 days whether the declaration is valid or not (Ibanez and Moya, 2009, p.650).

4.1 Sample

My interest lies in studying labor market conditions and violence caused by the cultivation of coca leaf. The dynamics of displacement may be very different in urban areas, where they may be consumers of coca-processed derivatives rather than producers.

Therefore, for all estimations, I restrict the sample to rural municipalities. In practice, I follow Dube, Garcia-Ponce and Thom (2014) and exclude largely urban municipalities, as measured by municipalities with populations of 100,000 or more according to the 2005 Population Census. This reduces the sample from 1,119 to 1,066 municipalities.

5 Empirical Strategy

Rainfall and Coca Leaf Yield

I first present evidence that rainfall is a predictor of coca leaf yield, and estimate :

$$Y_{pt} = \delta_p + \nu_t + \psi Rainfall_{mt} + \varepsilon_{pt} \quad (1)$$

where Y_{pt} is the coca yield obtained from harvesting the coca plants located in plot p at time t. t is the month-year pair when the harvest that produced the yield occurred. I measure monthly yield at plot level dividing the quantity of coca leaves harvested by the harvested area, which are both specific to the harvest observation. $Rainfall$ represents mean rainfall in the municipality where plot j is located at time t. δ_p represents a plot indicator, which controls for time-invariant observable and unobservable characteristics of the plots that could bias the weather coefficients if these characteristics were associated with both, weather conditions and yield. ν_t represents a linear time trend, and ε_{pt}, plot-specific monthly shocks. I expect ψ to be positive due to the positive association between rainfall and agricultural yield.

Labor Market Effects of Weather-Induced Productivity Shocks

I then study the labor market outcomes of positive rainfall shocks, caused by wetter-than-average months in coca suitable municipalities. Coca municipalities are not a random sample of the Colombian universe of municipalities. To overcome the endogenous stratification of municipalities between coca and non-coca areas, I created a variable called "coca-suitability". As explained below, the coca suitability variable is a binary indicator of whether coca has been cultivated in the municipality during at least one year during the period 1994, or 1999-2011.In particular, I estimate the labor income and demand effect of rainfall shocks in coca suitable areas as follows:

$$Y_{ijmy} = \delta_j + \nu_{my} + \beta t_s + \psi Rainfall_{jmy} + \alpha' X_{ijmy} + \varepsilon_{ijmt} \quad (2)$$

where i indexes individuals, j indexes municipalities, m indexes months and y indexes year. In 2, Y_{ijmy} represents both real labor earnings per hour and unemployment of individual i located in municipality j during month m of year y. X_{ijmy} is a vector of observed measures of productivity and outside options. These measures include gender, educational attainment, age, age squared, married status and urban/rural location.

ν_{my} are month*year fixed effects during the period January 2004-June 2010. These time effects further isolate the effect of the weather variation from any common trends in the Colombian municipalities and therefore help ensure that the relationship I am estimating is identified from idisyncratic local shocks. Complementary, spatially-specific trends are taken into account by including a department-specific linear time trend (βt_s).

Forced Displacement Effects of Weather-Induced Productivity Shocks

To infer the effect that productivity changes in coca-suitable areas have on forced displacement, I rely on time-series variation of rainfall and displacement for identification in a municipal panel data context. In this research design, inference is then based on how a municipality responds to different climatic conditions (in this case, rainfall), which vary over time. Here the assumptions necesary for causal inference are more likely to be met than in cross-sectional approaches, since the structure, history and geography of comparison populations (that is, populations within the same municipality) are nearly identical (Burke, Hsiang and Miguel, 2015).

To identifiy the effect of rainfall in displacement originated in coca-suitable areas, I interact the coca-suitability indicator with the municipal-monthly rainfall measure, and initially test the hypothesis that rainfall has a differential effect on forced displacement in coca suitable areas compared to non-coca suitable areas. To this end, I estimate Equation (3):

$$D_{jmy} = \delta_m + \nu_{my} + \beta t_s + \psi Rainfall_{jmy} + \alpha Rainfall_{jmy} * Coca_m + \varepsilon_{jmy} \tag{3}$$

where D_{jmy} represents forced displacement in municipality j during month m in year y. t is defined in month*year units, $Rainfall$ is the mean rainfall in municipality j during month m in year y. $Coca$ is a binary indicator of coca suitability, which is a binary indicator of whether coca has been cultivated in the municipality during at least one year during the period 1999-2011. This measure is preferred to a coca variable observed in municipality j in year y because coca cultivation may be the response to agricultural migration flows explained by forced displacement. $\delta_m$are municipality fixed-effects that absorb time-invariant characteristics, whether observed or unobserved, disentangling the precipitation shock from other sources of omitted variable bias. If different municipalities exhibit different average levels of conflict because of any number of cultural, historical, political, economic, gepgraphic or institutional differences between these municipalities, this will be accounted for by municipality-specific fixed-effect δ_m (Buerke, Hsiang and Miguel, 2015)[5].

$\nu_{my}$are month*year fixed effects during the period January 2004-June 2010. These time effects further isolate the interaction of the weather shock with the coca suitability variable from any common trends in the Colombian municipalities and therefore help ensure that the relationship I am estimating is identifying from idisyncratic local shocks. Complementary, the estimating equation also captures spatially-specific trends by including a department-specific linear time trend (βt_s).

The effect of rainfall on forced displacement in coca areas is $\psi + \alpha$. [6].

Equation (3) is explicity reduced form, and it focuses on the effect of the variation in precipitation in coca versus non-coca suitability on forced displacement. Given that precipitation varies plausibly randomly over time, as random draws from the municipality climate distribution, this approach has strong identification properties (Dell, Jones and Olken, 2014).

6 Summary statistics

Forced Displacement

The objective of this research is to identify the role of increasing coca leaf productivity on forceful displacement and local labor markets. Therefore, one of the main outcome variable of this research is forcefully displaced population, as measured by the number of people registered in Colombian government agencies as Internally Displaced. The frequency of this data is monthly and is reported per municipality. During the period of study, which covers January, 2004 to June, 2010, forced displacement reached very high numbers: 7.87 people per 10,000 inhabitants became internally displaced in Colombia per month (see Table 1, and appendix).

Labor Market Outcomes

6% of the adult population (older than 18 years old) in my sample report being unemployed. This means that the remaining 94% of the working force was either employed or self-employed. The mean of (log) wages is 7.21, which roughly corresponds to 4 dollars per hour.

[5]Temperature is not included in the analysis because over time variations are very small holding constant location

[6]Note that it is not possible to estimate a coefficient for the coca suitability indicator as the estimating equation includes a municipality fixed-effect variable; therefore, the two coefficients would be colinear since neither varies in time.

Rainfall

The mean precipitation in the municipalities I am studying is near 4 mm/day, or close to 120 mm per month. There is great variation in regional rainfall; while some municipalities witnessed no rain during certain periods of time, precipitacion was reported as high at 27 mm a day in other locations.

Geographic conditions and ocean-atmosphere-topography interactions generate extreme precipitation amounts over the Pacific coast of Colombia, including one of the rainiest regions on Earth - averaging 10,000–13,000 mm per year- (Poveda and Mesa, 2000).

There are regional variations in the precipitation cycles in the country. Central and western Colombia experience a bimodal annual cycle of precipitation with marked high-rain seasons (April–May and September– November), and low-rain seasons (December–February and June–August), while rainfall exhibits a uni-modal annual cycle (May– October) at the northern Caribbean coast of Colombia and at the Pacific flank of the southern isthmus. Another single annual peak (June–August) occurs at the eastern slope of the eastern Andes, resulting from the encounter of the moisture-laden trade winds from the Amazon with the Andes. The El Niño/Southern Oscillation (ENSO) is the main forcing mechanism of interannual climate variability from hours to seasons to decades. In general, the warm phase of ENSO (El Niño) begins during the boreal spring, exhibiting a strong phase locking with the annual cycle, and encompassing two calendar years characterized by increasing sea surface temperature anomalies during the boreal spring and fall of the onset year, peaking in winter of the following year. Anomalies then decline in spring and summer of the ensuing year. The annual cycle of average maximum daily flows indicates that ENSO effects are larger and felt earlier over the western Andes, whereas effects are smaller and felt later over the eastern Andes (Alvarez, Poveda and Rueda, 2011).

Coca Leaf Yield

Coca farmers harvest the coca leaf 4.85 times each year on average. Farmers report when (which month) they harvested coca leaf plants and how much the harvest was. The mean quatity harvested is 120 "arrobas", or 3,000 pounds[7]. I then calculated the monthly yield per plot dividing the quantity harvested by the harvested area. Averaging over all plots, the mean monthly yield in my sample is 92.26 arrobas/ha or 2,400 pounds

[7] 1 arroba is equivalent to 25 pounds

per hectare.

7 Results

7.1 Rainfall and Coca Leaf Yield

Table 2 presents the estimated coefficients of 1. Column (1) shows the estimated ψ if no time trend nor plot indicators are added. Each additional milimeter of rain is associated with an increase in coca yield of 0.44, and this coefficient is significant at all standard confidence levels.

This results suggest that there is a positive and significant relation between rainfall levels in the municipality and the observed coca yield. If a plot indicator is included in the estimations -column (2)-, the effect of rainfall on coca yield decreases to 0.337 but the coefficient is still significant (albeit at the 10% level). Column (3) shows the results of the OLS regression of yield on rainfall, including both a linear time trend (that controls for common shocks to all municipalities at time t) and a plot indicator. The coefficient is now 0.402. The plot time-invariant effect, the linear time trend and rainfall explain 17% of the variation in yield change.

7.2 Labor Market Effects of Weather-Induced Productivity Changes in Coca Areas

Results of the estimation of Equation 2are showed in Table 4, which was estimated for the sample of individuals whose place of residence was a coca suitable municipality (164 municipalities, see Table 3). Controlling for economic determinants of labor earnings, time-invariant municipality characteristics and time indicators, the estimated coefficient of the effect of the productivity shock generated by favorable precipitation is zero for labor earnings (Column 1). However, labor demand increases as a result of excess rainfall in coca suitable municipalities, as measured by the coefficient of rainfall in the unemployment equation (Column 2). The probability of unemployment decreases by 0.0013 log points as a result of an additional milimeter of rain in municipalities suitable for coca leaf cultivation, net of the effect of other (un)employment characteristics such as gender, educational attainment, age, age squared and married status. The standard error of the estimator is 0.00078 and the p-value of the hypothesis that the coefficient is zero is 0.107.

7.3 Forced Displacement Effects of Weather-Induced Productivity Changes in Coca Areas

Table 5 Column (1) presents the estimated coefficient of the effect of the productivity shock generated by favorable precipitation. The effect of excess rainfall on forced displacement in coca-suitable municipalities is $\psi + \alpha$ (2.517 - 3.526), -1.009, holding constant municipality and month*year fixed effects, as well as State linear trends. This result, shown in column (1), suggests that each additional milimeter of rainfall in excess of the municipality precipitation mean causes a decrease of an average of 1 person forcefully displaced per 10,000 people in the municipality.

Controlling for previous guerrilla presence

Next, I test whether local idiosyncractic shocks to coca productivity have an independent effect on displacement controlling for conditions that are favorable for the insurgency. Equation (4) further controls for insurgency-favorable conditions as measured by an indicator of guerrilla presence in municipality j in the year 1996[8].

$$D_{jmy} = \delta_m + \nu_{my} + \beta t_s + \psi Rainfall_{jmy} + \alpha Rainfall_{jmy} * Coca_m + \lambda_y G_j + \varepsilon_{mt} \quad (4)$$

In 4, G_j represents the binary indicator of guerrilla presence in municipality j as measured by whether there was at least one guerrilla attack or confrontation with government forces during the year 1996 in that municipality. $\lambda_y$is the coefficient of the interaction of the guerrilla presence indicator in municipality j interacted with the year variable.

Column (2) explores if shocks to coca productivity have an independent effect on displacement controlling for conditions favorable to insurgent presence. The effect of rainfall on force displacement in coca municipalities is -1.02 (2.839-3.863).

Because of the count nature of the outcome, in Equation (5) I adopt an exponential model (Cameron and Trivedi, 2005, pp. 802-808) and further estimate separately for coca and non-coca suitable areas:

$$D_{jmy} = \delta_m exp(\nu_{my} + \beta t_s + \psi Rainfall_{jmy} + \varepsilon_{jmt}) \quad (5)$$

[8] This variable is a binary indicator (0 or 1) of any insurgency action in the municipality in the year 1996, which is the earliest available year in the Universidad del Rosario dataset. On average, there are close to 30% of the municipality-month observations in my dataset that witness presence of guerrilla actions (clashes or attacks) in 1996.

Table 6 presents estimated coefficients for 5. Columns (1) and (2) present the negative binomial estimates of the effect of a positive rainfall shock on displacement in coca and non coca areas respectively. Consistent with the evidence above, positive productivity shocks measured by rainfall above the average municipality precipitation decrease forced displacement in coca areas but not so in non-coca areas. The estimated ψ is -1.22%, which suggests that an additional milimeter of precipitation above the municipality mean decreases forced displacement by 1.22% in coca-suitable areas. This coefficient is statistically significant at all levels and economically important, given the high incidence of displacement. The coefficient is very similar and statistically significant when the population control is added[9]. By contrast, in non-coca areas the effect of positive rainfall shocks is approximately ten times smaller and insignificant. Columns (3) and (4) report the results of the negative binomial model for these areas and the coefficients are -0.138% and -0.07% without and with the population control, respectively.

8 Instrumental Variables Estimates

A second way to test for coercion in coca suitable labor markets is to test whether high productivity months witness lower forced displacement. In therefore match coca leaf yield data with local violence and employ an Instrumental Variables estimation where changes in forced displacement are explained by coca leaf yield variations, and I instrument changes in coca leaf yield with rainfall.

Since the seminal work of Miguel, Satyanath and Sergenti (2004) on the impact of unforseeable weather conditions on economic growth and the outbreak of civil conflict and war in Africa, there has been an ongoing debate among economists about the use of precipitation as an instrument for economic variables in studies where the main outcome is conflict. Miguel, Satyanath and Sergenti (2004)'s study measures the effect of changes in income growth on changes in the likelihood of civil conflict, using macroeconomic data from Africa. Since civil conflict may affect economic growth, they isolate the effect of income that comes from variations in rainfall. Miguel and colleagues estimates imply that a five-percentage-point negative growth shock increases the likelihood of a civil war the following year by nearly one-half, at least in African countries.

More recently, other researchers have used rainfall to establish causality when look-

[9] This population measure is a prediction made by DANE, the statisticall office of Colombia in 2005 based on initial population census, so it is not affected by current displacement figures

ing at a host of political and economic outcomes. Bruckner and Ciccone (2011), test the theory of political transitions, finding that negative rainfall shocks are followed by significant improvement in democratic institutions. Their instrumental variables estimates indicate that following a transitory negative income shock of 1 percent, democracy scores improve by 0.9 percentage points and the probability of a democratic transition increases by 1.3 percentage points.

Mehlum, Miguel, and Torvik (2006) estimate the impact of poverty on crime in 19th century Bavaria, Germany. Rainfall is used as an instrumental variable for rye prices to address econometric identification problems in the existing literature. The rye price was a major determinant of living standards during this period. The rye price has a positive effect on property crime: a one standard deviation increased property crime by 8%. Higher rye prices lead to significantly less violent crime and the authors claim that higher beer prices, caused by the higher rye prices, are a likely explanation.

Bohlken and Sergenti (2010) focus on the relationship between economic conditions and riots. Specifically, these authors examine the effect of economic growth on the outbreak of Hindu–Muslim riots in 15 Indian states between 1982 and 1995. Similar to Miguel et al (2004), the authors employ instrumental variables (IV) estimation, using percentage change in rainfall as an instrument for growth. The results with IV estimation confirm that an increase in the economic growth rate decreases the expected number of riots and that this effect is significant.

Since rainfall can affect many social phenomena simultenously (see Dell, Jones and Olken, 2014, for a review), I restrict my sample to a small set of municipalities that are highly dependent on coca plantation and transformation into cocaine, and follow cocaleros (coca farmers) during every month for one year from these municipalities, matching their yields to local monthly violence.

I start by expressing displacement in the municipality as a function of municipal and coca farmers' characteristics:

$$D_{mt} = \beta_m + \beta_t + \gamma A_{mt} + \alpha' X_{mt} + \mu_{mt} \tag{6}$$

In equation 6, D_{it}represents displacement in municipality m at time t. A_{mt}represents the mean farmer's productivity and$X$ are variables that could affect the farmer's outside option, such as gender, age, migratory status and land ownership. I also include municipality fixed effects (β_m) to capture time invariant geographic characteristics that affect, on the one hand, how costly it is for a group to coerce farmers in municipality m -farmers located in isolation may be easier to coerce- but also may be related to the farmer's outside option, such as closeness to markets. The model includes year dummies to capture common shocks to all farmers, and in particular, the market price of coca leaf or its derivatives as well as the world demand of these products. The term μ_{mt} represents municipality-specific transitory shocks, and are allowed to be correlated accross time in all regressions.

The observed effort variable is yield (crop volume sold per unit of land, and I assume that all crop produced is sold). However, yield and productivity are not equivalent since productivity also depend on the use of inputs such as labor and fertilizer. If yield stands for productivity in the next equation:

$$D_{mt} = \beta_m + \beta_t + \gamma Y_{mt} + \alpha' X_{mt} + \varepsilon_{mt} \tag{7}$$

and I estimate the above equation by OLS, I will not be able to identify the effect of productivity on the use of violence. Therefore, I use an instrumental variables approach and instrument for yield with rainfall.

The first stage equation relating rainfall and coca leaf yield is:

$$Y_{mt} = \delta_m + \nu_t + \psi Rainfall_{mt} + \alpha' X_{mt} + \varepsilon_{mt} \tag{8}$$

In the equation above, $Rainfall$ is the mean rainfall in municipality m at time t. $Rainfall$ serves as instrument of the endogenous regressor Y_{mt}.

The instrumental variables approach requires the following two assumptions (Angrist, 2009). First, rainfall must be correlated with coca yield. Second, rainfall must be correlated with any other determinants of the violence outcomes of interest. In other words, corr($\mu, rainfall$) =0. This condition is called the exclusion restriction, and it words it requires that rainfall affects violence only through its effect on coca leaf yield in coca growing areas, conditional on the municipality fixed effects. In this context, the exclusion restriction is likely to hold given the high dependence of coca production on the particular sample I draw my conclusions from (described below), which suggests that the effect of rainfall on violence is explained solely by changes in coca leaf yield[10].

Second stage

Given that rainfall is a strong predictor of coca leaf plant (table 2), I proceed to estimate the effect that changes in coca leaf yield due to weather have on forced displacement.

The modified second stage equation that takes into account that plot indicators are

[10]The coca areas sampled for these surveys rely heavily on coca as currency; physical infrastructure is very poor which impedes that farmers can effectively sell other agricultural goods in the market and therefore their sources of income other than coca are very limited

included is:

$$D_{mt} = \delta_p + \beta_t + \gamma Y_{pt} + \varepsilon_{mt} \tag{9}$$

where D_{mt} stands for forced displacement in municipality m at time t. Here t is measured in months as before. Y_{pt} is the coca yield obtained from harvesting the coca plants located in plot p at time t. Plot location allows me to match plot information (on productivity) with municipal rainfall and violence data.

represents a plot indicator as before, β_t represents a linear time trend, and ε_{mt}, municipality-specific monthly shocks. I expect γ to be negative because the coerced sector yields higher returns with better rainfall, and therefore coercion efforts should increase in higher productivity months compared to lower productivity months and less coca farmers should be able to leave the coca contract in higher rainfall months than in lower rainfall periods.

Even though the equations can be expressed in two stages, estimations have been performed using a standard 2SLS estimator and clustering the standard errors at the municipal level.

In fact, results of the econometric estimation present evidence in the direction that when coca productivity is unexpectedly better due to positive rainfall shocks, displacement figures decrease. Table 3 presents the estimated γ. Column (3), which controls for a linear time trend and a plot indicator, suggests that one additional arroba of coca leaf per hectare harvested per month is associated with a reduction of forced displacement of 4.77 people on average, and this estimate is significant at all statistical levels. This estimate is economically meaningful, as the displacement mean in my sample is 7.887.

9 Confrontations and Mayor Killings in Coca Areas

In the previous section, I showed evidence that high productivity months relative to months of lower coca production, witness lower forced displacement in coca growing municipalities. According to the conceptual framework outlined in section 3, an increase in coca productivity should be associated with a decrease in forced displacement and also with expansion efforts by coercive non-State armed groups.

Ideally, I would test an increase in coercion as a result of coca productivity in the IV framework presented below. In absence of coercion data, I rely on coercion expansion efforts by coca-profiting non-State armed groups, measured by two variables: confrontations between these groups and government forces and mayor killings of coca growing municipalities.

I estimate then the effect of coca leaf yield instrumented with rainfall on the two measures of coercion efforts, as in the following equation (which reproduces the second stage estimated below):

$$Coercion_{mt} = \delta_p + \beta_t + \gamma Y_{pt} + \varepsilon_{mt}$$

Where $Coercion_{mt}$ stands for either confrontations between non-State armed groups and government forces or killings of coca growing mayors by these groups. As predicted by labor coercion models, increasing coca leaf production generated by good rainfall is associated with an expansion of the coercive sector, and in this case, of confrontations of coca-profiting non-State actors with government armed forces for higher-yielding growing areas. The estimated rise in confrontations is presented in Table 8. In Column (3), which presents my preferred specification that includes a linear trend and a plot fixed effect, the coefficient of clashes suggests that means that each additional unit of yield measured in arrobas per hectare of coca leaf is associated with an increase in confrontations of 0.067 on average, controlling for time-invariant characteristics of the coca plots. This estimate is statistically significat at the 1 percent level and is large in magnitude since the mean of clashes is 0.058.

Consistent with the former result, mayors of coca-growing municipalities face a higher risk of being killed by coca-profiting groups: Table 9 presents the estimated coefficient of 10 for mayor assassinations due to changes in coca yield, holding constant municipalitiy-specific characteristics that could affect coca productivity and violence. According to Column (3), an additional unit of coca leaf yield due to excess rainfall creates an average rise in the number of coca municipality mayors o 0.001, controlling for a plot fixed effect and a linear time trend. The coefficient is significant at the 5 percent level.

10 Negative Productivity Shocks and Displacement

Another way to test for the relationship between productivity and forced displacement is to look at the effect of a negative productivity shock. According to the economic framework outlined above, I would expect forced displacement to be inversely related to productivity. The reason would be that falling productivity makes a coca growing region less attractive since returns to coercive institutions would decrease as the resources available to expand these institutions. A decrease in coercion would then open the doors for farmers to earning a living off coca plantations, and/or free up non-coca cultivation opportunities for farmers. In other words, the fall in coercion would increase the farmer's effective outside option and make it less likely for the participation constraint to hold. This would imply then that more farmers would find it attractive to leave coca growing municipalities in periods of low production rather than in periods of high production.

Empirically, however, testing for this inverse relationship is complicated because in the agricultural sector even extreme amounts of rainfall are not necessarily bad for agriculture (Kaur, 2014). Therefore, I rely on the farmer survey collected by UNODC, which directly asks farmers whether they experienced a negative weather shock that partially or completely destroyed their coca plants. To test whether an inverse relationship holds between weather shocks and displacement using the farmer survey data, I estimate:

$$Displacement_{my} = \delta_m + \nu_y + \tau NegativeWeatherShock_{imt} + X'\beta + \varepsilon_{my} \tag{10}$$

where $Displacement_{mt}$ is the number of forcefully displaced population that left municipality m during year of survey y. X is a vector that represents farmer characteristics that affect migration decisions, such as whether farmer is an owner, gender, and previous migratory status. Negative weather shock is a self-reported variable that takes on a value of 1 if farmer reported a negative weather shock that affected the coca leaf yield in survey year y. Consistent with the results presented above and since the weather shock is negative, the estimated τ is positive. In column 1 of Table 10, the average difference in displacement in municipalities that experienced a negative weather shock is 331.28 people, controlling for municipality and year of survey effects. The coefficient is significant at the 10 percent level. In column 2, I present results that control for other determinants of migration decisions and correlates to coca productivity, such as land ownership, land area, migrant status, gender and age of coca farmer, and coca leaf specie. The estimated coefficient of the negative weather shock is 316.10, and significant at the 5 percent level.

11 Conclusions

The main goal of this paper is to estimate the effect of productivity shocks on local forced displacement. The context of this study is the Colombian coca farming activity, which is strongly controlled by armed illegal groups that benefit financially from this activity.

I employed an instrumental variables approach together with fixed effects estimators to calculate the effect of exogenous variation in productivity on the dynamics of the conflict. First, the results of the econometric analysis support the hypothesis that positive productivity shocks, generated by larger precipitation than municipality averages, are associated with lower figures of forced displacement in coca suitable municipalities than non-coca municipalities. Shocks to coca productivity have an independent effect on displacement controlling for conditions favorable to insurgent presence.

To understand the mechanisms behind these results, I turn to a sample of coca municipalities. First, I confirm that better rainfall that increases coca leaf production causes a rise in the demand for labor in coca growing municipalities in the wetter-than-average months. I also confirm that given the coercive nature of the coca trade, an increase in coca production does not change wages.

Instrumenting coca leaf yield with rainfall in coca-growing municipalities, my estimates present evidence in favor of the idea that increased coca production due to positive rainfall generate an expansion effort of the coercive sector measured by an increase in confrontations between coca-profiting groups and mayor killings in these areas. As predicted by a labor coercion economic framework, an increase in coca productivity is associated with a decrease in forced displacement. Finally, relying on farmer self-reported information on negative weather shocks that affect coca plants, my results suggest that when coca output is low, forced displacement increases in coca municipalities. This is in turn consistent with the explanation that in low production states, there is less interest in expanding the coercive (coca) sector by the non-State armed groups, and the effective outside option for the farmer is less restricted. Therefore, displacement is more likely to occur as the participation constraint of the farmer is more difficult to hold in low production periods.

The estimates of the effect of coca yield on coercion efforts and forced displacement are large in magnitude and statistically significant, suggesting that the effect of weather shocks on labor markets is mediated by the quality of the institutions where these markets are embedded.

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Table 1: Descriptive statistics

	Mean	sd	Obs.
Forced displacement[2]			
Displacement	**7.887**	**24.437**	**107,202**
Source: Vicepresidencia de la Republica based on several gov agencies			
Labor Market Outcomes[4]			
Log(wages)	**7.219**	**1.998**	**69,468**
Unemployment	**0.060**	**0.238**	**152,986**
Source: DANE			
Rainfall[2]			
Rain (mm/mean daily average)	**4.065**	**3.073**	**114,138**
Source: NASA			
Coca suitability			
Coca suitability index	**0.27**	**0.44**	**1,119**
Source: Simci, UNODC			
Coca productivity[3]			
Yield (arrobas per hectare)	**92.269**	**38.225**	**11,124**
Quantity harvested (arrobas)	**120.240**	**124.236**	**11,124**
Harvested area (hectares)	**1.261**	**1.094**	**12,971**
Number of harvests/year	**4.851**	**1.670**	**11,124**
Source: UNODC			

Notes:
1.This table presents summary statistics for the main variables used in this paper.
2. Observations are at the municipality-month-year level, during the period January 2004-June 2010.
3. Observations are at the harvest level, during the period 2004-2010.
4. Observations are at the individual level, and include adults (older than 18 years old) in the labor market who are either employed, self-employed or unemployed.

Table 2: Effect of rainfall on coca yield (First-Stage) Plot Panel Data

	(1)	(2)	(3)
		Dep. variable: Coca yield, t (2004-2010)	
Rain, t	**0.440**	**0.337**	**0.402**
	(0.138)***	**(0.148)***	**(0.117)*****
Time trend	**No**	**No**	**Yes**
Plot indicator	**No**	**Yes**	**Yes**
R-squared	**0.036**	**0.036**	**0.172**
N	**11,624**	**11,624**	**11,624**

Notes: Clustered standard errors at municipal level are in parentheses. Sample includes only coca municipalities. Each observation is at the plot-municipality-month-year level. *** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level.

Table 3: Match Between Labor Outcomes Survey and Climate-Conflict Database

	N	%
Coca municipalities	**164**	**28.67**
Non-coca municipalities	**408**	**71.33**

Notes: Coca is a time-invariant variable defined as an indicator (1 or 0) of coca presence during the period 1999-2010. If a municipality shows a least one positive value of coca presence in the municipality during the period 1999-2010, this variable takes a value of 1, and 0 otherwise.

Table 4: Labor Earnings Effect of Rainfall Shocks in Coca Areas

	(1)	**(2)**
Dependent variable		
	Log real labor earnings per hour	**Unemployment**
Rain	**0.00989**	**-0.00130**
	(0.0100)	**(0.000799)**
Municipality fixed effects	**Yes**	**Yes**
Month*Year fixed effects	**Yes**	**Yes**
State time trends	**Yes**	**Yes**
Socio-demographic controls	**Yes**	**Yes**
R-squared	**0.107**	**0.025**
Observations	**69,468**	**152,986**
Number of municipalities	**164**	**164**

Notes:Each observation represents a municipality-year-month. Variables not shown include municipality fixed effects, month*year fixed effects and linear time trends per State. Socio-demographic controls include gender, educational attainment, age, age squared, married status and urban/rural location. Sample includes only Coca municipalities. Coca is a time-invariant variable defined as an indicator (1 or 0) of coca presence during the period 1999-2010. If a municipality shows a least one positive value of coca presence in the municipality during the period 1999-2010, this variable takes a value of 1, and 0 otherwise. Rainfall is measured in mm. Clustered standard errors at municipal level are in parentheses. *** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level.

Table 5: Effect of Rainfall on Forced Displacement in Coca vs. Non-Coca Municipalities (Least Squares Estimation)

	(1)	(2)
Dependent variable	**Displacement Rate per 10,000 people**	
Rain	**2.517****	**2.839****
	(1.050)	**(1.183)**
Rain*Coca	**-3.526****	**-3.863****
	(1.650)	**(1.778)**
F-test State time trends (p-value)	**11.60**	**9.13**
	(0.000)	**(0.000)**
F-test Rainfall terms (p-value)	**2.92**	**2.95**
	(0.05)	**(0.05)**
F-test Guerrilla*year terms (p-value)		**4.62**
		(0.00)
Municipality fixed effects	**Yes**	**Yes**
Month*Year fixed effects	**Yes**	**Yes**
State time trends	**Yes**	**Yes**
Observations	**86,814**	**76,674**
R-squared	**0.016**	**0.017**
Number of municipalities	**1,113**	**983**

Notes: Each observation represents a municipality-year-month. Standard errors clustered at the municipal level are shown in parentheses. Variables not shown include municipality fixed effects, month*year fixed effects and linear time trends per State. Guerrilla presence is a time-invariant variable defined as an indicator (1 or 0) of guerrilla activity in the municipality in 1996. Coca is a time-invariant variable defined as an indicator (1 or 0) of coca presence during the period 1999-2010. If a municipality shows a least one positive value of coca presence in the municipality during the period 1999-2010, this variable takes a value of 1, and 0 otherwise. The dependent variable is defined as displaced population in the municipality per 100,000 people. Rainfall is measured in mm. *** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level.

Table 6: Effect of Rainfall on Forced Displacement in Coca and Non-Coca Areas (Negative Binomial Estimation)

	(1)	(2)	(3)	(4)
Dependent variable	Percentage change in Displacement			
	Coca areas		Non-coca areas	
Rain	-1.22***	-1.18***	-0.137	0.07
	(0.223)	(0.215)	(0.307)	(0.299)
Chi-square test State time trends (p-value)	1542.25	1481.97	5012.32	4720.93
	(0.000)	(0.000)	(0.000)	(0.000)
Chi-square test month*year terms (p-value)	3988.76	4172.55	4558.27	4846.00
	(0.000)	(0.000)	(0.000)	(0.000)
Controls for Population	No	Yes	No	Yes
Municipality fixed effects	Yes	Yes	Yes	Yes
Month*Year fixed effects	Yes	Yes	Yes	Yes
State time trends	Yes	Yes	Yes	Yes
Observations	23,088	23,088	57,642	57,642
Number of municipalities	296	296	739	739

Notes:Each observation represents a municipality-year-month. Variables not shown include municipality fixed effects, month*year fixed effects and linear time trends per State. Coca is a time-invariant variable defined as an indicator (1 or 0) of coca presence during the period 1999-2010. If a municipality shows a least one positive value of coca presence in the municipality during the period 1999-2010, this variable takes a value of 1, and 0 otherwise. The dependent variable is defined as displaced population in the municipality. Rainfall is measured in mm. *** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level.

Table 7: Effect of Coca Yield on Forced Displacement (Second-Stage)

	(1)	(2)	(3)
	Dep. variable: Forced displacement (2004-2010)		
Yield	-2.136	-6.089	-4.776
	(0.376)***	(1.509)***	(1.165)***
Instrument	Rain	Rain	Rain
Linear time trend	No	No	Yes
Plot indicator	No	Yes	Yes
R-squared	0.0012	0.0012	0.0025
N	11,088	11,088	11,088

Note: Sample includes only coca municipalities. Each observation is at the plot-municipality-month-year level. Clustered standard errors at municipal level are in parentheses. *** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level.

Table 8: Effect of Coca Yield on Clashes Between Illegal Groups and Government Forces (Second-Stage)

	(1)	(2)	(3)
	Dep. variable: Clashes (2004-2010)		
Yield	**0.004**	**0.086**	**0.067**
	(.001)***	**(0.018)*****	**(0.013)*****
Instrument	**Rain**	**Rain**	**Rain**
Linear time trend	**No**	**No**	**Yes**
Plot indicator	**No**	**Yes**	**Yes**
R-squared	**0.0003**	**0.0003**	**0.0011**
N	**11,088**	**11,088**	**11,088**

Note: Sample includes only coca municipalities. Each observation is at the plot-municipality-month-year level. Clustered standard errors at municipal level are in parentheses. *** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level.

Table 9: Effect of Coca Yield on Mayor Casualties (Second-Stage)

	(1)	(2)	(3)
	Dep. variable: mayor casualties (2004-2010)		
Yield	**0.000**	**0.001**	**0.001**
	(0.000)**	**(0.000)***	**(0.000)****
Instrument	**Rain**	**Rain**	**Rain**
Linear time trend	**No**	**No**	**Yes**
Plot indicator	**No**	**Yes**	**Yes**
R-squared	**0.0002**	**0.0002**	**0.0002**
N	**11,088**	**11,088**	**11,088**

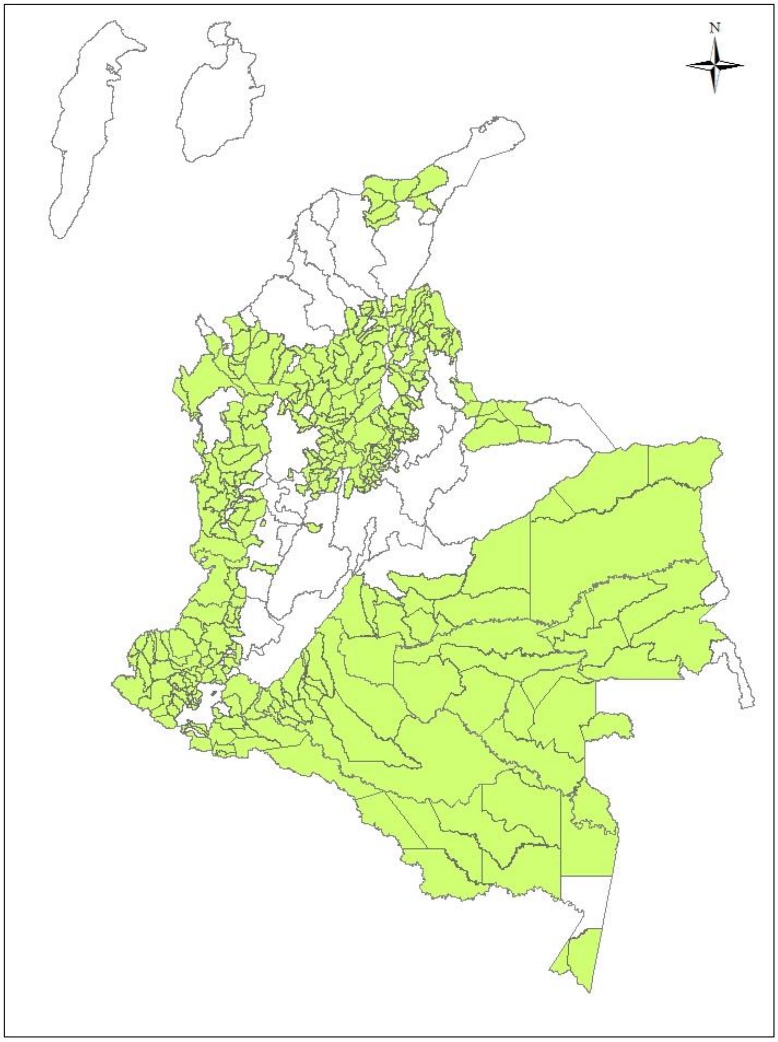
Note: Sample includes only coca municipalities. Each observation is at the plot-municipality-month-year level. Clustered standard errors at municipal level are in parentheses. *** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level.

Table 10: Effect of Negative Weather Shock on Forced Displacement, Household Data (OLS)

	(1)	(2)
	Dep. variable: Displaced population	
Self-reported negative weather shock	331.283	316.10
	(194.11)*	(157.77)**
Owner		26.29
		(60.05)
Land area		1.24
		(0.914)
Migrant		114.58
		(97.42)
Male		-0.89
		(22.91)
Age		-0.88
		(1.46)
Coca leaf specie	No	Yes
Municipality fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
R-squared	0.83	0.84
Number of municipalities	57	57
N	1,763	1,763

Notes: Regressors not shown include municipality and year indicators. Each observation is at farmer level. Clustered standard errors at municipal level are in parentheses. * is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level.**

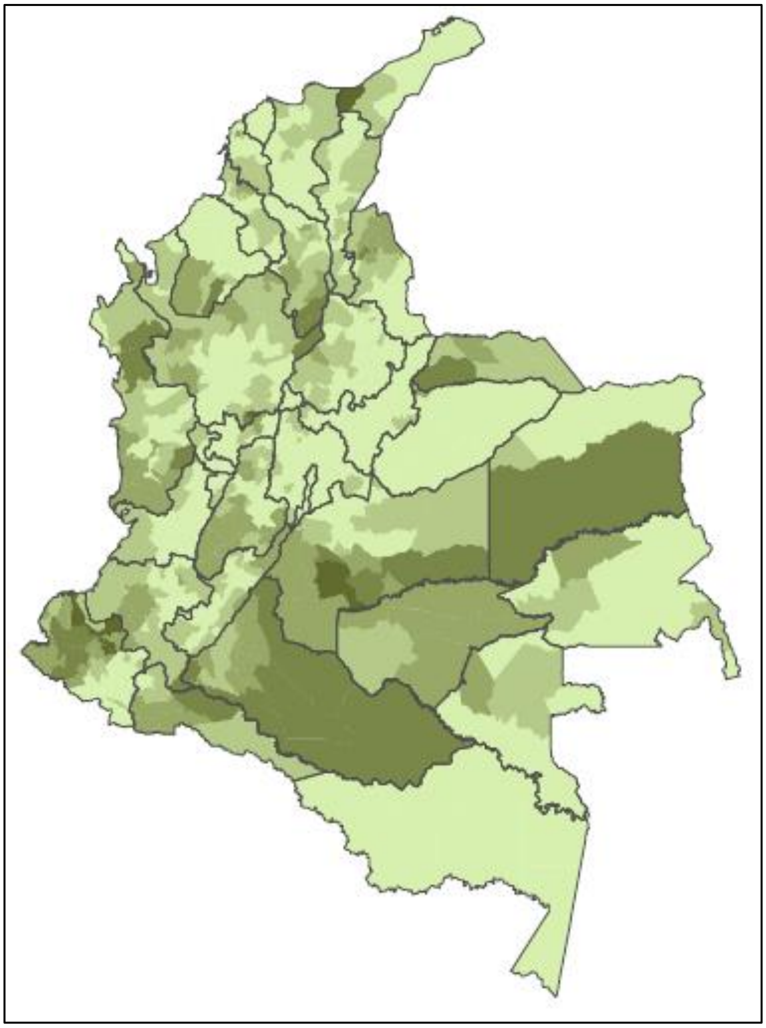
Annex A: Coca suitability map



Notes: Municipalities in green correspond to coca-suitable municipalities. Coca suitability is defined as a binary variable that takes on the value of 1 if the municipality has had coca presence as identified by satellite during at least one year since 1999-2011.

Sources: Coca satellite data by UNODC, municipality limits by Agustin Codazzi.

Annex B. Displacement per 10,000 population (2004-2010)



Notes: Darker municipalities exhibit greater intensity of forced displacement per 10,000 people in the municipality.

Sources: Violence data by Observatorio de Violencia, Vicepresidencia de la Republica de Colombia, municipality limits by Agustin Codazzi.